



econcern

environmental consultancy
'local to global – catchment to coastal'



Didgeridoo Lagoon System Management Plan

> Contents

> List of abbreviations	4
> Executive summary	5
> Background	5
Cape Bowling Green Bay Ramsar wetland	5
Lower Burdekin floodplain – identifying assets and threats	6
System Management Plan – scope and purpose	6
> Methods – assessment and reporting	8
Stakeholder consultation	8
Literature review	9
Field work	9
Management planning mapping	9
> Summary system assets, threats, and nominated management strategies/works	10
Assets	10
Threats/management issues	10
Nominated works	11
> System management plan, key threats to assets and recommended management strategies	11
Altered hydrology	13
System specifics	16
Recommendations	17
Aquatic weeds	19
System specifics	19
Water quality	27
System specifics	28
Recommendations	30
Fish passage barriers	33
System specifics	33
Recommendations	35
Lack of riparian vegetation	37
System specifics	39
Recommendations	43
Woody weeds	46
System specifics	47
Recommendations	47
Fire regime	49
System specifics	50
Recommendations	53
Grazing regime	55
System specifics	56
Recommendations	57
Critical wildlife habitat	58
System specifics	59
Recommendations	61
Climate stress	64
System specifics	66
Recommendations	67

> Innovative management	68
System specifics	68
Recommendations	69
> Bibliography	71
> Appendix 1 – Reach values, management issues and nominated works descriptions	75
> Appendix 2 – Management plan map sheets separate attachments	84

> List of abbreviations

BBIFMAC	Burdekin Bowen Integrated Floodplain Management Advisory Committee
BHWSS	Burdekin Haughton Water Supply Scheme
BMP	Best Management Practices
BOD	Biological Oxygen Demand
BRIA	Burdekin River Irrigation Area
BSC	Burdekin Shire Council
CAP	Conservation Action Planning
DIWA	Directory of Important Wetlands in Australia
EVNT	Endangered, Vulnerable and Near Threatened
DO	Dissolved Oxygen
ICM	Integrated Catchment Management
JCU	James Cook University
NRM	Natural Resource Management
RMA	Riparian Management Agreement
SMP	System Management Plan
TSS	Total Suspended Solids

> Executive summary

Econcern was contracted by NQ Dry Tropics in late 2021 to develop System Management Plans (SMPs) for five high value wetland systems located on the Lower Burdekin River floodplain approximately 50km south of Townsville, North Queensland. The development of these SMPs forms part of the Restoring the Bowling Green Bay Ramsar Wetlands project, funded by the Australian Government's National Landcare Program. These SMPs aim to improve environmental management outcomes in floodplain tributary and distributary creek systems that comprise the Cape Bowling Green Bay Ramsar wetland catchment. This current round of SMP development follows on from the initial SMP prepared by Econcern for the Lower Burdekin floodplain's Sheep Station Creek catchment in 2020 (Econcern 2021). The Sheep Station Creek catchment was chosen as the initial focus for SMP development because it had the longest history of environmental management investment of any Lower Burdekin wetland system. This history has provided much learning and delivered a range of innovative management outcomes. Many of the management issues identified in the Sheep Station SMP are generic to the Lower Burdekin floodplain and this initial SMP is referenced substantially in subsequent SMPs, including this document. However, as detailed in this SMP for the Didgeeridoo Lagoon system, there are a range of distinct environmental management challenges associated with the unique landscape, hydrological setting, and development history of any individual wetland system. These factors need to be recognised in any prudent extension of wetland management planning strategies from one system to adjoining areas.

The Didgeeridoo Lagoon system is hosted within a floodplain tributary channel of East Barratta Creek. The main and most upstream lagoon is 1km long and up to 60m wide. There are four more lagoons hosted in 3km of drainage system downstream of its confluence with East Barratta Creek. The upper catchment is comprised 6km of previously-seasonal creek channel flowing through floodplain drainage depressions supplied by a tailwater drain network. This network drains irrigated cane land within the Burdekin Houghton Water Supply Scheme (BHWSS). It has 3000ha of contributing catchment, which is nested in the Barratta Creek catchment of the Houghton River basin. Land use within the system is dominated by irrigated sugarcane agriculture. The hydrology is modified by irrigation scheme tailwater inflows. The system has biodiversity values of state and national significance and forms part of a nationally-listed wetland; has regionally significant remnant habitat; deepwater fish habitats; 'of concern' regional ecosystems; forms a regional habitat corridor, and has listed vulnerable species.

The main environmental management issues of the system relate to its altered hydrology, which is driven by irrigation scheme tailwater inflows. This altered hydrology contributes to cyclical infestations of floating aquatic weeds and the permanent domination of wet margins with exotic aquatic grasses, fish passage barriers associated with poor reach and instream structures. Riparian and frontage vegetation is degraded by a hot fire regime associated with an ungrazed exotic pasture understory and associated large dry season fire fuel loads.

This management plan has been developed for natural resource managers of the Lower Burdekin Floodplain. Over the past two decades these stakeholders have been involved in a range of innovative environmental management initiatives that have improved the condition of floodplain wetland systems. Actions have included the use of weed harvesters and excavators to remove aquatic weed infestations; developing cost-shared weed control programs instituted through Riparian Management Agreements (RMAs), and conducting multiple riparian revegetation programs. At the time, these initiatives were truly innovative in the sense they had not been done before in the seasonal dry tropics, or – in the case of RMAs – Australia. In the Didgeeridoo Lagoon system, management initiatives have included an aquatic weed control program established via an RMA. This SMP seeks to build on these actions and the experiences gained from other systems to identify further environmental management opportunities that could be pursued with stakeholder support.

This plan was prepared following site field work and consultation with landholder and other management stakeholders throughout November and December 2021, and in February 2022. Through this field work, a literature review, and targeted stakeholder engagement, it was possible to identify system asset values, threats to these assets, and management strategies and nominated works to address threats. The condition of riparian zone vegetation was also mapped and a management planning map covering the system was prepared. This management plan examines the management needs of the wetland system under 10 issue areas covering:

1. Altered hydrology;
2. Aquatic weeds;
3. Water quality;
4. Fish passage barriers;
5. Lack of riparian vegetation;
6. Woody weeds;
7. Fire regime;
8. Grazing regime;
9. Critical habitat loss, and
10. Climate stress.

While each issue is examined separately in terms of management needs and opportunities, the relationship and interaction between issues is also identified where relevant to support integrated management recommendations and solutions. Implementation of this plan's recommendations depends entirely on voluntary adoption by relevant management stakeholders and the availability of sufficient resources to facilitate them.

> Background

Cape Bowling Green Bay Ramsar wetland

Ramsar wetlands are those that are recognised as wetlands of international importance listed under the Ramsar convention. These are wetlands that are representative, rare, or unique wetlands or are important for conserving biological diversity. Australia currently has 65 Ramsar wetlands covering some 8.3 million hectares.

Five are in Queensland including the coastal Cape Bowling Green Bay in the Lower Burdekin. As a signatory to the Ramsar convention, the Australian Government has a legal responsibility to ensure for the wise use and conservation of Ramsar wetlands. To this end, NQ Dry Tropics has been funded by the Australian Government's National Landcare Program to restore high value wetland systems in the catchment of the Cape Bowling Green Bay Ramsar wetland. To approach this task strategically, a System Management Plan (SMP) was initially developed for an individual floodplain distributary stream that drains to the Ramsar site: Sheep Station Creek (Econcern 2021). Examining environmental management arrangements for this one entire creek catchment generated a useful System Management Planning (SMP) template. This can be applied, with some site-specific adjustment, to adjoining floodplain tributaries and distributaries comprising the Cape Bowling Green Bay catchment. With that objective in mind, this SMP has been developed for the Didgeridoo Lagoon system.

Lower Burdekin floodplain – identifying assets and threats

This wetland system management plan uses terminology and methodology aligned with Conservation Action Planning (CAP), more broadly applied by NQ Dry Tropics within its natural resource management (NRM) region. In essence a CAP seeks to identify the 'assets' within a given planning region, identify 'threats' to these assets, and develop strategies which may serve to reduce the threats to assets. Assets are recognised to fall within a range of non-mutually exclusive categories including:

- Environmental;
- Economic;
- Social, and
- Cultural assets.

In seeking to serve the improved environmental management of the catchment of the coastal Ramsar wetland, this SMP is primarily focused on environmental assets. However, the greater dimension of environmental assets needs to be considered and promoted in presenting the case for their conservation. For example, a healthy wetland system has recognised environmental value. Where this same wetland provides for nature-based recreation such as birdwatching or fishing, it also holds social value. If fish populations supported by the wetland include commercially-targeted species, it also holds economic value. If the site is of significance to Traditional Owners or the history of non-indigenous Australians, it also has cultural value.

While some asset values are complimentary, they can also sometimes be in competition. For example, the developed irrigation water supply systems of the Lower Burdekin floodplain are very important economic assets that have delivered employment and economic benefit to the regional community. They have, however, often come at a cost to the health of wetland systems impacted by the consequent modification of floodplain hydrological regimes that has accompanied irrigation development. Other examples of value conflict can occur where appreciation of the recreational values of a wetland, for instance, four-wheel driving may conflict with the conservation of sensitive biodiversity, or where a pasture species favoured as an asset for pastoral production acts as an invasive weed in wetland habitats. Ultimately it is for society's social, political, and legal systems to determine which values are managed for within a regional landscape. This SMP seeks to identify best management practice for identified environmental assets, while recognising that such management aspirations need to operate within a broader economic, social, and cultural context.

System Management Plan – scope and purpose

This SMP has been commissioned by NQ Dry Tropics to provide a blueprint for improved environmental management of the targeted wetland system. In doing so, it aims to support improved management and protection of the environmental assets of the Cape Bowling Green Bay Ramsar wetland on the coastal margin of the targeted system. The SMP's scope includes the ecological assets of the targeted wetland system, and also the biophysical condition, processes and management arrangements within the system's catchment area that may ultimately impact wetland condition.

This SMP aims to provide a 'go to' document for investment in the management of high value Burdekin floodplain wetlands. Recognising the vagaries of environmental management funding and the consequent often reactive nature of program investment, it provides a proactive planning tool that can direct management funding when it becomes available towards already-defined priorities. It also acts as a prospectus for those seeking to pursue funding applications or sponsor environmental management. Further, this SMP also seeks to document historical wetland management gains, the implementation issues surrounding them, and provide recommendations to better address outstanding environmental management challenges facing the contemporary wetland system.

The SMP's intended audience is the range of natural resource management stakeholders associated with the Lower Burdekin floodplain. These include riparian landholders, most of which are cane farmers; Sunwater; local government (Burdekin Shire Council); catchment heavy industry (such as Wilmar); Traditional Owners (represented by Gudjuda Reference Group Aboriginal Corporation); and the broader community, including community-based interest and NRM groups such as Burdekin Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC), Lower Burdekin Landcare, and NQ Dry Tropics.

Over the past two decades these stakeholders have been involved in innovative management initiatives that have improved the condition of wetlands that were considered highly degraded in the early 2000s back to relatively healthy, though modified, aquatic ecosystems today (Econcern 2021). Innovative management approaches implemented have included the use of weed harvesters and excavators to remove neglected aquatic weed infestations; the development of a cost-shared aquatic weed control programs instituted through RMAs; fish passage provision around instream infrastructure, and reach-scale riparian revegetation programs. At the time, these initiatives were truly innovative in the sense that they were novel approaches for the seasonal dry tropics, or – in the case of RMAs – were Australian-firsts.

Implementation of this plan's recommendations depends entirely on their voluntary adoption by landholders and other relevant management stakeholders and the availability of sufficient funding and material resources to facilitate it.

Didgeridoo Lagoon system overview

Location and geomorphic setting

The Didgeridoo Lagoon system is located 68km south of Townsville and 16km to the east, southeast of the township of Giru in the Lower Burdekin region. The system is hosted within a floodplain distributary channel (and possibly historically the main channel) of the East Barratta Creek system. The main lagoon within the system is 1km long and up to 60m wide. There is 3km of drainage system hosting four more separate lagoons including cut-off oxbows downstream of the main lagoon to its confluence with the East Barratta Creek channel.



Figure 1. Didgeridoo Lagoon Catchment (highlighted in white) relative to the Cape Bowling Green Bay Ramsar wetland site (green line), and relative to the Bruce Highway and Barratta Creek (right).

Above the main lagoon there is a further 6km of previously seasonal (but now near perennial) creek channel flowing through floodplain drainage depressions that is supplied by a constructed tailwater drain network draining irrigated cane land within the Burdekin Haughton Water Supply Scheme (BHWSS), operated by Sunwater. Up to 8km of constructed drain mainstem extends upstream to the boundary of the contributing catchment. Some 3000ha of contributing catchment drain to the system. This is nested within the Barratta Creek sub catchment of the defined Haughton River basin, though the area functionally forms part of the Burdekin River floodplain during high flow events.

Hydrology – natural and modified

Like all wetlands in the seasonal dry tropics, the natural hydrology of the system was highly seasonal and related to the timing and magnitude of the annual wet season. Now the dominant influence on the dry season hydrology of the contemporary Didgeridoo Lagoon system is aseasonal inflows of irrigation tailwater and supply channel overflows from the BHWSS and adjoining farmland. These inflows override the historically seasonal characteristics of the system and are a major driver of its water quality and other condition factors such as aquatic weed infestation. Wet season hydrology remains an important contributor to site geomorphology and habitat resetting. These factors include floodplain catchment runoff, which has been increased by levelling for farm development and associated drain construction; overbank distributary flood breakouts from Barratta Creek; upstream back flows at the confluence with the flooded East Barratta Creek system, and floodplain inundation and overland flows during large events. Much of the system's catchment is also underlaid by shallow sand bedded alluvial aquifers of varying confinement that interact with surface water features such as the lagoons. These aquifers have been subject to irrigation driven groundwater rise in recent decades.

Land use, tenure and remnant vegetation

The majority of the system and its catchment area is freehold land. Other tenures present include a broad road reserve adjoining and to the north of the current highway alignment, which includes a cross-section of lagoon and adjoining remnant vegetation areas. The lower third of the lagoon system upstream of the highway is also Crown watercourse, and an area of Crown reserve occurs on the eastern bank of the lagoon system south of the highway crossing. There is also a broad leasehold easement running through the system north from the highway to East Barratta Creek. Large areas of remnant vegetation that form a habitat corridor within the BHWSS also occur on leasehold land managed by Sunwater. In terms of land use, the system's catchment is dominated by irrigated sugarcane agriculture. Remnant vegetation on Sunwater land has been retained nominally for conservation use, and is also leased for grazing. While the remnant floodplain vegetation (open woodland) on Sunwater land has high integrity and associated conservation value, most remnant riparian vegetation adjoining the lagoon system has some level of past clearing or hot fire disturbance; though the reach upstream of the confluence with East Barratta Creek retains greater diversity and structural integrity.

Key assets and values

The Didgeridoo Lagoon system provides productive deepwater fish habitats that contain good barramundi populations and functions as nursery habitat for first year class fish. The system also has high waterbird and other wetland fauna habitat values, including supporting populations of both fresh and estuarine crocodiles, freshwater turtles and raptors. High terrestrial habitat values are associated with the better condition reaches of riparian vegetation in the lower system and frontage woodland, and the remnant floodplain vegetation retained on Sunwater land that hosts populations of macropods and arboreal mammals. It also acts as a regionally-important habitat node and cross-floodplain drainage wildlife corridor that links remnant habitat areas of Jerona Station in the north with retained BHWSS habitat areas in the south, which ultimately link to Mount Kelly and the Burdekin riparian corridor in the east, and the Haughton riparian corridor in the west.

Historical and current management

The main past environmental management investment in the system has been an RMA that operated in the mid-2000s for several years. Burdekin Shire Council still periodically sprays infestations of water hyacinth within the lagoon adjoining the Bruce Highway when floating weed mats become apparent.

Ongoing threats, management challenges

The most significant ongoing threat to the condition of the Didgeridoo Lagoon system is altered hydrology due to aseasonal inflows of irrigation tailwater and supply channel overflows from the Sunwater-operated BHWSS in the upper catchment. Impacts include a loss of seasonality via reduced dry season water level drawdown and the associated proliferation of floating aquatic weeds and exotic grasses (hymenachne, para), which impacts native aquatic plant communities and water quality. Riparian and frontage vegetation condition throughout the upper lagoon system has also been impacted by hot fires. An ongoing hot fire risk is associated with large fuel loads created by an ungrazed understorey of exotic guinea grass on levees and frontage areas. Water quality impacts associated with BHWSS inflows and weed proliferation include sustained turbidity, elevated nutrients, organic loading, and dissolved oxygen depletion. Road crossing culverts and piped outlets in the lower system represent fish passage barriers that are only bypassed during large flood flow events. Woody weeds on drainage lines of the upper system, including rubber vine and chinee apple, with new species emerging such as neem tree and java plum (*Syzygium cumini*). A site-specific risk to bank stability occurs immediately downstream of the new highway crossing where high flows are directed onto the eastern bank. In the longer term, riparian and remnant vegetation may also be impacted by groundwater rise and land use intensification.

> Methods – assessment and reporting

Stakeholder consultation

Stakeholder consultation for the preparation of this management plan was undertaken during November to December 2021 and February 2022 and involved:

- on-site consultation with riparian landholders of the wetland system;
- meetings with representatives from community organisations involved in project work within the targeted wetland system, including Lower Burdekin Landcare, BBIFMAC and NQ Dry Tropics;
- consultative meeting with Sunwater;
- meeting with Burdekin Shire Council managers and operational staff involved in overseeing the aquatic weed control program service delivery; and
- informal engagement with researchers from research and development (R&D) providers that have worked across the Lower Burdekin floodplain, primarily at TropWater, James Cook University (JCU).

For each interviewed landholder, engagement involved non-structured questioning about impressions of the environmental status of the creek; opinion of the adequacy of existing management arrangements; suggestions for additional or improved management approaches, and willingness and/or nominated preferences for conducting various on-ground environmental management works on the landholders' riparian landholdings. The

latter are captured as 'nominated works' in Appendix 1 and presented on catchment management plan sheets (Appendix 2).

Literature review

Literature reviewed for preparation of this plan was sourced from 'grey literature' associated with previous NRM management plans, strategies, and consultant reports from the Lower Burdekin, plus formal scientific journal papers covering topics usually directly related to the Lower Burdekin floodplain study area. A range of information was also sourced online from Queensland Government agency sites including [Queensland Globe](https://qldglobe.information.qld.gov.au/) (<https://qldglobe.information.qld.gov.au/>), [Wetland Info](https://wetlandinfo.des.qld.gov.au/wetlands/) (<https://wetlandinfo.des.qld.gov.au/wetlands/>), and [DES regional ecosystem descriptions](https://apps.des.qld.gov.au/regional-ecosystems/) (<https://apps.des.qld.gov.au/regional-ecosystems/>).

Field work

Most field work was conducted in conjunction with landholders. Once site access permission was granted by landholders, some sites were subsequently revisited to gain additional information. Information was collected primarily by noted observation and digital images and included details about: riparian vegetation condition, weed infestation status, evidence of fire history, status of revegetation sites, potential fish passage barriers, water infrastructure, habitat values, incidental records of flora or fauna, observations of land degradation, and potential works sites.

Management planning mapping

Maps of riparian vegetation condition were produced to inform environmental management planning for the wetland system (Appendix 2). These were generated by using a computer-based geographic information system (ArcGIS) to draw lines (polygons) around features on digital aerial images that depicted different classes of riparian vegetation condition. Eleven classes of riparian condition were defined, including overstorey vegetation, grasses, and within channel aquatic classes. These are below and in Appendix 2:

1. Remnant vegetation.
2. Degraded remnant.
3. Revegetated.
4. Exotic trees.
5. Grassland.
6. Exotic grasses.
7. Cumbungi.
8. Open water.
9. Native aquatic plant-covered water.
10. Floating aquatic weed-covered water.
11. Water with emergent aquatic plants.

Mapping system reaches into these riparian condition classes provides a basis for:

- Examining the overall and relative ecological condition of the wetland system;
- Identifying system-scale drivers of ecological degradation;
- Developing generic management recommendations for reaches dominated by condition types;
- Defining strategic priorities for restoration and protective management; and
- A timeline baseline to compare with future creek condition states.

In addition to riparian vegetation condition, GPS-referenced points collected in the field for reach asset values, management issues and nominated works are also displayed on the management plan maps (Appendix 2).

> Summary system assets, threats, and nominated management strategies/works

Reach assets, threat management issues and nominated works compiled during the development of this SMP are tabulated in Appendix 1 and presented on management planning maps (Appendix 2). They are described and summarised below.

Assets

These are ecological values associated with the wetland and/or adjoining riparian ecosystem that are significant at scales beyond this site alone. They are underpinned by criteria such as productivity, biological diversity, habitat connectivity, representativeness, and habitat provision that serve fish and wildlife populations and nature conservation objectives at reach, catchment, regional, state or even national scales.

The main ecological asset values identified for the Didgeridoo Lagoon System include:

- A series of deepwater perennial lagoons that host diverse fish populations, vulnerable estuarine crocodiles and waterbird and woodland bird populations, which forms part of wetland listed in the Directory of Important Wetlands in Australia (DIWA).
- High value fish habitats, including key nursery and adult habitat for the migratory and recreationally and commercially-important barramundi.
- A large area of intact remnant floodplain woodland and wetland vegetation retained within a habitat corridor and node network of the Burdekin Haughton Water Supply Scheme (BHWSS) area that links across the floodplain from the Haughton to Burdekin Rivers. This area contains matters of state environmental significance, for example, 'of concern' regional ecosystem and habitat for Endangered, Vulnerable and Near Threatened (EVNT) wildlife species; has records for listed vulnerable bird species, and has good populations of arboreal mammals and macropods, reptiles, and amphibians.
- A diverse range of bird habitats and populations covering numerous group types, including woodland and grassland species, migratory passerines, owls, raptors, waterbirds, and waterfowl.
- A retained corridor of riparian and frontage woodlands that provides a north-south wetland and wildlife habitat corridor that links the extensive remnant floodplain habitat areas of the BHWSS in the south with the extensive remnant coastal habitat areas of Jerona Pastoral Property in the north.
- Diverse and structurally-complex creek riparian vegetation remnants that provide habitat for a diversity of aquatic and terrestrial fauna, including estuarine crocodiles, freshwater turtles, other reptiles, migratory fish and passerines, and other woodland birds, owls, raptors and bats.
- An interface wetland system between intensive production and protected landscapes (including the Ramsar wetland) that provides a range of ecosystem services to the downstream receiving environment, including water quality processing, primary production, and flows of materials and biota.
- A high-profile aesthetic wetland adjoining the national Bruce Highway that contains state land and provides opportunities for management demonstration sites and public use and appreciation.

Threats/management issues

System management issues include aquatic and riparian zone threat management concerns that are characteristic of a wetland reach or specific to it. They also include threat management issues that occur at more than one site within the wetland system, and are well demonstrated by a particular reach example. Some identified threat management issues have impacts that affect the wetland ecosystem at a catchment scale.

The main system management issues for the Didgeridoo Lagoon system include:

- Aseasonal inflows of irrigation scheme (BHWSS) tailwater that has generated both altered hydrology and water quality impacts that act as the primary driver for secondary threats such as aquatic weed infestation, loss of critical habitat associated with the seasonal water level zone, and poor reach condition fish passage barriers.
- A hot fire regime throughout the mid-system resulting from large dry season fire fuel loads created by an ungrazed understory of exotic pasture grasses, principally guinea grass, that has resulted in the degradation and loss of frontage woodland and riparian vegetation communities over the past two decades.
- Cyclical infestations of floating aquatic weeds and sustained infestation of aquatic grass weeds that represent a symptom of the altered hydrology and water quality of the system and result in secondary impacts to water quality, fish passage, and native aquatic plant communities and associated habitat resources.
- Fish passage barriers associated with aquatic weed chokes and physical structures (road crossing culverts).

- Further spread of exotic trees/woody weeds and rubber vine and associated condition decline of remnant riparian vegetation (upper catchment).
- Localised erosion risks to channel stability associated with the removal of high bridge infrastructure.
- Longer term risks associated with irrigation-driven groundwater rise and land use intensification.

Nominated works

This is a non-exhaustive list of wetland system asset threat management strategies or works that were identified over the course of project field work, or subsequently during desktop-based assessment. They are proposals only and implementation would be subject to landholder endorsement, funding resourcing, appropriate agency approvals where required, and further landholder and management stakeholder engagement.

Nominated management works for the Didgeridoo Lagoon system include:

- Prevent or reduce aseasonal inflows of BHWSS tailwater to the system to reinstate seasonal hydrological character to the lagoon and lower system and mitigate some of the impacts associated with aseasonal inflows. Management options potentially include:
 - Reduce the supply of channel overflow volumes, and
 - Promote off-stream tailwater reuse for drain water.
- Establish a collaborative controlled grazing (mobile herd) and fire regime management system throughout the mid-system (ideally in conjunction with seasonal drawdown of water levels) to:
 - control exotic aquatic grass margins (without spaying);
 - promote native emergent aquatic plant communities;
 - reduce frontage and levee dry season fire fuel loads;
 - protect and promote the regeneration of remnant riparian and frontage woodland vegetation.
- Revegetate trial sections of the lagoon system's bank margin and levees and existing grass weed chokes with shade-casting riparian vegetation to reduce the dominance of exotic aquatic grasses on water margins, to reduce fire fuel loads on levee areas, and to facilitate open channel ways.
- Trial a catchment-based line of control 'partial-eradication' approach for targeted floating aquatic weed species (water hyacinth, water lettuce).
- Conduct targeted woody weed and rubber vine control to prevent the further spread of novel exotic tree species into the lower system and improve the condition of riparian habitats remnants in the upper system within the BHWSS-retained habitat areas.
- Install rock armouring protection of the stream bank reach experiencing undercutting due to changed flow conditions associated with the Bruce Highway upgrade.
- Start addressing identified fish passage barriers, both physical and poor reach conditions, with an updated fish survey to inform works prioritisation.
- Support the implementation of groundwater monitoring and investigations that examine any linkages between groundwater behaviour and floodplain remnant vegetation condition, and between lagoon and system water levels and groundwater accession risks.
- Engage management stakeholders to work towards establishing formal nature conservation management arrangements for the retained remnant floodplain habitat corridor and node network within the BHWSS.

> System management plan, key threats to assets and recommended management strategies

Wetland system catchments are perhaps one of the most readily-identified examples of an integrated system. In other words, changes in the condition of one component of the system influences and impacts the status of other components. When considering the management of a wetland system, the Integrated Catchment Management (ICM) approach developed in Queensland in the 1990s (DPI 1993) still offers one of the most useful frameworks for considering how management initiatives across a range of issues serve to deliver benefits for the system as a whole.

Based on consultation with management stakeholders, a literature review and field investigations, the following 10 threat management issues have been identified as important to the ecological health of the Didgeridoo Lagoon system. These are:

1. Altered hydrology;

2. Aquatic weeds;
3. Water quality;
4. Fish passage barriers;
5. Lack of riparian vegetation;
6. Woody weeds;
7. Fire regime;
8. Grazing regime;
9. Critical habitat loss, and
10. Climate stress.

While each issue is examined separately in terms of threat management needs and opportunities, the relationship and interaction between issues is also identified where relevant to support integrated management recommendations and solutions. One example of a threat that operates across nearly all other threat management issues is the emerging impact of climate change, which has a demonstrated capacity to exacerbate existing environmental stress.

Altered hydrology

Types and impacts

The natural hydrology and associated ecology of wetlands within the seasonal dry tropics, including those of the Lower Burdekin floodplain, is highly seasonal and related to the timing and magnitude of the annual wet season. Annual inundation in response to wet season rainfall, connection to floodplain distributary channel flows, the subsequent cessation of flow, waterhole isolation and water level draw-down through the dry season – sometimes to complete drying – provide key drivers and stimuli for biophysical processes that determine the ecological character of the Lower Burdekin's natural floodplain wetlands. These seasonal events provide for germination of aquatic plants; reproduction, movement and recruitment of fish populations; nesting, and breeding of waterfowl; flushing of organic matter, scouring, and habitat resetting within drainage channels; seasonal changes in water quality, and processing and assimilation of catchment nutrient loads.

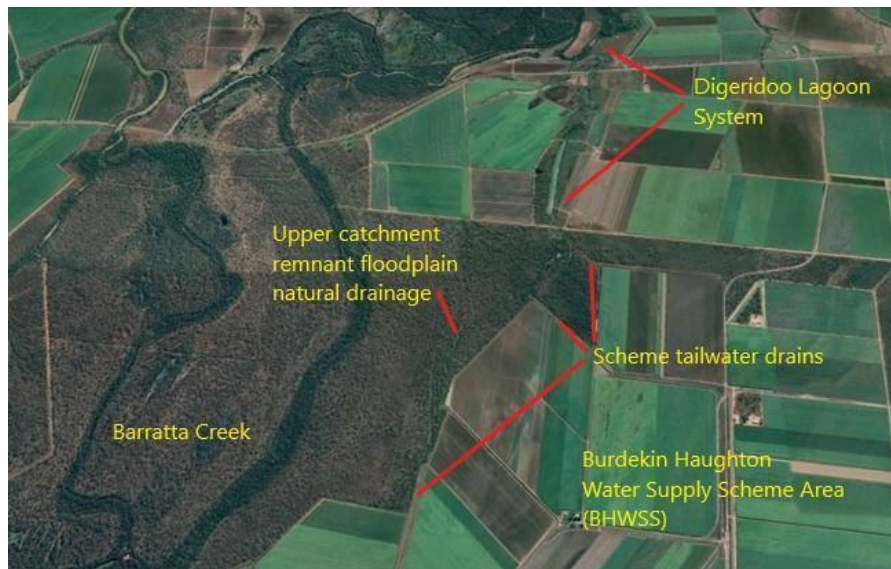


Figure 2. Didgeridoo Lagoon system viewed from upper catchment, looking downstream (north).

In the contemporary, modified floodplain system, the hydrology of the majority of freshwater wetlands, including most stream networks, is influenced by irrigated farm and/or irrigation scheme development within contributing catchment areas. Irrigation tailwater, including supply channel overflow from Sunwater's owned and operated BHWSS, or individual farms, drain to low-lying areas that host wetlands. Often, in the case of the BHWSS, this is via large, constructed drains. Within both the Burdekin Delta and floodplain, distributary stream channels are used by both Sunwater and Lower Burdekin Water operations to convey water pumped from main rivers (Houghton, Burdekin) to deliver surface water for irrigators and to recharge shallow groundwater aquifers. Across large areas of the BHWSS, irrigation-driven groundwater rise (Figure 5) has also occurred to the extent that some water tables now discharge to surface drainage networks. Elevated groundwater is also suspected of directly impacting the condition of native vegetation, including riparian zones in some areas of the floodplain (Photo 2).



Photo 1. BHWSS tailwater drain RB2/1 inflow to upper system (December 2021). Although some of this observed flow represents the tail of a rainfall event, this drain does flow throughout most of the year.



Photo 2. Sustained high water levels within the Didgeridoo Lagoon system. The appearance of features consistent with salt scalds on adjoining frontages, and an apparent decline in the vigour of adjoining floodplain vegetation,

suggest some reaches may be experiencing impacts associated with groundwater rise.

The collective impact of irrigation tailwater, channel overflow, pumped flows and elevated groundwater discharge is that historically seasonal floodplain stream systems, such as Ironbark, Barratta, Collinson's, Sheep Station, Plantation, Kalamia, and Saltwater creeks, and many smaller unnamed distributaries, are now perennial or semi-perennial; maintaining connective flows or seepage between wetland water bodies that were historically isolated, or even dried during the dry season. These aseasonal inflows contribute to a reduction in dry season drawdown of lagoon water levels and altered water quality (higher turbidity and nutrient loading). This altered hydrology and water quality has generated major changes to wetland aquatic plant communities, increased the abundance of fringing exotic aquatic grasses and floating weeds; decreased the abundance or diversity of native water lilies, submerged aquatic plants, sedges, and other emergent aquatic plants; and impacted associated habitat values for wetland fauna, including birds, reptiles and fish. The colonisation of historically drying, but now saturated, distributary channels by impenetrable stands of cumbungi bullrush has also impacted system water quality, fish passage, and channel hydraulic capacity in addition to habitat values.

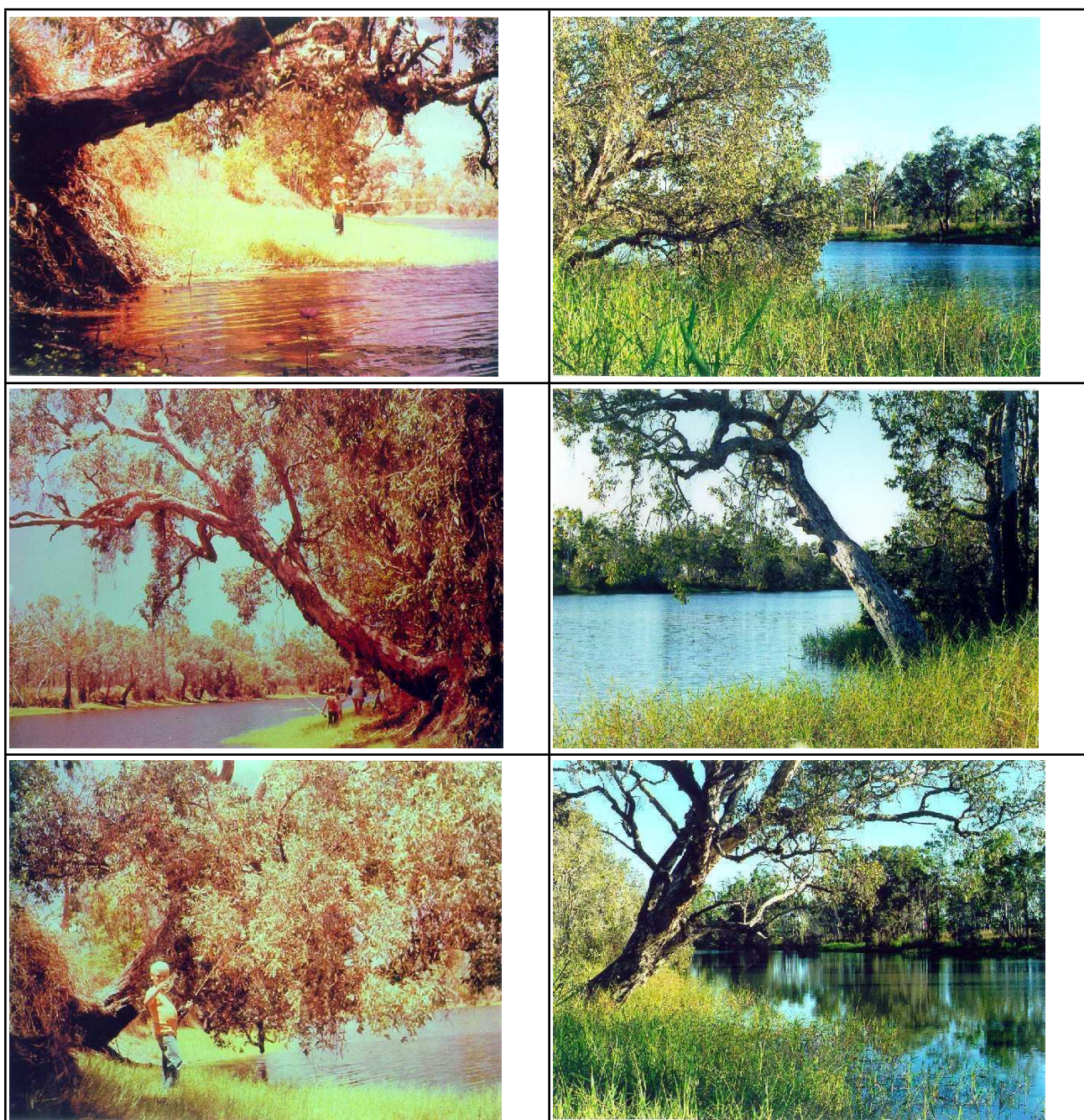


Figure 3. Photos of the most upstream lagoon in the Didgeridoo system (Hoey's Hole). These include images from 1971 (left) from the author's family's personal collection when the system still retained a highly seasonal character, and images from 1999 (right) taken in approximately the same location after the system had been hydrologically modified by irrigation

scheme tailwater inflows (and possibly associated groundwater rise) from the BHWSS area. NB: In 1971, native versus exotic fringing grasses, presence water lillies, clearwater, 1m+ dry season water level drawdown.

A positive habitat impact associated with increased stream perenniality has been the development of denser and more diverse riparian vegetation zones along some previously seasonal creek systems. Some stakeholders have expressed concerns that this also represents a flow capacity impact, though comparisons with unshaded, weed-filled channels have not been tested.

Another form of altered hydrology impacting the Burdekin floodplain and coastal wetlands is the damming and bunding of stream channels and floodplain drainage depressions. These are usually established to form watering points and/or ponded pasture forage for grazing stock. In near-coastal areas such structures also inadvertently, or intentionally, exclude tidal ingress, the latter sometimes being employed by water managers as a saltwater intrusion prevention groundwater management tool. Where these structures are established in tidally-influenced areas, estuarine and brackish vegetation (mangroves, samphire flats, bulkuru sedge) upstream of the bunds is replaced with freshwater vegetation, and downstream areas risk becoming hypersaline. In some catchment settings where inflows to bunded areas remain seasonal, the habitat quality of wetlands that establish within them can be good. Where such areas are subject to sustained aseasonal inflows and reduced seasonality, they usually become dominated by exotic aquatic grasses, floating weeds and/or cumbungi. Independent of bunding or damming, sustained aseasonal flows of freshwater into estuarine areas such as the Barratta Creek estuary is changing their salinity regime, water quality, and primary productivity as weeds such as hymenachne advance into areas previously characterised as tidal.

Development of much of the floodplain to agriculture has also altered its runoff hydrology. Whereas the natural floodplain was comprised of diffuse drainage networks including depressions, distributary channels and isolated basins, the developed floodplain has been filled, levelled, and served by constructed drainage systems which, in the case of the BHWSS, can be large high flow capacity systems (Figure 2, Photo 1). This results in less detention of runoff on the floodplain, and a more rapid conveyance to receiving natural drainages and wetland systems by peakier flow events. These peakier, higher velocity flows have a greater capacity to transport contaminant loads (sediment, nutrients) and erode channels, both natural and constructed.



Photo 3. January 1964 aerial image of the lagoon system upstream of the highway characterised by a lily-fringed, clear tannin-stained open water body, open water connection between reaches, and a vegetated floodplain. Cattle yards visible top right and cattle pads visible on floodplain.



Photo 4. April 2018 aerial image of the same lagoon system reach, characterised by turbid water; margins dominated by hymenachne, para grass, and floating aquatic weed rafts; an exotic pasture-dominated, largely treeless floodplain; and weed chokes between reaches.

The upper catchment Burdekin Falls Dam represents another basin-scale alteration of hydrology that also impacts floodplain wetlands. This dam acts as a detention area during high rainfall events across the basin, serving to reduce the height and frequency of Lower Burdekin flood peaks that previously would have broken out of the river channel into floodplain distributaries, scouring and resetting habitat conditions for channel-hosted wetlands. Riverbank levees constructed to prevent such outbreaks and protect farmland have also reduced the occurrence of these ecologically-important flows. Another impact consequence of the Burdekin Falls Dam capturing flood events is that, while river baseflows historically drained to clear, now water reticulated through irrigation scheme areas remains turbid for most, if not all, the calendar year. This sets in

train a host of water quality-associated impacts for a river and floodplain system that naturally had high clarity water outside of the annual wet season.

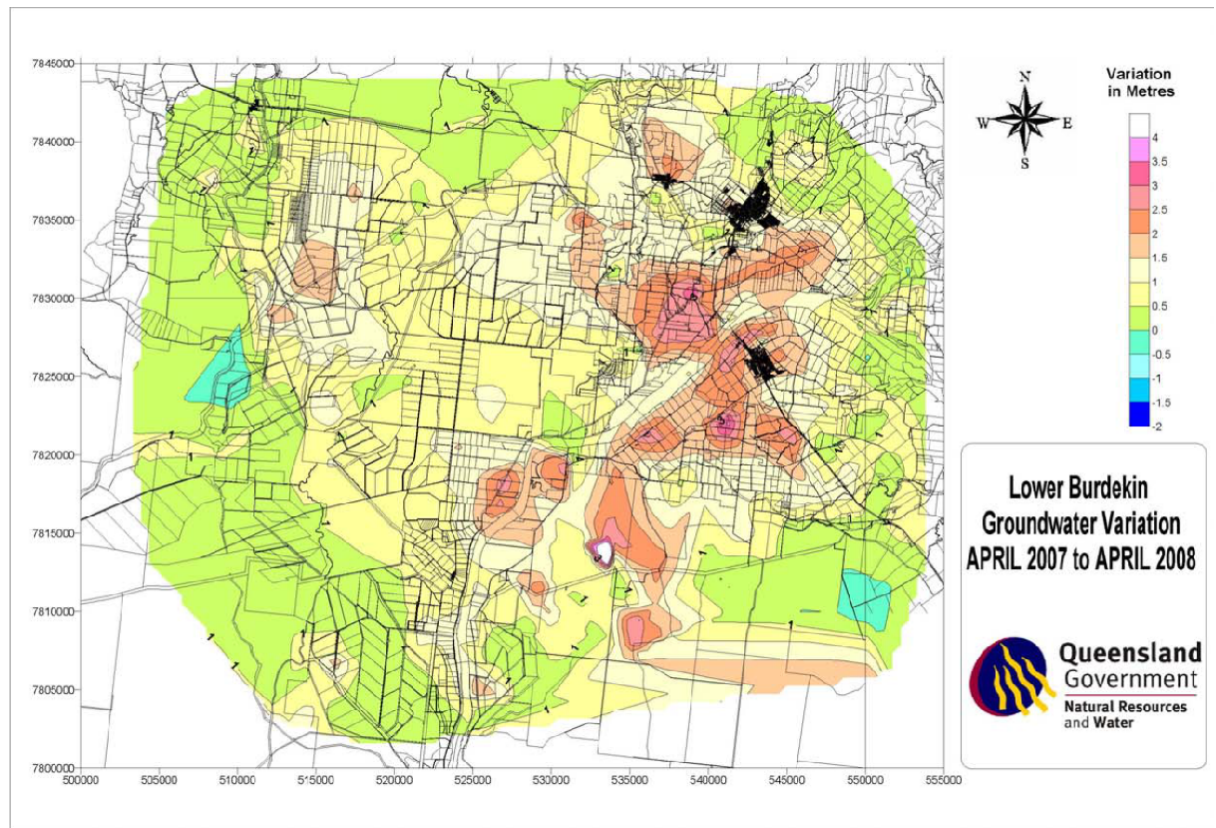


Figure 5. Didgeridoo Lagoon system headwaters (red dot) within the area of the Lower Burdekin floodplain experiencing groundwater rise.

System specifics

The hydrology of the contemporary Didgeridoo Lagoon system has been modified from its natural condition by much of its contributing catchment area being converted to irrigated agriculture, including a significant proportion of its upper catchment which now lies within the Sunwater-managed BHWSS. Hydrological change has been driven by modifications to catchment runoff response, the volume and seasonality of surface flows, and rising groundwater tables. Aseasonal inflows of BHWSS tailwater into its upper catchment of the lagoon system (M1) is the most apparent driver of altered hydrology. These inflows contribute to near-perennial flow through the downstream drainage system and a major reduction in dry season drawdown of system water levels. Historically, lagoon water levels within the system varied from basin full in the wet season to up to several metres of drawdown into the basin through the dry season (Figure 3). Most lagoons through the system exhibited dry season perennality, even prior to BHWSS inflows, suggesting they represent groundwater windows with good connectivity to adjoining shallow aquifers. This altered hydrology has generated major changes in aquatic plant communities, water quality, and associated habitat values for wetland fauna. These are described below.

Aquatic plant communities – The lagoon's modified hydrology, including sustained water levels, creates conditions suited for domination of the water edge and shallow zone by exotic 'ponded pasture' grass species, including hymenachne, para grass and aleman grass (M4). These grasses now dominate areas that previously supported emergent, submerged and floating beds (like water lilies) and native aquatic plants (Figure 3, Photo 3). Infestations of floating aquatic weeds promoted, in part, by the modified hydrological conditions and elevated nutrients, including water hyacinth, water lettuce and salvinia, periodically also infest sections of the lagoon system. Historically, the dry season drawdown of water levels within the lagoon system created important habitat zonation that allowed a range of native aquatic plant species to occupy different edge zones, including emergent plants on seasonally exposed banks; native fringing aquatic grasses (for example, spikey mud grass, Figure 3); submerged plants in open shallows; and rooted beds of water lilies in deeper shallows. Competition from aquatic grass and floating weeds and a lack of seasonal water level drawdown have all served to reduce the area, abundance, and diversity of these native aquatic plant communities within the lagoon system.

Water quality – The most apparent water quality change from natural conditions in the lagoon system is higher turbidity and nutrients. Most of this change is related to the quality of BHWSS tailwater inflows, rather than altered hydrology per se (see *water quality* section), although there are known and potential altered hydrology drivers to water quality risks faced by the contemporary system. Elevated rates of runoff in levelled and drained upper catchment areas would convey higher loads of suspended sediment and other contaminant loads than the undeveloped floodplain. Under natural hydrological conditions, contaminant loading was limited to wet season inflows, after which suspended sediment settled, colloids were attenuated in aquatic vegetation, and nutrients were processed (utilised, stored and/or denitrified). Under the contemporary situation of sustained aseasonal inflows, turbidity and nutrient loading extends throughout much of the calendar year. Under natural conditions of water level drawdown, fringing plant biomass (and its contained organic nutrients) would be stranded on bank margins as water levels recede and evaporative and/or drainage losses from the lagoons are replaced with high quality groundwater inflows. On the contemporary floodplain, groundwater inflows pose a potential pathway for contaminant loads including nutrients, salinity and agri-chemical residues. A less apparent, though potentially more ecologically significant, water quality impact facilitated by the system's altered hydrology is the degradation of dissolved oxygen levels. These reduced levels result from aquatic weeds choking channels and smothering open water surfaces, and from excessive growth of submerged aquatic plants under sustained water level conditions.

Habitat values – Altered hydrology impacts to wetland habitat values generally result from secondary linkages. For example, altered hydrology promotes aquatic weed growth, aquatic weed growth creates anoxic (low dissolved oxygen) creek reaches, which then decrease fish habitat values and create fish passage barriers. Some impacts can be direct, for instance, sustained high wetland or groundwater levels result in water-logging death of riparian or floodplain vegetation. The seasonal native aquatic plant communities described above are identified as a specific critical habitat type directly impacted by altered hydrology. Their diversity and abundance represent feeding, nesting, egg laying, and sheltering habitat resources for waterbirds and fish. Exposed dry season lagoon banks favoured by aquatic reptiles and many waterfowl species is another example of a habitat directly lost to altered hydrology, although the invasive potential of exotic aquatic grasses means that restoration of hydrological variability alone may not restore this habitat asset. While controlled grazing has an important role for reducing the bank side dominance of these grasses (see *grazing regime* section), its effectiveness is strongly influenced by the hydrology of the system. Sustained water levels keep floating margins of exotic aquatic grasses inaccessible to grazing stock, whereas water level drawdown provides grazing access.

The significance of groundwater rise as a potential driver of impact within the Didgeridoo system has not been ascertained by this planning study and is nominated as an area for further investigation with water management authorities. Sunwater has current monitoring groundwater data, yet some is subject to privacy provisions. Irrigation-driven groundwater rise is recognised for much of the system's catchment area (Figure 5). Along some frontage areas on the eastern side of the lower lagoon system, stands of remnant vegetation have been observed anecdotally over a decadal timeframe to succumb to dieback with no obvious evidence attribution to insect attack or hot fire impact. Other features indicative salt scalded and/or waterlogged soil (Photo 2) suggests groundwater rise may be a contributory factor (M8).

A small site-specific altered hydrology impact was also noted in the company of a concerned landholder immediately downstream of the old highway crossing. During the construction of the new highway crossing of the Didgeridoo Lagoon system, culverts beneath the old highway crossing were removed along with the crossing. This has contributed to a change in the downstream flow direction under larger events with higher flows now placing more pressure on the eastern bank than occurred previously when the culverts trained flow toward the centre of the channel. This could ultimately lead to the undercutting of the bank and a new breakout distributary channel to the east. This outcome is not desired by the landholder (M13).

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage with BHWSS operator Sunwater and other stakeholder representatives (particularly water users, riparian landholders) to investigate and implement viable options for reducing the volume of aseasonal flows of scheme tailwater into Didgeridoo Lagoon system (W1). This would reinstate the seasonal drawdown of the lagoon water level and associated seasonal water quality conditions and aquatic plant communities. Nominated options include:
 - a. Promote reuse of tailwater to reduce flow volumes in three drainage channels (RB2/0, RB2/1 and RB2) feeding to Didgeridoo Lagoon system via zero cost incentives and/or establishing recycle pit infrastructure (the latter potentially able to be supported by public funding due to public benefit).
 - b. Improved/modernised (telemetric) flow allocation/scheduling to reduce channel overflow and to avoid/minimise channel contribution to downstream tailwater flows.
 - c. High level negotiations occur between NQDT and the Department of Resources to seek a Lower Burdekin floodplain area management plan. This plan would encompass the waiving of overland flow and watercourse access/licence fees where it can be demonstrated that sought

volumes can be supplied by excess aseasonal flows emanating from farm irrigation and BHWSS area tailwater.

2. As part of implementing 1 (above), engage with Sunwater and local irrigator stakeholder representatives to have access granted to current monitoring data. This data could improve understanding about the relationship between groundwater and lagoon system water levels and connectivity between the two. Further, the potential role of managing surface drainage and flows as part of the management of groundwater rise and its implications for seasonal hydrology and Didgeridoo Lagoon system management planning.
3. In conjunction with implementing 1 (above), engage with Sunwater to examine options for improving the runoff hydrology of the BHWSS area. In particular, identifying how detention function and detention areas could be retrofitted within channels and areas adjoining the drainage network to reduce the drainage modulus and associated transport of contaminants to downstream receiving wetlands, such as the Didgeridoo Lagoon system.
4. Facilitate, on behalf of the adjoining landholder, engagement with Department of Environment and Science, Department of Transport and Main Roads, and other relevant agencies to identify the bank erosion risk associated with the removal of the old Bruce Highway crossing of the system and to facilitate resources and permit approvals for stabilisation works (W9).

Aquatic weeds

Types and impacts

Aquatic weeds are commonly cited as the most significant cause of ecological impact within Lower Burdekin floodplain wetland systems (Waltham *et al* 2020, Tait 2013, Perna *et al* 2012, Veitch *et al* 2007, Tait & Perna 2001). They create blockages to flow and fish passage; outcompete native aquatic vegetation; generate high fire fuel loads in seasonally dry riparian vegetation (in the case of aquatic grasses); cause collapses in instream dissolved oxygen levels via organic loading; and cover open water surfaces, consequently impacting fish and other fauna habitat availability and quality. While these impacts are attributed to weeds, it should be recognised that observed weed infestation levels are often a symptom of other ecological impact drivers which promote weed proliferation. These include altered hydrology increasing aquatic habitat availability and reducing water level seasonality, and increased availability of nutrients associated with catchment land use and runoff, regulated inflows, and irrigation tailwater. Given the ongoing use of the Lower Burdekin floodplain's land and water resources for irrigated agriculture, these drivers of weed proliferation will, to some degree, remain part of most modified ecosystems. Effective weed management needs to be ongoing if management stakeholders want wetland ecological values to be retained or improved. Considering the costs associated with aquatic weed management, there is a strong impetus for control practices to be as effective as possible and for innovative developments that provide for continuous improvement in management approaches.

A large range of aquatic weed species are recorded from the Lower Burdekin floodplain, with most of these recorded for the Didgeridoo Lagoon system (Table 1). Aquatic weeds include floating, submerged, and fringing emergent growth forms including aquatic grasses. There are also a number of emerging aquatic weed risk species identified in the *Burdekin Shire Biosecurity Plan* (BSC 2020) that have been more recently recorded in the shire or adjoining regions (Table 2). While exotic species are more commonly recognised as 'weeds', several native aquatic plants (Table 1) have also become weedy in nature under the modified ecosystem conditions of the developed floodplain. Some native species (for example, cumbungi) are now responsible for major ecological and economic impacts. The impacts generated by aquatic weeds vary between species, although some impacts are common to most and often a suite of aquatic weed species are involved in impact-generating infestations (Table 1).

System specifics



Photo 5. 1979 aerial photo of the most upstream lagoon in the Didgeridoo Lagoon system with a light band of native aquatic plants (water lilies, spiky mud grass) visible around the perimeter of the water body.



Photo 6. 1985 aerial photo of the most upstream lagoon in the Didgeridoo Lagoon system with a mat of floating aquatic weeds (interpreted as water hyacinth) visible at the upstream and downstream margins of the lagoon.

Management history and approaches

Personal observations (Figure 3) and aerial photo interpretation suggest that the Didgeridoo Lagoon system was relatively free of aquatic weeds up until the early 1980s. The system's seasonal hydrology and grazing land use supported native aquatic plant communities and limited the infestation potential of exotic aquatic pasture species, such as para grass, despite it being widely naturalised through the Lower Burdekin at that time. The

cause of the appearance of water hyacinth in the system by 1985 (Photo 6, 8) ahead of major hydrological changes associated with the development of the BHWSS can only be speculated, though could possibly be associated with rice production adjoining the upper system and introduction of seeds via adhesion to birds. Another alternative is by intentional introduction possibly in association with a commercial zoo that kept exotic biota and was located on the banks of the lower system (Didgeridoo Zoo).

Following the development of the BHWSS in the early 1990s (Photo 17) altered hydrology and water quality conditions along with the alienation of grazing from the landscape supported the proliferation of aquatic weeds through the system.



Photo 7. 1971 aerial photo of the downstream lagoons in the Didgeridoo Lagoon system illustrating clearwater and fringing water lilies in all water bodies.

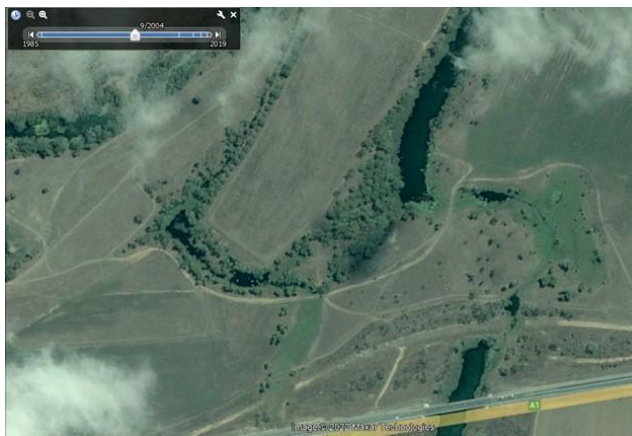


Photo 8. 1985 aerial photo of the downstream lagoons in the Didgeridoo Lagoon system illustrating photo signatures consistent with floating aquatic weed mats.

By the mid-2000s floating water hyacinth and aquatic grasses, including para grass and the more recently-introduced hymenachne, were forming infestations through the lagoon system. There are prominent floating weed mats noticeable in the lagoon adjoining the highway and more significant surface-covering infestations in the lagoons below the highway.

At this time the Burdekin Shire Council (BSC) engaged Didgeridoo Lagoon system riparian landholders in a Riparian Management Agreement (RMA) through its land protection officer. The RMA shared the cost of a boat-based, chemical (glyphosate) spraying control program for the main weed species of concern, including water hyacinth and hymenachne. Other cost-sharing partners in the RMA included BSC and NQ Dry Tropics. Despite linkages between weed infestations and BHWSS inflows to the system, Sunwater was not engaged in this RMA. The RMA operated for several years until paid participation waned and some landholders opted to exercise their own control responsibility. Following the dissolution of the RMA, BSC have continued to periodically spray the highway lagoon when floating weed mat accumulations become obvious. The landholder of the lagoons downstream of the highway has also continued to exercise control via both edge-based spraying and physical removal via excavator.

Over the past 18 years the weed infestation status of the system has varied significantly between years (Figure 6). Aerial photo interpretation suggests the system's main lagoons upstream of the highway are not as vulnerable to floating weed mat closure as the lagoons downstream of the highway (Figure 6), and weed management efforts have generally been successful in maintaining them as open water bodies. At the time of field investigations in December 2021, all main lagoons above and below the highway were free of floating weed mats (Photo 10, 11, 13). Not even individual propagules of the larger floating weed species, namely water hyacinth and water lettuce, were readily observed. Some of this weed-free status may be attributable to a high flow spate in November that preceded December field work, though aerial photo interpretation suggests infestation levels of floating weeds in this system do not readily form surface-covering infestations as they do in other regional floodplain distributary systems. Further seasonal observation is required to substantiate this hypothesis.



2004



2013



2016



2019

Figure 6. Aquatic weed infestation/open water status of the Sandy Waterhole Lagoon downstream of the Bruce Highway, illustrating variable conditions between years from heavily infested (2013, 2016) to a relatively open water body (2004, 2019).

Aquatic grass weeds

Aquatic grasses, including hymenachne, para and aleman, are perhaps the most significant operating aquatic weed threat to the Didgeridoo Lagoon system. As noted in the preceding section, these infestations are recognised to impact native aquatic plants and edge habitats and contribute to low dissolved oxygen levels (Burrows *et al* 2006). Most of the significant weed chokes identified within the system, including those with the capacity to act as fish passage barriers, can be attributed to combined infestations of these grass species (Photo 4, 24, 27, 28). Open reaches of the tributary floodplain stream in the upper catchment are also dominated by hymenachne (Photo 9, 34). All these grasses are amenable to chemical-based control, although experience in other systems indicate aleman is resistant to the commonly-used herbicide glyphosate and requires targeted use of Verdict. Given their extent and distribution through the system, a chemical-based control program is likely to be cost-prohibitive and relatively futile given their reinfestation potential. Targeting of specific channel choke created by infestations of these weeds may be more strategic, particularly if timed to precede wet season high flows, which would serve to break-up sprayed chokes. Broad acre and sustained control methods are ultimately required to deliver a system scale reduction in aquatic grass infestation levels and impacts. Based on past management trials and experience in other systems (Tait 2011), integrated use of five management tools is recommended including:

1. seasonal timing or manipulation of hydrology (i.e., water level drawdown);
2. targeted grazing regime;
3. controlled burning;
4. riparian vegetation shading, and
5. spot spraying.

Approaches to using these tools are described in the *Altered hydrology*, *Lack of riparian vegetation*, *Grazing regime* and *Fire regime* sections. Even without access to all these tools, management trials have demonstrated that many are individually, or in combination with one other, capable of delivering effective control of aquatic grass weeds.



Photo 9. Previously seasonal floodplain tributary stream in the BHWSS upper catchment with hymenachne-dominated bank margins (Dec 2021).



Photo 10. The most upstream lagoon (Hoey's Hole) in the Didgeridoo Lagoon system exhibiting a floating aquatic weed-free status (Dec 21).



Photo 11. The original Didgeridoo Lagoon adjoining the Bruce Highway exhibiting a floating aquatic weed-free status (Dec 21).



Photo 12. The most downstream lagoon (Sandy Waterhole) in the Didgeridoo Lagoon system exhibiting a floating aquatic weed-free status (Dec 21).

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage with BSC and correspond with riparian landholders of the Didgeridoo Lagoon system and all other potential RMA cost-sharing organisational partners (including Sunwater) to canvas support for re-establishing an active paid participation RMA for the system.
2. As part of the correspondence (above) seeking support for the re-establishment of the RMA, discuss the benefits of the program, including options that may encourage greater landholder support, for example, considering:
 - i. Responsibilities under the *Biosecurity Act 2014* general biosecurity obligation (GBO).
 - ii. Program annual costs per participant and likely number of supported system interventions.
 - iii. Potential for expanding or altering focal control sites and scope (Recommendation 4) within the system.
 - iv. The 'value proposition' of the existing RMA arrangement and the desirable outcome of all landholders participating in costs.
 - v. Opportunities for landholders to provide feedback or more directly be involved in delivery of control program.

3. If landholder support is not obtained to reinstate a paid participation RMA, seek to establish a supplementary control program involving at least the organisational partners BSC, NQ Dry Tropics and Sunwater. These organisations could be focused on trialling strategic site and seasonal control interventions (Recommendation 4) instead of regular system spraying interventions.
4. Given the currently relatively low levels of infestation of the system by floating aquatic weeds and the presence of spatially-fixed problem weed choke reaches, there could be merit in changing the focus of a reinstated RMA (Recommendation 2) or a supplementary weed control program (Recommendation 3) to strategic site and seasonal control interventions. This could include:
 - I. Trialling a catchment-based line of control 'quasi-eradication' approach for targeted floating aquatic weed species (water hyacinth, water lettuce) within the lagoon system. This trial would be planned to follow a high-flow flushing event and would aim to eradicate floating weed refuges/reinfestation sources for targeted species. It would work from the top of the catchment downstream, with two or more closely-repeated control events. Given the accessible size of the system, it is suggested that drones could be used for identifying post-flood flow weed refuges and for monitoring eradication effectiveness, including timing and sources of reinfestation if it occurs. If access and/or favourable cost benefit analysis supports it, small weed refuge eradication may also be viable for drone-based spraying.
 - II. Using spray-based control of specific channel weed chokes created by aquatic grass infestations, timed to precede wet season high flows. These efforts would serve to break up sprayed chokes.
5. NQ Dry Tropics engage system management stakeholders to deliver effective control of exotic aquatic grasses hymenachne, para and aleman throughout the system. This would ideally involve using more than one of the following management tools in an integrated manner:
 - I. Seasonal timing or manipulation of hydrology (i.e., water level drawdown);
 - II. targeted grazing regime;
 - III. controlled burning;
 - IV. riparian vegetation shading, and
 - V. spot spraying.

These actions would follow a recommended initial focus on controlled grazing, as per the methods and opportunities described in the *Altered hydrology*, *Lack of riparian vegetation*, *Fire regime* and *Grazing regime* sections of this SMP.

Table 1. Aquatic weeds of Lower Burdekin wetland systems

Common name (* = native)	Genus species	Growth form, habit and main impacts	WONS	Queensland Biosecurity Act 2014 category	Priority target weeds of BSC's Aquatic Weed Management Plan 2020-2025	Management methods and notes
Water hyacinth	<i>Eichhornia crassipes</i>	Floating species. Forms rafts that get colonised by other emergent and surface scrambling species particularly aquatic grasses. Large infestation cover water surface of lagoons and channels and create anoxic (no dissolved oxygen) reaches and fish passage barriers. Blocks channel flows, increases flood risks and creates mosquito breeding habitat.		3	X	Physical (weed harvester, rake excavator), registered chemicals and biological (weevils). Raft concentration (i.e. culvert gates) and catchment isolation methods potentially useful. Nutrient removal via harvesting.
Water lettuce	<i>Pistia stratiotes</i>	Floating species. Floating plant with similar habit as water hyacinth. Contributes to mixed species floating weed mats.		3	X	Physical (weed harvester), biological (weevil) and registered chemicals. Nutrient removal via harvesting
Salvinia	<i>Salvinia molesta</i>	Floating species. Prefers still water. Covers and shades water surface and contributes organic loading, decreasing dissolved oxygen levels.	X	3	X	Registered chemicals and biological (weevil). Nutrient removal via harvesting.
*Azolla	<i>Azolla spp</i>	Floating species. Prefers still waters. Floating plant with similar habit and potential impact to salvinia. Indicative eutrophication.		Not categorised		Physical – water quality management – indicative of high nutrients.
Para grass	<i>Urochloa mutica</i>	Emergent aquatic grass. Occurs in dense monocultural stands in moist drainage depressions and riparian vegetation understorey. Extends onto and binds floating weed mats. Shades shallows, excludes native aquatic plants, block channels, suppresses native vegetation recruitment, introduces high fire fuel loads into riparian zones, contributes high organic loading, depletes dissolved oxygen levels.		Not categorised		Physical (rake excavator), registered chemicals and grazing. Implementation of effective grazing systems including the use of water level drawdown is key to the management of this species.
Hymenachne	<i>Hymenachne amplexicaulis</i>	Emergent aquatic grass. Occurs on bank edge zone and grows into water ~2m deep. Extends onto and binds floating weed mats. Similar suite of impacts to para grass but extends into deeper water and not as far up bank onto levees.	X	3	X	Physical (rake excavator), registered chemicals and grazing. Use of haloxyfop down to the water line will protect the natural recruitment of native macrophytes and trees.
Aleman grass	<i>Echinochloa polystachya</i>	Emergent aquatic grass. Occurs on bank edge zone and grows into water ~2m deep. Extends onto and binds floating weed mats. Blocks channels. Outcompetes native aquatic plants on bank edge and shallows zones.		Not categorised		Physical (rake excavator), registered chemicals and grazing. Use of haloxyfop down to the water line will protect the natural recruitment of native macrophytes and trees.
*Rice grass	<i>Leersia hexandra</i>	Emergent aquatic grass. Extends onto and binds floating weed mats, forms major infestation in deeper waters of lower catchment bunded drainages.		Not categorised		Physical (rake excavator and/or weed harvester), registered chemicals and grazing. The effectiveness of the weed harvester on this species has not yet been assessed. Good waterfowl habitat.

*'Water green'	<i>Ipomoea aquatica</i>	Emergent/floating aquatic vine. Occasionally extends onto and binds floating weed mats.		Not categorised		Physical – not generally a significant problem unless part of weed mat. Good habitat.
*Cumbungi	<i>Typha domingensis</i>)	Emergent bull rush. Occurs in water edge zone in most of catchment but forms major infestations in lower catchment bunded drainages. Blocks channels, creates anoxic reaches/fish passage barriers due to high biological oxygen demand (BOD) of accumulated organic material. Decreases native plant diversity and waterbird habitat.		Not categorised		Registered chemicals, potentially water level manipulation and physical (burning, harvesting), i.e. removal of root stock with an excavator. Prevention of tailwater inflows/draining to create seasonal drying has been demonstrated to be very successful.
*Duckweed	<i>Ceratophyllum demersum</i>	Submerged aquatic. Forms dense non-rooted submerged beds. Causes depletion in dissolved oxygen values below levels lethal for aquatic organisms/fish during summer night-time respiration and/or turbid wet season inflows.		Not categorised		Physical – weed harvester, shading, water level manipulation, pump foot valve protection. Good habitat.
Cabomba	<i>Cabomba caroliniana</i>	Submerged aquatic. Cabomba is an aggressive perennial that can form dense canopies below the water surface. Infestations displace native plants and animals, affect water quality, and impede recreational water users.	X	3	X	Only recorded from Healey's Lagoon. Mechanical control – hand-pull small infestations, taking care to remove entire plant to prevent re-infestation. Use harvesters on larger areas for temporary control. Herbicide control – Carfentrazone is currently the only herbicide registered for control of cabomba.
*Giant lotus	<i>Nelumbo nucifera</i>	Emergent lily bed. Mainly recorded from more seasonal sub catchment wetland reaches. Emergent plant of bank edge grows in water ~2m. Can block channels, creates foundation for accumulation of floating weed mats.		Not categorised		Registered chemicals, potentially water level manipulation and physical (harvesting, cutting). Good habitat.
*Umbrella sedge	<i>Cyperus exaltatus</i>	Emergent sedge aggressive secondary coloniser on floating 'platforms' weeds. Occurs throughout creek system in water edge zone but forms extensive occurrences in moist margins and depressions of lower catchment-bunded drainages.		Not categorised		Registered chemicals, potentially water level manipulation and physical (harvesting, cutting) – not major problem. Good habitat.
*Smart weed	<i>Persicaria decipiens</i>	Emergent plant that occurs in moist drainage depressions and riparian vegetation zones and extends onto and binds floating weed mats. Forms mono cultural stands usually in response to grazing pressure.		Not categorised		Registered chemicals, physical – not generally a significant problem unless part of weed mat. Good habitat.

Table 2. Emerging aquatic weed risk species of the Didgeridoo Lagoon system

Common name	Genus species	Growth form, habit and main impacts	WONS	Qld Biosecurity Act 2014 category	Management methods and notes
Arrowhead 	<i>Limnocharis flava</i>	An anchored aquatic plant with erect stems that grows in saturated, fertile, and muddy conditions as a perennial plant in areas with sufficient moisture. Can also be annual where moisture is seasonal. Plants grow up to 1m above the waterline. Colonises shallow wetlands and margins of deeper waterways. Blocks channel flows, traps silt, increases flood risks, creates mosquito breeding habitat, reduces access to waterways and displaces native plants and animals. Has been recorded in the Townsville local government area.		2, 3, 4 & 5	No herbicides are registered to specifically control limnocharis and there are no known biological control agents. <i>Biosecurity Act 2014</i> requires that new infestations must: • be reported to Biosecurity Queensland on 13 25 23; • be identified and removed by approved officers, and • have locations recorded prior to removal. Classed as very high risk in <i>Burdekin Shire Council Biosecurity Plan</i> (BSC 2020).
Sagittaria 	<i>Sagittaria platyphylla</i>	Emergent aquatic perennial up to 1.5m tall. Grows in irrigation channels, drains, creeks, rivers, lagoons, dams, and wetlands. Establishment favoured by slow moving or static shallow water. Forms floating mats, blocking irrigation ditches, shallow dams, and waterways. Invades and degrades natural wetlands. Competes with native water plants. Has been recorded in the Townsville local government area.	X	3	No herbicides are registered to specifically control sagittaria. Off-label use permits PER80934 allow for the use of glyphosate as a foliar spray. Control is best carried out when water levels are low. Hygiene and containment measures need to be applied to prevent further spread downstream. Mechanical control – place all removed plant material in sealed plastic bag, leave in sunlight to decompose, then dispose of at council-approved landfill. Alternatively, leave material in sun to dry, then burn. Classed as very high risk in <i>Burdekin Shire Council Biosecurity Plan</i> (BSC 2020).
Water mimosa 	<i>Neptunia oleracea</i>	Floating perennial weed that attaches to bank at water's edge. Stems to 1.5m long, grow out over water and form spongy, fibrous covering between nodes. Grows on land in damp soil or on water as thick floating mats. Commonly found in and around freshwater pools, swamps, and canals. It is a nitrogen-fixing legume that releases nitrogen into water bodies. This can lead to increased algal blooms and encourage growth of other weeds. Restricts water flow and increases water loss through evapotranspiration. Smothers water surface, shading out native aquatic plants, leads to deoxygenated water and impacts fish populations and creates mosquito habitat. Has been recorded at Saltwater Creek in the Burdekin local government area.		2, 3, 4 & 5	No herbicides are registered for control and there are no known biological control agents. Mechanical control – Remove all plant matter from infested water body and pull plants out of surrounding banks, making sure to remove attached root system. Dispose of plant parts in an appropriate waste facility or rubbish bin. Water mimosa is a restricted invasive plant under the <i>Biosecurity Act 2014</i>. • All sightings must be reported to Biosecurity Queensland within 24 hours of the sighting. • It must not be given away, sold, or released into the environment without a permit.

		Has been subject to sale and distribution through Asian communities and gardeners.			Classed as very high risk in <i>Burdekin Shire Council Biosecurity Plan</i> (BSC 2020).
--	--	--	--	--	---

Water quality

What are the issues and state of knowledge?

Water quality in seasonal Lower Burdekin floodplain wetlands is naturally variable through the year. Under natural predevelopment conditions, water quality in distributary stream systems and their hosted wetlands transitioned from turbid floodplain-inundating flows in the wet season, settling and clearing into the non-flow period of the early dry season, and then interacting with groundwater that maintained perennial lagoons during the water level drawdown period of the late dry season (Perna *et al* 2012). Seasonal 're-setting' of water quality would then follow with wet season rainfall leading to local catchment run-in, then flow initiation, and – in larger events – Burdekin or Haughton River overbank flushes down distributary systems (Davis *et al* 2017). In seasonal drying wetlands, water quality generally progressed through to the clearing phase and then into a critical period with higher temperature and turbidity and lower dissolved oxygen prior to drying.

In the contemporary, modified floodplain system, wetland water quality is largely driven by the condition of sourced Burdekin or Haughton River water supplying irrigators via regulated creek flows; aseasonal inflows of farm irrigation tailwater or BHWSS channel overflow; the condition of creek reaches, particularly their weed infestation status, and by the quality and contaminant load of surface and groundwater inflows from their catchment.

Some of the processes and key drivers of water quality associated with predevelopment hydrological conditions no longer occur as frequently, in the natural seasonal period, or at all. For example, flow cessation, dry season water level drawdown, groundwater domination of inflows, Burdekin/Haughton River overbank flood flow flushing and scouring (Perna *et al* 2012). However, even under the contemporary modified regime, wetland water quality still undergoes major seasonal variation with the early summer wet season, including pre-flushing flow or flood inundation, being identified as the period of greatest water quality stress for hydrologically-modified systems (Burrows *et al* 2006, Veitch, *et al* 2007).



Photo 13. Tributary drainage entering the top of the Horseshoe Lagoon system from the BHWSS area. Inflows are typically turbid but elevated above average in this image due to recent rainfall in December 2021.



Photo 14. BHWSS tailwater within a constructed drain tributary of the Didgeridoo Lagoon system. Abundant algal growth within the drain is indicative of available nutrients.

Very few sites within the Lower Burdekin floodplain have been a focus for regular water quality monitoring programs, and those conducted by industry groups of government agencies are often subject to privacy non-disclosure provisions. Therefore, our state of knowledge is mainly informed by studies examining water quality issues more generally across the floodplain and within selected drainages, and for some specific fish habitat and weed management investigations (Burrows *et al* 2006, Davis *et al* 2013, 2014, 2017, Veitch *et al* 2007, Loong *et al* 2005, Perna 2005, Pearson *et al* 2003, Hunter *et al* 1998, Hunter *et al* 1996, Keating *et al* 1995).

Data collected in the Lower Burdekin and broader GBR catchment is available at:

<https://www.reefplan.qld.gov.au/tracking-progress/paddock-to-reef/modelling-and-monitoring>

<https://qgsp.maps.arcgis.com/apps/MapSeries/index.html?appid=9d1aad1e2b444ec6a1890e4032284147>

Water quality issues associated with aquatic ecosystem impacts in the Lower Burdekin floodplain, including the Didgeridoo Lagoon system and downstream-receiving environments, such as the Cape Bowling Green Bay Ramsar wetland and the GBR World Heritage Area, include:

- low dissolved oxygen (DO);
- high turbidity/total suspended solids (TSS);
- elevated nutrient levels;

- agri-chemical residues, and
- salinity.

The drivers/likely causes, potential impacts, and data and management notes for these issues are summarised in Table 3. Specific considerations for this system management plan are discussed below.

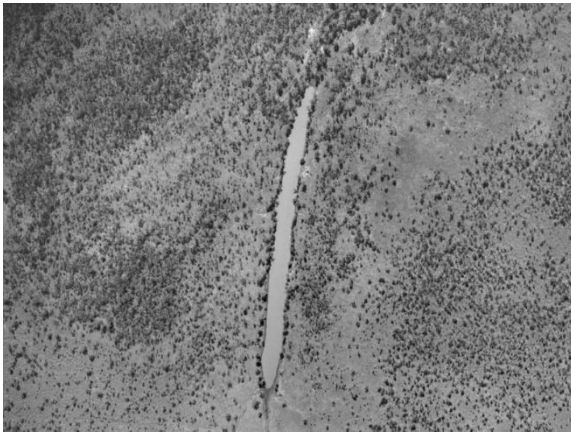


Photo 15. Image of turbid water taken in January 1964 following wet season run-in to the main lagoon.



Photo 16. Catchment scale farm tailwater recycling basin in the system's western catchment (also Photo 21) Such infrastructure serves to reduce off-farm export of nutrients and other contaminant loads.

System specifics

Under its natural predevelopment condition, the Didgeridoo Lagoon system's water quality was seasonally variable, as described for a typical floodplain waterbody above. Catchment run-in and/or inundating floodplain flows filled the system with turbid water during the wet season. Historical aerial imagery captured at a time when catchment land use was solely beef cattle grazing (1964) show lagoon banks and immediate catchment areas relatively bare from grazing. A full turbid lagoon illustrates the historical turbidity of wet season run-in to the main lagoon (Photo 15).

Following wet season flows, suspended solids settled, and the water cleared typically to a dark tannin-stained colour (Figure 2). Nutrient loads delivered to the system with wet season run-in were processed and taken up by riparian vegetation and instream and fringing aquatic plant communities. During dry season water level drawdown, some aquatic plant biomass would be removed from the water column by being stranded on exposed banks. The perennial nature of all the larger lagoons upstream of the highway would also suggest a high level of groundwater connectivity.

During the development of the Burdekin River Irrigation Area (BRIA) in the early 1990s, irrigation scheme tailwater drains were routed into the headwaters of the Didgeridoo Lagoon system (Photo 17). These tailwater drains convey catchment runoff, farm irrigation tailwater, and supply channel overflow from the now BHWSS area. As discussed in the *Altered hydrology* section, inflow volumes from the BHWSS tailwater drainage scheme to the system are substantial and 'aseasonally' extend into the dry season period, which – historically – was a time of clearing water quality and receding water levels. Tailwater discharging from the BHWSS is typically turbid (Photo 1, 13, 14) and, depending on the proportion that is farm irrigation runoff versus supply channel overflow, contains varying elevated loads of nutrients. Even where nutrient loads are not significantly high in scheme tailwater, the throughput volume received by the Didgeridoo Lagoon system represents nutrient loading substantially higher than what the system would have received naturally.

Downstream of BHWSS inflows, local farming catchments also contribute irrigation tailwater to the system and potential nutrient and agri-chemical residue contaminant loads, including via groundwater connectivity. However, many adjoining farms do drain away from the system's high levees and a regional catchment scale tailwater recycling basin captures most runoff emanating from farm blocks in its western catchment (Photo 21).

Depending upon the volume of BHWSS inflows, turbid water is sometimes attenuated by channel weed blocks within middle reaches of the system (Photo 17, 18). In some years with lower levels of irrigation demand and/or generated tailwater volumes the system does clear into the dry season (Photo 19). Though this seasonal process and timing is not consistent across years (Photo 20).

The consequences of aseasional inflows to the system are integrated impacts across both altered hydrology and water quality. While the loss of seasonal hydrology, particularly a lack of water level drawdown, has created conditions for the proliferation of aquatic weeds, the prolific growth and cycling infestations of these weeds has also been facilitated by the nutrient loading of the system. Independent of farm runoff, some nutrient loading is carried in low concentration on the fine colloids associated with the source Burdekin River water and become significant due to throughput volume.



Photo 17. Turbid inflows to the upper catchment lagoon following construction of irrigation scheme tailwater drains (white earthworks in lower part of image) in Apr 1994.



Photo 18. Turbid tailwater inflow attenuated in upper lagoon in contrast to natural dry season clear tannin water in lower system in Aug 2006.



Photo 19. In years of lower BHWSS inflows and/or cleared Burdekin River source water, the entire lagoon system still clears in the dry season, Oct 2009.



Photo 20. Sept 2019 dry season status with large turbid inflow from BHWSS.

Turbidity is itself a water quality impact for a system with ecology and dependent biotic communities adapted to clear water throughout the dry season, including visual predator fish and filter-feeding aquatic insects.

Prolific growth of aquatic weeds and the creation of channel weed chokes with water surface and edge-covering weed mats (Photo 27, 28) – and associated high 'biological oxygen demand' (BOD) organic loading – create water quality impacts associated with low dissolved oxygen levels. These affect ecosystem health and fish

passage, and habitat suitability. Chemical control of aquatic weeds can exacerbate dissolved oxygen impacts and nutrient loading drivers of aquatic weed infestation because sprayed dead weed biomass with a high BOD sinks, decomposes, and returns organic nutrients to the water column.



Photo 21. A large farm tailwater recycling basin established in the system's western catchment provides effective interception of nutrient loads associated with irrigation runoff.



Photo 22. Where farm tailwater drains to natural low-lying areas it promotes the growth of exotic pasture species which, when ungrazed, create a hot fire risk.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage system management stakeholders to implement *Altered hydrology* section recommendations as a pathway toward reducing the principal driver of water quality degradation within the system.
2. Engage system management stakeholders to implement *Aquatic weed* section recommendations as a pathway toward reducing the secondary driver of water quality degradation within the system.
3. Engage system management stakeholders to implement *Lack of riparian vegetation*, *Fire regime* and *Grazing regime* section recommendations. These actions would create a pathway towards increasing the resilience of the system to secondary water quality impacts associated with reduced riparian vegetation cover (increased water temperatures, reduced dissolved oxygen levels, proliferation of submerged aquatic plants and associated diel cycling of dissolved oxygen levels) and grass weed infestation of edge zones (organic loading, surface smothering).
4. Communicate the underlying elevated nutrient driver of aquatic weed infestations to system catchment producers. Seek to showcase existing practitioners and/or incentivise the engagement of 'adopters' in trialling methods or practices that serve to reduce off-farm export of nutrients and tailwater to the receiving tailwater drainage system, including on-farm Best Management Practices for fertiliser use and irrigation, tailwater recycling, wetland treatment trains, and runoff detention management.

Table 3. Lower Burdekin floodplain water quality issues

Issue	Drivers/likely causes	Potential impacts	Data and management notes
Low dissolved oxygen	• Aquatic weed-infested waterway reaches promoted by near-perennial regulated flows/sustained water levels and high nutrient availability. • Biological Oxygen Demand (BOD) associated with bacterial decomposition of organic material produced or trapped by aquatic weeds, including grass margins inundated by higher wet season water levels. • Night-time or turbid inflow-promoted respiration of submerged aquatic plants and attached periphyton. • Prevention of instream photosynthesis/oxygen production by turbidity/weed shading. • Prevention of aeration of water surface due to weed covering. • High BOD of organic loads in catchment run in during wet season. • Deoxygenated groundwater inflows. • Lack of River overbank flooding flushes in wet season. • Lack of riparian shading/higher water temperatures.	• Fish kills. • Anoxic stream reaches that function as fish passage barriers. • Deoxygenated 'blackwater' flows to downstream receiving environments, including upper reaches of estuaries. • Reductions in instream productivity, biodiversity (including aquatic macro invertebrates) and fishery resources. • Increased solubility and mobilisation of nutrients in sediments.	Issue well documented by site specific and regional catchment studies (Perna 2003, 2004, 2005, Loong <i>et al</i> 2005, 2006, Burrows <i>et al</i> 2006, Veitch and Tait 2007). <u>Management needs/opportunities</u> • Reduced aquatic weed and submerged plant biomass. • Greater riparian shading. • Reduced instream nutrient availability. • Reduced BOD/organic loading in catchment run-in. • Targeted monitoring to increase understanding of specific issues, including: ○ Impact of aseasonal flow cessation and water clarification on DO levels through lagoon system. ○ Role of BOD load in catchment run in on DO status. ○ DO levels through weed-choked channel areas, including under different flow conditions up to and including wet season flows of different magnitude.
Turbidity	• Mean annual total suspended solid (TSS) loads underpinning turbidity have increased, on average, six-fold in GBR catchment rivers since European settlement. • Burdekin Falls Dam receives turbid wet season flood flows and has minimal colloidal settlement. • Irrigation supplies pumped from Burdekin River flows supplied from persistently turbid Burdekin Falls Dam. • Catchment soil erosion and sediment loads carried in local catchment surface runoff influences turbidity levels during wet season.	• Multiple times natural run-in loading of receiving water bodies with attached nutrients. • Reduced instream primary productivity. • Reduced submerged water plant diversity and density. • Reduced success of visual predator fish and impacts to sensitive aquatic invertebrates (for example, filter feeders).	Issue well-documented at a regional scale with few catchment studies (Perna 2003, 2004, Davis <i>et al</i> 2014, 2017). <u>Management needs/opportunities</u> • Few management options exist for turbidity imported with Burdekin River water from the BHWSS. • For local contributing catchment area: there is opportunity to reduce sediment loads in runoff through management of soil erosion risks and catchment groundcover. Also via the design of farm drain systems to prevent erosion and incorporate detention basins and controlled rates of run-off and discharge to stream networks.
Nutrient loading	• Nutrient load attached to colloids in irrigation supplies pumped from turbid Burdekin River. • Catchment land and water use practices that result in off-farm/property losses (including via groundwater flows) of nutrients, for example, on farm fertiliser use, irrigation tailwater, and post-harvest runoff of high BOD sugar. • Organic nutrients released from decomposing aquatic weed and submerged plant biomass, for example, following weed spraying and during elevated wet season flows.	• Eutrophication (nutrient pollution) of waterway. • Promotion of aquatic weed/submerged plant growth and associated impacts. • Algal blooms, dissolved oxygen crashes, and fish kills. • Export of elevated nutrient loads to downstream receiving environments,	Issue documented regionally, but no site data available. DES is currently establishing real-time monitoring stations on regional creek systems. Previous regional monitoring has recorded Burdekin Wetland concentration exceedances above ecosystem health guidelines (Perna 2003, 2004, Loong <i>et al</i> 2005, Davis <i>et al</i> 2013, 2014, 2017). <u>Management needs/opportunities</u> • Improve on-farm/property practices, for example, fertiliser application rates and practices and irrigation scheduling and volumes.

Issue	Drivers/likely causes	Potential impacts	Data and management notes
	- Wet season local catchment run-in of sediment and attached and dissolved nutrient loads. - Mobilisation of nutrient loads accumulated in bottom sediments (particularly when water becomes anoxic).	for example, Ramsar wetland and GBR lagoon.	- Removal and/or control of aquatic weed and submerged plant biomass. - Promotion of riparian vegetation buffers and emergent aquatic plant stream margins with nitrate stripping/uptake functions. - Design farm drainage systems to provide nutrient interception and processing capacity, including riparian and aquatic vegetation, detention and recycling basins and controlled rates of runoff/discharge.
Agri-chemical residues	- On-farm use and practices that lead to off-farm losses including inadequate chemical storage, application methods; timing (especially in relation to rain and irrigation events) and conditions; wash down, and irrigation practices. - Off-farm movement via irrigation tail water, groundwater accession and rainfall runoff. - On-stream use for aquatic weed control.	- Direct lethal effects on periphyton and phytoplankton. - Long-term, low-dose pesticide exposure can produce effects in freshwater organisms after several generations affecting growth, metamorphosis, locomotor activity, antipredator behaviours, immune capacity, infections, and gonadal condition. - Sublethal effects on endocrine systems of fish and endocrine disruption in amphibians. - Export of pesticide residue loads to downstream receiving environments. For example, Ramsar wetlands and GBR lagoon present impact risks to mangroves, seagrass, algal endosymbionts in corals and benthic microalgae.	Issue documented regionally, including in adjoining drainages, regional groundwater and at Burdekin farm drainages. Previous monitoring of floodplain creek systems have recorded concentration exceedances above ecosystem health guidelines for both low and event flows. Research indicates mixed pesticide residues produce impacts effect equivalent to higher concentration (Davis <i>et al</i> 2013, 2017, Hunter <i>et al</i> 1998, Hunter <i>et al</i> 1996, Keating <i>et al</i> 1995). <u>Management needs/opportunities</u> - Improved on-farm/property practices, e.g., pesticide application rates and use timing in relation to rain and irrigation events, irrigation methods and applied volumes. - Increase use of recycle pits and treatment wetlands. - Real time monitoring and reporting at paddock/sub catchment scale to tie results to practices. - Design farm drainage systems to provide contaminant load interception and processing capacity, including riparian and aquatic vegetation, detention and recycling basins and controlled rates of runoff/discharge.
Salinity	- Rising saline groundwater contaminating adjoining aquifers and/or discharging to surface water features - Marine saltwater intrusion into coastal freshwater wetlands or aquifers promoted by high(er) sea levels or drawn down freshwater aquifers	Physiological stress or death of freshwater biota or exposed terrestrial vegetation.	Emerging management issue for BHWSS and near coastal areas. <u>Management needs/opportunities</u> - Reduced accession surface water to groundwater. - Management groundwater rise potentially including dewatering bores and conjunctive use/discharge. - Bunding saltwater intrusion pathways and maintenance of hydraulic head for coastal freshwater aquifers. - Accommodation of landward migration of coastal wetland mosaic.

Fish passage barriers

Fish movement needs

The Lower Burdekin floodplain's native freshwater fish community (Table 4) needs to undertake a range of movements to fulfill life history cycles and to distribute to suitable floodplain distributary creek and wetland habitats (Veitch *et al* 2007, Carter and Tait 2010).

The main classes of life cycle movement are:

- Resident – can complete life history at resident site.
- Potamodromous – needs to move within catchment to different freshwater habitats, for example, from pools to running riffles, gravel beds, or off-stream floodplain swamps.
- Amphidromous – young recruit from marine environments, but adults breed in lower freshwater.
- Anadromous – lives in both fresh and marine environments but moves to freshwater to breed.
- Catadromous – lives in both fresh and marine environments but moves to marine to breed.

Even resident species capable of breeding and recruiting juveniles without needing to move to different areas or habitats will still naturally undertake intra-catchment movements to distribute their population and colonise new areas. Potamodromous species are compelled to undertake intra-catchment movements within the wetland system to access required breeding and/or nursery habitats, for example, floodplain wetlands or flowing riffle reaches. Diadromous species are those that need to move between fresh and marine environments to reproduce and include the latter three of the life cycle types (listed above). Most diadromous species in tropical Queensland, including the iconic barramundi, are catadromous; meaning they spawn as adults in marine waters and, as juveniles, recruit back to freshwater habitats. In evolutionary time, all species – regardless of their life history cycle – need to be able to move within their range to maintain healthy gene flow between populations.



Photo 23. Piped culvert under a farm road crossing of the Didgeridoo Lagoon system drainage channel just upstream of its confluence with East Barratta Creek. High flow velocities and vertical drops create a fish passage barrier that could only be circumvented during flood inundation.



Photo 24. Hymenachne and para grass infestations of the stream channel create anoxic (low dissolved oxygen) reaches that act as water quality fish passage barriers. Revegetation of such narrow channel settings with dense canopy, shade generating tree species (like Leichhardt's) will limit the density of understory aquatic grasses.

System specifics

Natural connectivity patterns

In seasonally dry climates, like that of the Lower Burdekin, the timing of fish movement activity is highly seasonal and influenced by connected flow opportunities that are tied to the wet season conditions under which fish evolved. Though some movement behaviour, like attraction to flows, is pursued opportunistically across seasons. Historically, the distributary drainages of the Burdekin floodplain, such as the Didgeridoo Lagoon system, were seasonal and only flowed during the wet season, often for only short periods. They then transitioned to a chain of isolated waterholes in the dry season. Fish passage connectivity was only provided when catchment runoff, flood plain inundation and/or Barratta Creek flood outbreaks generated flow events.

These connective flows provided opportunities for resident species to recolonise seasonal habitats and gave other life history types opportunities to access habitats required for successful breeding. In the case of catadromous species like barramundi, this involved movement of adults to estuary mouths to breed and return

movement of juveniles from coastal nursery swamps lower in the Barratta Creek system. For example, those of the Lochinvar area to upstream lagoons.



Photo 25. Two adjoining farm road crossings of the lower reaches of the system downstream of the Bruce Highway utilise piped culverts. These generate high flow velocities that would act as fish passage barriers under a broad range of flow conditions.



Photo 26. Farm road crossing on the downstream end of the largest lagoon located in the upper reaches of the system. While this crossing is inundated by elevated flows, its capacity to pass fish during recessionary and low base flows has not been assessed.

Fish survey data for the Didgeridoo Lagoon system is limited to one lagoon situated immediately beside the Bruce Highway (Burrows and Davis 2009). These records are supplemented by the author's personal observations (Table 4). Some 24 species of freshwater fish are recorded from the system including three exotic species. This represents high fish biodiversity for a Burdekin floodplain site. Examining the list of fish not recorded at the site, it is the author's expert opinion that further survey work could add two or more additional species to the total. Recorded fish include six diadromous and four potamodromous species, including relatively large numbers of the estuarine breeding barramundi. This survey data suggests that the movement requirements of most species are being met within the system at least as far upstream as the highway.

Types of barriers

Notwithstanding the high diversity of fish recorded for the Didgeridoo Lagoon system, a range of potential fish passage barriers have been identified within it. Fish survey results would suggest that these barriers (at least those between the highway lagoon and downstream reaches) are being inundated during high flow flood events. However, not all fish species or size classes move during large flood events, and in poorer wet seasons, flows may not be sufficient to enable fish to circumvent identified barriers. Best Management Practice for the system would be to rectify barriers if, and when, resources become available. Benefits could be realised in greater diversity, mixed age classes, and abundance of movement-dependent species. Fish passage barrier threats to asset values are listed as management issues (M) in Appendix 1 and are mapped in Appendix 2. They include instream structures and poor reach conditions including:

- a road crossing (Photo 26) at the downstream end of the system's main lagoon (M6);
- two proximal road crossings (Photo 25) with pipe culverts that convey water at relatively high flow velocities during base flows, creating a fish passage barrier under a broad range of flow conditions outside of road inundation (M14);
- a road crossing immediately upstream of the system's confluence with the larger East Barratta Creek system (Photo 23) with a single pipe culvert (and associated floodgate cap) that conveys water with high flow velocities presenting a fish passage barrier under all-but-road-inundating flow levels (M16);
- seasonally weed-choked reaches (Photo 27, 28). This generic class of barriers are not permanent or fixed in location. They include areas with dense aquatic grass growth with or without floating aquatic weed mats that have combined to create poor water quality (low dissolved oxygen), and physical barriers that can be impassable in years where wet season flow events are only moderate.



Photo 27. Severe weed choke comprised of both aquatic grasses and floating weed species in the middle reaches of the system. Low dissolved oxygen (anoxic) water quality conditions associated with these weed chokes create a water quality fish passage barrier.



Photo 28. Another aquatic weed choke a reach downstream from that illustrated (left). While large flood flows associated with good wet season rainfall can create circumventing fish passage through such features, flows associated with lower wet season rainfall do not.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage a fisheries survey provider to collect current fish survey data for the Didgeridoo Lagoon system via a site stratified assessment that uses comparative methods to sample the most upstream lagoon, the highway lagoon, and the lowermost lagoon with an catch analysis emphasis on size class frequencies of species, as well as species presence/absence.
2. Field officers to engage site landholder and seek access permission to conduct site investigation of base/recessionary flow conditions associated with farm road crossing at the downstream end of the most upstream lagoon (Hoey's Hole). If flow conditions do present a fish passage barrier, seek resources and landholder support for a works solution to improve fish passage under the road crossing (W5).
3. Engage fishway passage expertise to work with the landholder of the system reaches downstream of Bruce Highway to identify design and permitting solutions for providing fish passage through two farm road crossing culverts (W11) and a third road crossing/floodgate culvert upstream of East Barratta Creek confluence (W14). This landholder has engineering skills and expertise and has expressed a willingness to address the fish passage needs of the farm's stream crossings, but could be further incentivised by funding/material resourcing and provision of expert support for design and/or permitting requirements.

Table 4. Life cycle movement requirements of fish recorded from floodplain freshwater wetland systems (*exotic)

Name	Genus and species	Life cycle movement	Recorded Didgeridoo *Burrows & Davis 2009 ** pers Obs. author
Tarpon	<i>Megalops cyprinoides</i>	Catadromous	*
Long-finned eel	<i>Anguilla reinhardtii</i>	Catadromous	*
Bony bream	<i>Nematalosa erebi</i>	Resident	*
Salmon catfish	<i>Arius graeffei</i>	Anadromous / Potamodromous	**
Rendahl's tandan	<i>Porochilus rendahli</i>	Potamodromous	*
Butter jew	<i>Neosilurus ater</i>	Potamodromous	*
Hyrtl's tandan	<i>Neosilurus hyrtlii</i>	Potamodromous	
Snub-nosed gar	<i>Arrhamphus sclerolepis</i>	Resident	
Long-tom	<i>Strongylura krefftii</i>	Resident	**
Fly-speckled hardyhead	<i>Craterocephalus stercusmuscarum</i>	Resident	*
Eastern rainbow fish	<i>Melaanotaenia splendida</i>	Resident	*
Barramundi	<i>Lates calcarifer</i>	Catadromous	*
Jungle perch	<i>Kuhlia rupestris</i>	Catadromous	
Agassiz's glassfish	<i>Ambassis agassizii</i>	Resident	**
Sailfin glass perch	<i>Ambassis agrammus</i>	Resident	*
Spangled perch	<i>Leiopotherapon unicolor</i>	Potamodromous	*
Striped grunter	<i>Amniataba perchoides</i>	Resident	**
Mouth almighty	<i>Glossamia aprion</i>	Resident	*
Mangrove jack	<i>Lutjanus argentimaculatus</i>	Catadromous	
Archer fish	<i>Toxotes chatareus</i>	Resident	*
Scat	<i>Scatophagus argus</i>	Catadromous	
Bully mullet	<i>Mugil cephalus</i>	Catadromous	
Giant herring	<i>Elops hawaiiensis</i>	Catadromous	
Milkfish	<i>Chanos chanos</i>	Catadromous	
Silver biddy	<i>Gerres filamentosus</i>	Catadromous	
Empire gudgeon	<i>Hypseleotris compressa</i>	Catadromous	*
'Boof headed' gudgeon	<i>Hypseleotris midgleyi</i>	Resident	*
Purple-spotted gudgeon	<i>Mogurnda adspersa</i>	Potamodromous	*
Snakehead gudgeon	<i>Giurus margaretaea</i>	Catadromous	
Sleepy cod	<i>Oxyeleotris lineolatus</i>	Resident	*
Big-headed gudgeon	<i>Philypnodon grandiceps</i>	Potamodromous	
Flathead goby	<i>Glossogobius giurus</i>	Amphidromous	
Speckled goby	<i>Redigobius bikolanus</i>	Amphidromous	*
*Mosquito fish	<i>Gambusia holbrooki</i>	Resident	*
*Three-spot gourami	<i>Trichogaster trichopterus</i>	Resident	**
*Tilapia	<i>Oreochromis mossambicus</i>	Resident	**

Lack of riparian vegetation

What is it and why is it important?

The riparian zone is the interface between land and a watercourse or wetland. Riparian zone vegetation is an important component of the landscape because it supports a range of biophysical functions and values. These functions include:

- bank erosion protection;
- maintenance of channel stability and form;
- nutrient uptake;
- interception of sediment loads;
- providing leaf litter food sources and structural habitat, including root undercuts/snags for aquatic ecosystems;
- shading and cooling the water's edge and preventing dense submerged aquatic plant growth, thereby maintaining the water's dissolved oxygen carrying capacity;
- excluding sun-loving aquatic and levee grasses, thereby helping to maintain open water habitat and channels, reduce wildfire fuel loads and risk, and decreasing pest rodent harbourage habitat;
- providing wildlife corridors and refuge habitats, including for predators of adjoining cane land pests, and
- flood protection, by reducing catchment runoff rates and slowing the velocity of channel breakout flows.

In intensively developed landscapes like the Lower Burdekin, the riparian zone assumes additional importance because it is often the most significant area of remnant natural habitat. Given its location at the interface between terrestrial and aquatic ecosystems, the riparian zone is important to both. The quality of instream aquatic habitats is often determined, to some degree, by the condition of the riparian zone (Figure 7). Due to these high ecological and catchment functional values, areas lacking riparian vegetation can present threats to the function and value of the aquatic ecosystem. Therefore, rehabilitation of the riparian zone is a priority focus for nature conservation and catchment management project investment.

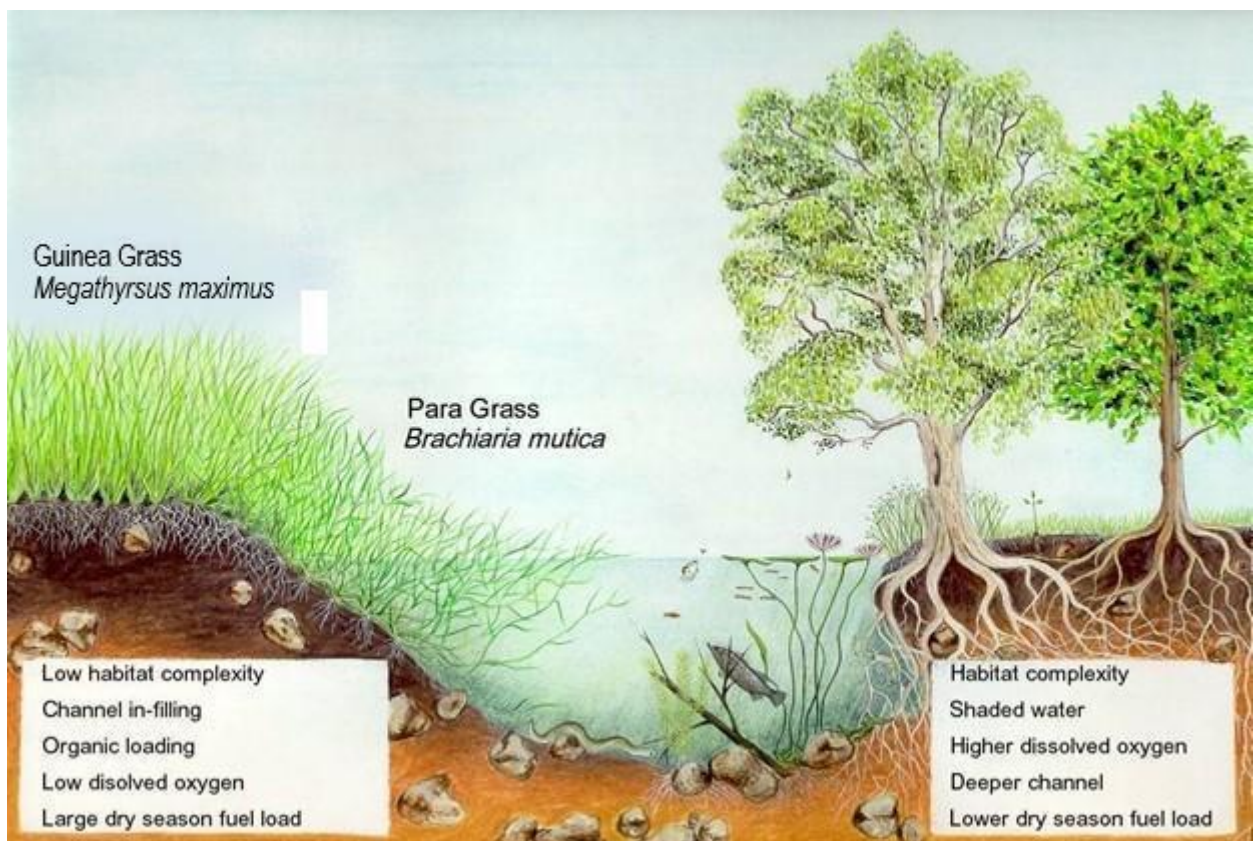


Figure 7. Contrasting ecosystem function and features of an exotic pasture dominated (left) versus native vegetation-dominated (right) riparian zone (Illustration by Lois Genis).

In the developed landscapes of the Lower Burdekin, the condition of the riparian zone has often been impacted by a range of land and water resource use pressures, some historical and some current. These include past and ongoing clearing of vegetation; altered stream flows, water levels or soil moisture; elevated nutrients;

woody, grass, and vine weed invasion; uncontrolled fire, stock grazing and trampling pressure; bank erosion, channelisation; land filling, and rubbish dumping.

Table 5. Riparian zone rehabilitation approaches for different existing condition contexts

Existing condition context	Potential rehabilitation strategy	Notes
1. Areas of remnant vegetation	Protect from clearing, monitor, and control weeds, implement fire management suited to vegetation type. Extensive revegetation.	Total fire exclusion is appropriate for fire sensitive and/or closed canopy riparian forests.
2. Areas of degraded remnant vegetation	If in ungrazed landscape, control/spay out exotic pasture grasses with grass selective herbicides. If in a grazed landscape, manage stock grazing and trampling pressure to keep exotic understory pastures subdominant, allow natural seedling recruitment and avoid accumulation of large fire fuel loads. Monitor and protect natural regeneration, conduct 'in fill' planting revegetation (plus stock protection, weed control and watering maintenance) if required for denuded sections, implement fire management suited to vegetation type. Extensive revegetation with 'fill in' intensive revegetation.	Often includes some areas devoid of remnant native vegetation that may require more intensive rehabilitation approaches, for example, as per 3.
3. Areas with no remnant native vegetation, for example, reaches dominated by exotic grasses	In grazed landscapes stock exclusion fencing is required to support intensive revegetation efforts. Control/spay out weeds, prepare site for revegetation (holes, mulch, irrigation/watering), plant and maintain (stock protection, weed control, watering) and protect from fire at least until vegetation established at ~24 months. Intensive revegetation.	Initial site preparation may include use of controlled burn to open site access. Direct seeding with fire stimulated germination species (wattles) prior to burn, or ash bed germinating species (eucalypts, melaleucas) post-burn can add additional recruitment where seasonal/soil moisture conditions suit. Potential erosion risks of high rainfall or flows should be considered if site spray out or burning is planned.
4. Areas of remnant/degraded remnant vegetation with a high exotic pasture grass fire fuel load and associated hot fire risk	If site large enough/suitable, implement controlled grazing (or other means of grass weed control) and fire management suited to vegetation type. Control woody weeds, monitor and protect natural regeneration. Extensive revegetation with 'fill in' intensive revegetation.	If site includes areas devoid of remnant native vegetation consider fencing configurations that create protected grazing exclusion areas to allow more intensive rehabilitation approaches, as per 3. For small sites unsuited to grazing, for example, narrow riparian corridors, fire exclusion and alternate grass weed control preferable.
5. Areas of remnant/degraded remnant vegetation with sustained high grazing pressure	If possible, implement grazing spelling and monitor/protect natural regeneration. Alternatively, establish grazing exclusion fencing around areas of degraded remnant and rehabilitate as per 2, or fence off areas lacking native vegetation and rehabilitate as per 3. Extensive revegetation with 'fill in' intensive revegetation.	Extended spelling that allows accumulation of a fire fuel load and controlled burning suited to the vegetation type can promote recruitment of fire-germinated species whose abundance has been reduced under a sustained grazing regime.

Depending upon the condition of the riparian zone, different rehabilitation strategies may be appropriate (Table 5, 6). Where riparian vegetation has been lost completely or partially, revegetation is often a desired rehabilitation strategy. Both intensive and/or extensive revegetation methods may be applied for riparian zone rehabilitation, and these have been described in extensive detail along with the identification of riparian zone rehabilitation objectives, operational planning, and suitable species selection in the Sheep Station Creek System Management Plan (Econcern 2021).

System specifics

The status of riparian vegetation condition within the Didgeridoo Lagoon system is summarised for the upper, mid, and lower system and sub reaches in Figure 8 (below).



Lower system – Bruce Highway downstream to East Barratta Creek confluence

Initial reach: sparse overstory vegetation, dense para grass understory, hot fire risk exposed.

Sandy Waterhole (main lagoon): relatively contiguous, narrow, lacks ecotone, relatively diverse, areas of guinea grass understory, evidence of past fire impacts.

Sandy Waterhole – Barratta Creek: contiguous, dense (including refuge nodes), diverse, structurally complex, lacks ecotone, localised fire impacts, hymenachne infestation of open canopy sections.

Photos: 7, 12, 24, 29, 30, 45 and Figure 6.



Mid system – Bruce Highway upstream to BHWSS area

Highway lagoon: non-contiguous, isolated stands, lacks ecotone, medium diversity and condition, guinea and para grass understory, hot fire risk exposed, evidence hot fire impacts, denser node upstream margin and adjoining reserve, possible high groundwater risk.

Highway lagoon – Farm crossing: non-contiguous, isolated stands, regenerating ecotone, mostly medium diversity and condition, guinea and para grass understory, hot fire risk exposed, evidence severe hot fire impacts (dead mature riparian and adjoining frontage trees), dense, diverse and structurally-complex node with refuge value uppermost reach, possible high groundwater risk.

Farm crossing – BHWSS: Open, narrow, semi-contiguous, guinea and para grass understory, hot fire risk exposed, evidence hot fire impacts, good ecotone west bank, sparse (fire damaged) east bank, waterlogging risks.

Photos: 2, 3, 4, 7, 8, 10, 11, 15, 25, 26, 27, 28, 33, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 49, 50 and Figure 3.



Upper system – Sunwater-managed BHWSS area

Natural floodplain drainage channel: good diversity, good structural complexity, pristine ecotone, canopy density increasing (Figure 9) in response to aseasonal tailwater flows, abundant woody weeds (chinee apple, java plum) and rubber vine threatening to degrade/dominate the canopy. Bank understory includes native aquatic plants and grasses, open wet margins dominated by hymenachne, ungrazed fuel load would present late dry season hot fire risks.

Constructed tailwater drainage channels: no overstory riparian vegetation, variable in-channel vegetation, in-channel banks often partially bare and subject to erosion, particularly where comprised of dispersive sodic soils.

Photos: 1, 9, 13, 31, 34, 46 and Figure 9.

Figure 8. Didgeridoo Lagoon system riparian vegetation condition status and threat issues.

Where discussion relates to values, management issues or nominated works listed in Appendix 1 or mapped in Appendix 2, the designated (V, M or W) number is referenced.

As noted in Figure 8 above, the status of riparian vegetation through the Didgeridoo Lagoon system is variable in terms of its landscape/land use context and its condition relative to its natural character. Historical aerial photo interpretation shows that much of the riparian and adjoining floodplain frontage areas of the Didgeridoo Lagoon system hosted relatively open eucalypt and melaleuca woodland vegetation (Photo 3, 15). This was used for grazing purposes and maintained by burning. In contrast, the lower system downstream from Sandy Waterhole had a denser forest structure associated with its occurrence on and adjoining the more incised, well-watered and fire-protected channels of East Barratta Creek (Photo 29). While all larger lagoons from Sandy Waterhole upstream had a defined riparian zone, it was usually limited by seasonal aridity, fire exposure to a single tree width, and exhibited an open structure with separation between tree crowns (Photo 3, 15; Figure 3).

Through the system's development history, broad tree clearing, and agricultural development did not encroach onto the riparian zone upstream of the highway, although individual trees were cleared. Downstream of the highway, the denser forest was cleared up to the high bank riparian vegetation zone to accommodate agricultural development. Relatively protected from fire and exposed to aseasonal flows, retained riparian corridors in the lower system have developed a denser closed canopy structure through time (Photo 30). Conversely riparian vegetation in the broader retained frontages of the upper system has been subject to hot fire impacts, and possibly waterlogging stress, and has generally undergone a reduction in corridor continuity and canopy cover, except for isolated nodes (see *Fire regime* section).



Photo 29. 1964 Aerial image of the lower system below the highway. This illustrates the naturally denser riparian forest structure (left half image) associated with the Barratta Creek system relative to the more open riparian communities of the upper lagoonal system (Photo 3, 15).



Photo 30. Contemporary aerial image of the lower system. Note that clearing to facilitate agricultural development has occurred up to the riparian zone and retained riparian vegetation has increased in density in response to fire protection and modified hydrology. In contrast, broader frontage areas were retained between agriculture and riparian areas in the upper system (Figure 8) but the density of riparian and frontage vegetation has declined in response to a hot fire regime (see *Fire regime* section).

Within the BHWSS remnant floodplain woodland areas in the upper catchment (Figure 8) the riparian zone and adjoining floodplain woodland has not been cleared or subject to hot fires associated with exotic grass groundcovers. Conversely, it is undergoing a trend towards canopy closure in response to higher soil moisture conditions associated with aseasonal flows of scheme tailwater (Figure 9). It is also subject to infestation of a range of woody weeds and hymenachne (see *Aquatic weeds* and *Woody weeds* sections).

Despite the range of described impacts to its condition, the extent of remnant riparian vegetation within the system and its recuperative capacity is assessed to be good. The priority management needs are landscape-based regenerative approaches that can confront pervasive threats, rather than intensive revegetation approaches. System-scale strategies for improving the status of riparian vegetation are described in the *Altered hydrology*, *Aquatic weeds*, *Woody weeds*, *Fire regime* and *Grazing regime* sections, with the latter two being of primary importance.

However, at a smaller scale, several potentially valuable management applications and sites for more intensive riparian revegetation efforts have been identified. Some of these sites could function as trials or demonstration sites for broader system application if successful. Alternatively, they could demonstrate the shorter term condition outcomes that could be achieved by more extensive landscape approaches in the longer term, or provide an alternative to extensive landscape approaches. These alternatives include:

1. Planting with dense canopy-forming species to shade out fringing exotic aquatic grasses from the water's edge and/or fire fuel load-creating guinea grass from levee banks. Experience in other Burdekin wetland systems (Econcern 2021) has shown dense canopy-forming tree species, like Leichardt trees, are capable of excluding para grass and hymenachne from channel margins. Other levee bank species, including pongamia, damson, and paperbarks can successfully shade out guinea grass. While the historically-seasonal upper Didgeridoo Lagoon system did not support a dense riparian canopy vegetation community, the soil moisture conditions of the hydrologically-modified system will. Naturally, any such intensive revegetation proposals would need to be kept protected or separated from reaches where more extensive landscape methods involving controlled grazing or burning were being applied. Some nominated sites include:
 - a. the highway lagoon, including the freehold western side where the landholder has expressed support; or the downstream road reserve (M12); or eastern bank Crown reserves (M10), subject to stakeholder support (see *Critical habitat* section for cadastral map);
 - b. para grass-dominated channels leading to Sandy Waterhole immediately downstream of the old highway alignment, subject to landholder support;
 - c. margins of Sandy Waterhole with guinea grass understory, subject to landholder support;
 - d. state land (Crown watercourse) section of lagoon reach upstream from the highway lagoon (M7)
 - e. aquatic grass weed channel chokes (Photo 27, 28: *Fish passage barriers* section) – one is on Crown watercourse, and the other is subject to landholder support;
 - f. trial a bank section of the most upstream lagoon (Hoey's Hole), subject to landholder support. NB: Leichardt trees do not appear to have occurred in the open fire-mediated seasonal lagoon riparian communities of the upper system, but would readily establish there under the modified hydrological conditions if protected from fire; and
 - g. trial hymenachne-infested bank sections of the upper catchment floodplain tributary drainage within the BHWSS. NB: As above, Leichardt trees do not appear to have occurred in the open fire-mediated seasonal lagoon riparian communities of the upper system, but would readily establish there under the modified hydrological conditions.
2. Planting ecotone eucalypt woodland adjoining riparian vegetation zone (M9, M17). An ecotone is essentially the boundary between different vegetation assemblages or ecosystem types. These areas are often of great importance to fauna, including arboreal mammals such as squirrel gliders, because of the greater diversity of habitat and food resources available. Opportunities to allow for the regeneration or planting of woodland margins adjoining creek 'riparian' vegetation corridors vastly improves habitat value and corridor function in developed landscapes. Within the Didgeridoo Lagoon system, ecotonal woodland has been lost to hot fire regimes upstream of the highway and historical clearing downstream of the highway. Some nominated sites include:
 - a. adjoining riparian vegetation corridor of the lowermost reach of the system immediately upstream of the confluence with East Barratta Creek, subject to landholder support;
 - b. adjoining existing narrow riparian vegetation corridor of Sandy Waterhole where frontage width exists between production areas, subject to landholder support;
 - c. existing remnant riparian vegetation backing the highway lagoon, including the freehold western side where the landholder has expressed support; or the downstream road reserve (M12); or eastern bank Crown reserves (M10), subject to stakeholder support (see *Critical habitat* section for cadastral map); and
 - d. existing remnant (or revegetated) riparian vegetation backing state land (Crown watercourse M7) section of lagoon reach, upstream from the highway lagoon.
3. Trial revegetation of BHWSS tailwater drain channel section. Much of the upper catchment of the Didgeridoo Lagoon system and adjoining catchments that drain the BHWSS are comprised of constructed tailwater drains. Conventional engineering wisdom is that these structures should be kept free of vegetation to maintain the structural and functional integrity of the drains. Most of the drains are over designed in terms of flow capacity. They have partially bare channel walls, which are subject to erosion, and are colonised by in channel vegetation that is periodically controlled by chemical spraying. An alternative management solution is that these drains could accommodate vegetation that improved their ecological function while meeting their hydraulic function. Key elements could include shade generating species that provide shade-based exclusion of sun-loving grass weeds; shallow root mat species that stabilise channel walls against erosion, without threatening structural integrity; and instream emergent aquatic plant species that provide nitrate stripping and suspended sediment attenuation.

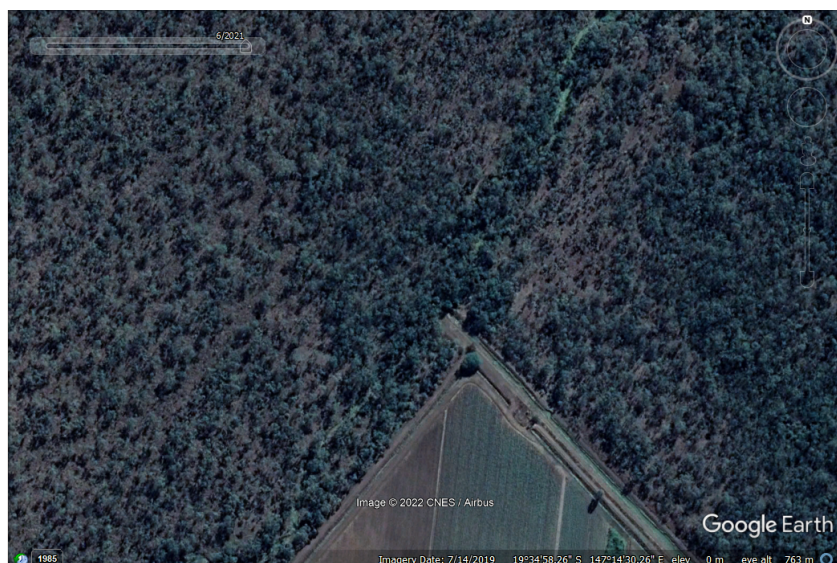
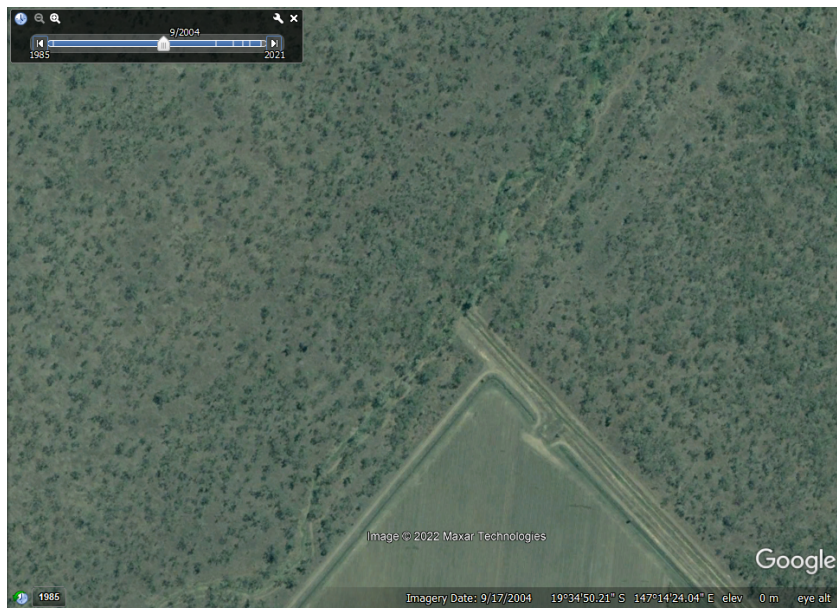


Figure 9. Thickening response of riparian vegetation of floodplain drainage channel to aseasonal tailwater inflows (top: 2004, centre: 2016, bottom: 2021).

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage system management stakeholders in the pursuit of system scale, landscape-based, regenerative approaches that can address pervasive threats impacting the status of the system's riparian vegetation as described in the *Altered hydrology*, *Aquatic weeds*, *Woody weeds*, *Fire regime* and *Grazing regime* sections, with the latter two nominated as being of primary importance.
2. Seek funding and engage system management stakeholders including landholders, BSC, Sunwater and state agencies to develop demonstration sites. These sites would showcase the benefits of planting with dense canopy-forming species. These species can shade out fringing exotic aquatic grasses from the water's edge and/or fire fuel load-creating guinea grass from levee banks.
3. Seek funding and engage system management stakeholders including landholders, BSC, and state agencies to develop demonstration sites to showcase the benefits of planting ecotone eucalypt woodland adjoining riparian vegetation zone at one or more of the range of sites nominated above (W13).
4. Engage and negotiate with Sunwater to identify prescriptive risk reduction requirements and a suitable drain reach to conduct a monitored trial revegetation of a BHWSS tailwater drain channel section.
5. As part of negotiating access to state lands for proposed revegetation activities, seek to engage management stakeholders in the development of a formal Vegetation Regeneration and Public Access and Use Options Management Plan for the Crown reserve (W7) and road reserve (W8) adjoining the highway lagoon. Also for the state land/Crown watercourse on the lagoon reach upstream of the highway lagoon (see *Critical habitat* section).

Table 6. Mapped riparian vegetation condition class – ecological value, management issues and identified revegetation needs and opportunities

Exotic grasses
• Has low ecological value, presents hot fire risks to remnant native trees and adjoining cane farms, and harbours rodent crop pests. • Can provide suitable cover and bank stability for excavator-maintained channel reaches. • Growth of aquatic grass species (para, aleman, hymenachne) onto water bodies blocks water flow and creates floating aquatic weed mats. This reduces water dissolved oxygen and creates biological oxygen demand (BOD) when grass decomposes in water, particularly when inundated by elevated flows/water levels, creating anoxic 'blackwater'. • Fire risks can be reduced by fuel load reduction with controlled grazing where site conditions allow. • Where no remnant native trees are present, revegetation is dependent on more intensive methods, for instance, seedling planting. • Establishing a shade-generating overstorey tree canopy that controls grass density and reduces bank-side anchor points for aquatic grass species provides a catchment-scale revegetation target.
Remnant vegetation
• Has high ecological value, including providing habitat for fauna uncommon in developed landscapes. • Mapped units can include significant areas of exotic grass and degraded remnant classes. • Condition can trend positively or negatively depending on operating pressures, e.g., weeds, grazing regime, fire regime, physical disturbance, and hydrological change. • Controlled grazing of exotic grass understorey can reduce fire fuel loads and associated hot fire risks and, with spelling, promote natural regeneration. • Exclusion of fire, or a controlled burning regime, can promote increased canopy development and suppression of understorey fuel loads, and promote natural regeneration. • Provides baseline comparison sites, target species lists and seed sources for regeneration of equivalent reach areas. • Provides nucleus areas for strategic regeneration of adjoining riparian areas. • 'Fill in' planting can be used to increase mid and overstorey canopy development, though promoting natural regeneration is more appropriate where integrity is high. • Priority management focus for remnant vegetation is protection and represents a more cost-effective investment than revegetation.
Degraded remnant
• Ecological value is variable depending on landscape context, but can provide important habitat resources, including feeding and nesting sites within a modified landscape. • Mapped units usually include significant areas of exotic grass and may include exotic trees/woody weeds. • Condition can trend positively or negatively depending on operating pressures including weeds, grazing regime, fire regime, physical disturbance, and hydrological change. • Controlled grazing of exotic grass understorey can reduce fire fuel loads and associated hot fire risks and, with spelling, promote natural regeneration. • Exclusion of fire or a controlled burning regime can promote increased canopy development and suppression of understorey fuel loads, and promote natural regeneration. • Remnant trees provide the opportunity to use more extensive revegetation approaches, for instance, the promotion of natural regeneration via seedling recruitment and growth • 'Fill in' planting/intensive revegetation can be used to target denuded areas along with promoting natural regeneration within remnant stands. • An integrated mix of intensive and extensive revegetation approaches is an appropriate management focus and provides a catchment-scale revegetation target.
Revegetated
• Observed ecological value is generally high, particularly where the area includes mature remnant stands or individual trees of the original vegetation community. • Primary management focus is protection and maintenance, particularly in relation to reinfestation by grass weeds and associated hot/uncontrolled burn risks. • Some sites warrant 'fill in' intensive revegetation to address areas denuded by uncontrolled burns and/or die-off of short-lived pioneer species. • Good opportunity to increase habitat values by dedicated understorey/groundcover planting and introducing physical habitat features, like, logs, artificial nest hollows.
Exotic trees
• Ecological value is limited in monocultural plantings (orchards) but can be higher when mixed with remnant native species. Can provide some nesting and feeding habitat resources and a range of useful functional values, for example, stabilising stream banks, and shading out aquatic grass weeds, and duckweed around pump intakes.

- Where mixed with native tree species, selected control and clearing and 'in fill' revegetation can be used to regenerate sites toward native vegetation dominance.

Grassland

- 'Catch all' class for grassland areas that are not the 'exotic grasses' class associated the immediate riparian zone (above). When this includes native grasslands, it can have high habitat values for grassland-dependent species, particularly granivorous birds.
- Riparian areas that represent cleared areas are an appropriate focus for intensive revegetation, particularly adjoining lagoons subject to aquatic grass weed infestation.

Woody weeds

Types and impacts

Woody weeds threatening the condition of Lower Burdekin wetland systems include exotic trees and vines that infest riparian zones and catchment areas to the detriment of native habitat values, catchment processes and production values. The key species recorded in the Lower Burdekin are listed in Table 7 (below). Although some woody weeds are utilised as shelter or food habitat resources by native fauna, their occurrence within native vegetation communities results in the competitive exclusion of native plants. Native fauna have evolved and developed direct or indirectly-dependent relationships with these native flora. For example, while canopy-dwelling birds may inhabit an exotic tree canopy, it will generally not support the same populations of native insect food sources that a native tree canopy will. The greatest scope for impact occurs where weeds have the invasive capability to dominate a regional ecosystem setting to the exclusion of native biodiversity and/or change native vegetation structure and/or function. For example, severe infestations of rubber vine can create 'vine towers' that completely smother and collapse host trees, destroying the vegetation structure (e.g., closed canopies) required by dependent species and opening the vegetation community to further weed infestation, such as sun-loving grasses.



Photo 31. Stands of mature and recruiting young java plum *Syzygium cumini* beginning to dominate the riparian vegetation canopy at the confluence of a BHWSS tailwater drain (right) with the floodplain drainage channel (left) headwaters of the Didgeridoo Lagoon system.



Photo 32. Close-up view of the invasive but undeclared environmental weed java plum *Syzygium cumini*, an exotic fruit tree extensively planted as shade trees.

Where vegetation structure gets completely altered by woody weed infestation, secondary impacts may also be generated. For example, a rubber vine tower causing canopy collapse opens-up fire-sensitive riparian vegetation to secondary weedy grass infestation, which leads to its exposure to fire impacts. Dense canopy-forming woody weed species such as chinee apple can form closed canopy infestations that shade out understorey grass in formerly open woodland areas. This reduces pastoral productivity and exposes understorey areas to increased soil erosion in the event of heavy rainfall or floodplain overland flows.

Not all species are declared weeds under the *Queensland Biosecurity Act 2014*. Control methods vary from various forms of chemical spraying, including basal cut and foliage spraying; the use of bio controls like rubber vine rust fungus (*Maravalia cryptostegiae*); and the use of fire. Heavy machinery is also often used for clearing more dense infestations where access for other forms of control is limited, or control by other methods is cost exorbitant. Where heavy machinery is employed the risks to remnant vegetation stands mixed within woody weed infestations need to be managed to avoid impact to remnant habitat values.

In recent decades there has been substantial investment by NQ Dry Tropics in the control of woody weed infestations at Lower Burdekin wetland sites, including two nationally significant wetlands: Serpentine Lagoon and Woodhouse Lagoon. Other sites have included Churches Lagoon (on Sheep Station Creek) and Collinson's Lagoon adjoining the Bruce Highway. An observed reduction in rubber vine infestation levels has also been noted over the past two decades at some sites, including Barratta Creek where rust fungus successfully established during a series of wetter years.

Levels of woody weed infestation vary between systems but, overall, the extent of infestation across the greater floodplain remains significant. Investment in further control needs to be informed by strategic priorities to make effective use of limited resources. Intervening in low level infestations, including at upper catchment sites before they spread downstream and/or become more extensive, represents prudent investment. Public investment in the resources required to tackle large extensive infestations can only be justified where there are high value wetland assets at stake and/or a production dividend that promotes landholder engagement and co-investment.



Photo 33. Rubber vine infestation within riparian vegetation at the upstream margin of the most upstream lagoon in the system.



Photo 34. Didgeridoo Lagoon system headwater drainage conveying runoff from the BHWSS. Remnant vegetation areas of the BHWSS hold extensive infestations of a growing list of woody weed species including chinese apple (background right) and rubber vine (foreground left).

System specifics

Overall levels of woody weed infestation within private lands of the Didgeridoo Lagoon system are relatively low, suggesting landholders have maintained active control vigilance. While scattered individuals of chinese apple and isolated occurrences of rubber vine (Photo 33) observed on private lands present little current impact to habitat values, they do represent a prudent target for maintaining the low woody weed infestation status of the lower system.

The most significant woody weed threat lies within BHWSS lands in the system's head waters. Widespread infestations of chinese apple occurring through remnant floodplain woodlands and a larger and growing list of woody weed species observed along drainage lines (Photo 34) suggest a less-than-vigilant woody weed control program is operating in these areas. Given the location of these weed infestations in the headwaters of the system, the risk of spread to the lower system is significant. It is in the interest of all management stakeholders that greater control efforts are invested in the remnant vegetation areas of the BHWSS.

Some weed species emerging as significant environmental threats within the BHWSS are undeclared or even recognised with the *Burdekin Shire Council Biosecurity Plan 2016-2019*, for example java plum *Syzygium cumini* (Photo 31, 32). Other species are not declared at a state level but are declared as local weeds within the plan, for example, neem tree *Azadirachta indica*. Field investigation observations of these and other exotic tree species along drainage lines within the BHWSS suggest that infestations are at an early, yet critical, threshold. Beyond this point, habitat values will be significantly impacted and control capacity challenged.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Engage with Sunwater and other management stakeholders and identify resourcing opportunities to instigate a rubber vine and woody weed control program. This program would include targeting undeclared exotic tree environmental weeds within the riparian corridor and immediately adjacent catchment areas along the length of the BHWSS tailwater supplemented floodplain creek headwater (W3).
2. In the pursuit of Recommendation 1 (above), and recognising the primary source area function of BHWSS lands, additional resources be made available to enable control teams to conduct an eradication through the low level infestations of rubber vine/woody weeds in the lower system reaches within private lands.
3. Form a multi-stakeholder working group to progress establishing formal nature conservation management arrangements. This includes a managed woody weed control program for BHWSS remnant habitat corridors and nodes (M2).

Table 7. Woody weeds of management concern on the Lower Burdekin floodplain

Common Name	Species	Growth habit	Comments/nature of impacts	Biosecurity status/control methods
Chinee apple	<i>Ziziphus mauritiana</i>	Large shrub or small spreading tree up to 8m tall and 10m in canopy diameter.	Forms dense impenetrable groundcover and native midstory excluding, infestations.	Chinee apple Business Queensland
Parkinsonia	<i>Parkinsonia aculeata</i>	Small, hairless tree up to 10m tall.	Forms dense impenetrable groundcover and native midstory excluding, infestations.	Parkinsonia Business Queensland
Prickly acacia	<i>Vachellia nilotica</i>	Thorny shrub or small tree up to 5–10m tall.	Forms thickets in open grassland /woodland, reduces groundcovers.	Prickly acacia Business Queensland
Yellow oleander	<i>Cascabela thevetia</i>	A large tree that can grow up to 10 m high.	Outcompetes native canopy species. Poisonous to stock and humans.	Captain Cook tree or yellow oleander (daf.qld.gov.au)
Golden shower tree	<i>Cassia fistula</i>	A spreading tree that is semi-deciduous usually grows less than 10 m tall, but has the capability of reaching up to 20 m in height.	A weed of riparian vegetation, open woodlands, wetland margins, roadsides, coastal environs and offshore islands.	golden shower tree Weed Identification – Brisbane City Council
Castor oil plant	<i>Ricinus communis</i>	A tall branching, annual or perennial shrub that grows to 3m.	Invades floodplains, riverbanks, may form thickets. Seeds, and to a lesser extent, the leaves are toxic to livestock and humans.	Castor oil plant Business Queensland
Neem	<i>Azadirachta indica</i>	Fast-growing evergreen generally 15-20m tall, with crown diameter up to 20m.	Outcompetes native canopy species.	Neem tree Business Queensland
Devils fig	<i>Solanum torvum</i>	An upright shrub or small tree usually growing 0.8-3 m tall.	A weed of closed forests, forest margins, waterways (i.e., riparian areas), plantation crops, roadsides, pastures, disturbed sites, and waste areas.	Devil's fig Weed Identification – Brisbane City Council
Leucaena	<i>Leucaena leucocephala</i>	Shrub up to 6m tall.	Forms thickets in riparian zones and alluvial plains, stalls native regeneration and excludes groundcovers.	Leucaena Business Queensland
Java plum	<i>Syzygium cumini</i>	Tropical evergreen tree that can reach heights of up to 30m.	Outcompetes native canopy species.	Environmental weed
Tamarind	<i>Tamarindus indica</i>	Moderate to large evergreen tree, up to 24m in height, and 7m in girth.	Outcompetes native canopy species.	Environmental weed
Rain tree	<i>Samanea saman</i>	Large to massive, evergreen, spreading, umbrella-shaped and symmetrical trees that grow to 60m tall with a crown up to 80m broad.	Spread into native forests, and outcompetes native canopy species, particularly along stream margins and in disturbed areas	Rain tree (daf.qld.gov.au)
Rubber vine	<i>Cryptostegia grandiflora</i>	Climbing vine up to 30m tall in trees, untidy shrub up to 1–2m tall.	Forms dense impenetrable groundcover-excluding, canopy dominating /collapsing infestations.	Rubber vine Business Queensland
Lantana	<i>Lantana camara</i>	Heavily branched shrub growing in clumps, thickets, or vines.	Forms dense impenetrable groundcover-excluding infestation that can extend to the midstory.	Lantana Business Queensland
Elephant ear vine	<i>Argyreia nervosa</i>	Perennial woody vine climbing up to 10m high.	Forms canopy-dominating/collapsing infestations.	Elephant ear vine Business Queensland

Siam weed	<i>Chromolaena odorata</i>	Dense, tangling bush up to 2-3m tall, scrambles up trees to 20m.	Forms canopy-dominating/collapsing infestations.	Siam weed Business Queensland
-----------	----------------------------	--	--	---

Fire regime

Need

Inappropriate burning has long been recognised as a primary cause of deteriorating riparian vegetation condition in the lower Burdekin region (BBIFMAC 1999). Fire impacts both sapling recruitment and mature trees. Field work undertaken for the preparation of this management plan identified that burning, particularly in the late dry season, continues to impact Lower Burdekin riparian vegetation condition.

Most native vegetation within the region has some adaptation to fire, which is a natural feature of ecosystems within the seasonal dry tropics. However, most native vegetation has evolved within a certain set of 'fire regime' parameters (see insert box below). If the experienced fire regime is more intense or frequent than its adapted capacity, it will result in mortality of trees and saplings and corresponding declines in vegetation structure, species diversity and associated habitat values.

For native vegetation fire is not only a destructive force but also a regenerative one. Many types of riparian trees particularly wattles (*Acacia spp.*) and others, like casuarina and grevillea, have seed whose germination is promoted by fire. Other riparian species, like melaleuca and eucalyptus, have seed that is released from capsules by fire and readily germinates in an ash bed soil layer and/or groundcover openings created by burning. A range of weed species, including rubber vine and para grass, are fire sensitive and controlled burning can provide a riparian restoration tool, along with a fire risk mitigation role.

Fire regime – describes the pattern of burning experienced by a site, or suited to a particular vegetation community, and is commonly characterised in terms of:

- frequency (interval period between fires);
- seasonality (time of year);
- intensity (determined by burn conditions, including time of day, wind, soil moisture, fuel load), and
- extent (amount of habitat type or site burnt per event or year).

Without management attention to the fire regime experienced by the creek's riparian zone, valuable remnant habitat areas will continue to decline in condition and ecological gains made by revegetation or regeneration of riparian zones can be lost.

Causes/constraints

There are several factors contributing to the often-destructive fire regime experienced by riparian zones within the Lower Burdekin region (Tait 2011). These factors may also be considered constraints to implementing an appropriate fire regime. They include:

Large fuel loads – Amongst many Lower Burdekin wetland riparian zones, habitat remnants are ungrazed. This factor, combined with invasive exotic grasses, like guinea grass/green panic, para grass, and elephant grass commonly result in large annual fire fuel loads within habitat remnants. These exotic grasses produce greater standing biomass than native grass species and have a long growing season due to seasonally-extended soil moisture promoted by regulated stream flows and/or irrigation tailwater.

Annual fire exposure – The Lower Burdekin remains one of the few sugar growing regions in Australia where burning is employed pre-harvest to remove cane trash. Most remnant habitat areas on the floodplain occur near cane fields. Consequently, most are exposed to one or more close proximity annual burning events in surrounding cane fields. This presents a high likelihood of remnant habitat areas also experiencing an annual fire frequency, particularly where cultural practices have long favoured 'cleaning' up pest harbourages and fire fuel loads in remnant habitat areas during or after cane field burning.

Risks to cane crops promote late dry burning – Most cane farmers are unwilling to consider utilising fire as part of surrounding landscape management until cane crops have been harvested to avoid the risk of uncontrolled fire. At a regional level, cane harvesting is not completed until late in the dry season when conditions tend to promote 'hot' fires. This means that any intentional burning of habitat remnants after cane has been harvested is often damaging to vegetation structure, composition and ecological values, and there are fewer opportunities to conduct beneficial 'cool' or less intense 'controlled burns'.

Landscape setting

Appropriate fire regime guidelines suited to the native vegetation types that occur on the Burdekin floodplain have been defined by state government agencies (see Econcern 2021). However, these guidelines assume that fire management is occurring in extensive natural landscapes. The Lower Burdekin floodplain is dominated by irrigated agriculture. Remnant natural habitat tends to occur as isolated 'islands' and non-continuous, narrow riparian corridors surrounded by a 'sea' of developed landscape. In this context, natural landscape fire management approaches that depend on patchy burning of the surrounding landscape mosaic cannot be readily utilised; particularly when most of the surrounding landscape is developed crop land. Limiting the extent of a vegetation type or remnant patch that is burnt in any one event or year is also challenging where it only occurs in small patches surrounded by a landscape that is burnt annually.

Implementing an appropriate (including no) fire regime

The appropriate fire regime for floodplain vegetation remnants will vary with vegetation type and landscape setting. Importantly, it needs to be recognised that the most appropriate fire regime for some riparian habitat remnants is total fire exclusion. This applies particularly where the remnants include fire-sensitive species; and/or are comprised of narrow riparian corridors with limited fuel loads; and are not separated sufficiently from adjoining cane farms to avoid being an uncontrolled fire risk.

Regionally applicable guidelines for the implementation of appropriate controlled burning practices and fire regimes for Lower Burdekin wetland vegetation remnants within different farming landscape contexts were developed for the Sheep Station Creek SMP (Econcern 2021). Burdekin land managers interested in the use of fire as an ecological management tool are referred to that document for more detailed information.



Photo 35. Aerial view of the most upstream lagoon taken in 2006. Areas of pale green groundcover in the levee woodland represent exotic guinea grass versus the pale brown signature of more native grass-dominated groundcover.



Photo 36. Aerial view of the most upstream lagoon in 2019. Although the site has not been subject to vegetation clearing, the reduced density of woodland trees on the right bank compared to 2006 (left) is apparent. A sustained hot fire regime associated with ungrazed pasture grasses is implicated.

System specifics

Historically, much of the riparian and adjoining floodplain areas of the Didgeridoo Lagoon system hosted relatively open eucalypt and melaleuca woodland vegetation with native grass groundcovers, and was used for grazing purposes. With land use intensification towards irrigated agriculture, most of these areas are no longer grazed. In the absence of grazing, the presence of altered hydrology, and elevated soil moisture, many levee areas previously vegetated with native grasses are now dominated by invasive exotic pasture species.

Ungrazed exotic pasture grasses such as guinea and para grass create fire fuel loads larger than native grass site equivalents. When burning is conducted with large fire fuel loads in the late dry season – when cane crops have been harvested and fire risks to crops are low – the resultant hot fires can severely impact riparian and floodplain vegetation, causing the death of mature trees and degraded canopy. These impacts can be to the extent and condition that facilitate further dominance of invasive understorey grasses (M3). As well as posing further hot fire risks to remnant vegetation, increasing pasture grass density also serves to suppress native seedling recruitment. These combined processes appear to have contributed to the reduced density and diversity of remnant riparian vegetation and adjoining floodplain woodland on retained lagoon frontage areas adjoining farmland along the lagoon system upstream of the highway (Photo 35, 36). As discussed in the

Altered hydrology section, there is also evidence that sustained lagoon water levels, water logging and possibly groundwater rise may be contributing to the reduced vigour and death of some riparian and floodplain vegetation.

A significant area of the Didgeridoo Lagoon system's uppermost catchment is comprised of remnant floodplain habitat areas that were set aside nominally for nature conservation purposes during the development of the BHWSS area, formerly known as the Burdekin River Irrigation Area (BRIA). Despite being 'reserved', this area has never been brought under any formal nature conservation tenure or management arrangements. Although the area retains very high nature conservation values, its condition is subject to longer term decline due to a lack of effective, woody weed, grazing, or fire regime management. Wallaby populations within these remnant areas and wildfire risks to adjoining cane farms also serve to create management conflict with adjoining land users. In the absence of visible management, the area suffers from inappropriate management practices such as waste dumping, vegetation clearing and hot (late dry season) fire regime burns.



Photo 37. A Google Earth image captured in September 2004 indicates a recent burn of the main upstream lagoon banks with burnt crowns that have not yet dropped their leaves visible on the left bank.



Photo 38. An image of the same reach (left) taken from a low flying aircraft in 2005. The bright green groundcover visible on the left bank is guinea grass, a pyrophytic (fire-loving) species. Reduced canopy density and vigour, including dead crowns, is visible on left bank's woodland.



Photo 39. An image of the same reach as photo 37 taken from a low flying aircraft in 2007. Dead native overstorey vegetation (foreground right), including lagoon margin riparian vegetation, is visible. Most dead vegetation occurs within guinea grass stands (yellowish green groundcover).



Photo 40. Next reach downstream from (left) taken from a low flying aircraft in 2007. Dead native overstorey vegetation (background right) includes mature riparian vegetation (foreground right). Most dead vegetation has fire scars and occurs within guinea grass stands (yellowish green groundcover).

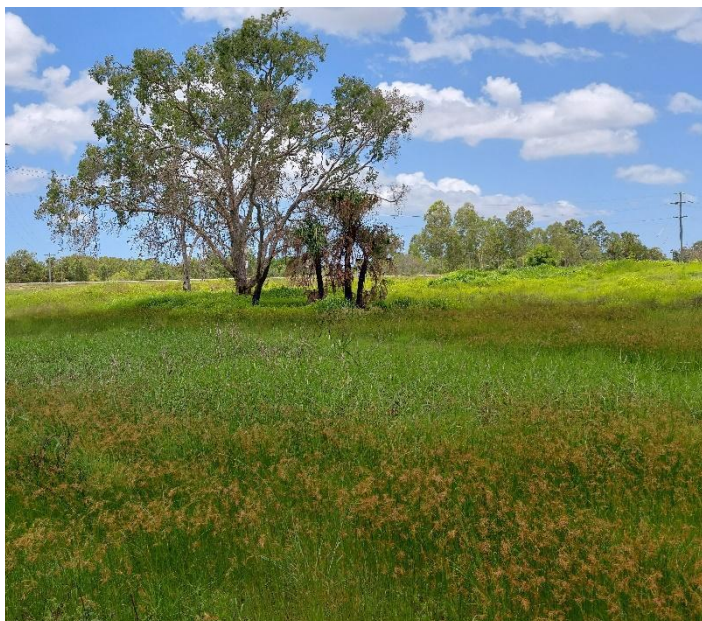


Photo 41. A positive outcome of burning of seasonal wetland basins is the promotion of native groundcover biodiversity, seen in this image.



Photo 42. Livistona palms are a fire-adapted and hardy species. Remnant native vegetation dominated by Livistona is usually indicative of a hot and frequent fire regime.

While inappropriate hot burning regimes are implicated in the demise of native overstory vegetation condition, appropriate burning can promote native vegetation biodiversity, particularly of groundcovers. Site investigation of a seasonal wetland that had been subjected to a hot fire found that, although overstory vegetation had been damaged, the recruiting groundcover was predominantly native (Photo 41), as opposed to the exotic pastures that characterised the site before the fire. While exotic guinea grass is pyrophytic (fire loving), most exotic aquatic grasses, like hymenachne and para grass, are fire sensitive despite the capacity of the latter to generate large fire fuel loads. Trials involving the integrated use of seasonal hydrological conditions, also known as hydrological management, to drawdown water levels and expose these aquatic pastures to drying have been shown to significantly reduce the dominance of these species and promote recruitment of native aquatic plant margins (Tait 2011). This outcome is also found in trials using applied grazing pressure to reduce fuel loads, and controlled burning to kill plants stems (Tait 2011).



Photo 43. Large fuel loads associated with ungrazed guinea and para grass understory provide the conditions for a 'hot' fire regime indicated by fire scars and a lack of natural sapling recruitment.



Photo 44. Dead and damaged overstory trees due to a hot fire regime in this ungrazed seasonal wetland and a lack of sapling recruitment point toward long-term degradation of its native woody vegetation.

As discussed in the *Lack of riparian vegetation* section, the system's lowermost reach has a denser and more diverse riparian vegetation corridor with good canopy condition that has been maintained relatively free of dense pasture grass understorey and associated hot fire risks. Current fire management practices include the landholder's desire to remove fallen palm frond fire fuel loads from beneath livistona palm stands. This results in local hot fires that serve to further promote the fire-loving palms and keeps an open, or further opening, canopy structure. Some of the species at risk of being impacted by these fires include shade-generating trees such as Leichardt's that are recruiting along the channel in response to the perenniality of the modified creek

system (Photo 45). A weed species that benefits from a more open canopy is hymenachne, which is also distributing along the now-perennial stream channels. Excluding fire from the livistona understory could promote more canopy closure and keep the channel free of hymenachne, reducing the need for spray-based control. Fire risks associated with accumulated palm fronds would need to be considered.



Photo 45. Large fire scar on paperbark (foreground, left) associated with 'clean up' burning of livistona palm fronds, which promotes further palm growth (seedlings recruiting, front left). Young Leichardt trees recruiting in centre of image are fire sensitive. If protected from fire and allowed to develop a full closed canopy, they would serve to exclude hymenachne grass growth on stream channel (background, right).



Photo 46. Extensive area of remnant floodplain woodland within the system's upper catchment in the BHWSS area. Appropriate fire regime management is critical for the maintenance of biodiversity values within these retained habitat areas, and for the reduction in wildfire risk to adjoining farmland.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced.

1. Use the release of this SMP as an opportunity to conduct a fire regime and controlled burning communication and an extension program targeting riparian landholders, local fire wardens, and RFS members via shed meetings, field days, other appropriate forums, and via published material. Key topics for communication include:
 - a. Ecological impact of hot fire regimes and their association with an ungrazed exotic grass understory.
 - b. The role of controlled grazing in reducing fire fuel loads and supporting cooler burns.
 - c. The fire sensitivity of exotic aquatic grasses, like hymenachne and para. Also, the capacity for an integrated use of controlled burning and grazing, ideally with seasonal or managed drawdown of water levels, to reduce the abundance of these grasses at a system scale.
 - d. The appropriateness of fire exclusion as a 'burning regime' for riparian zones with, or that are capable of supporting, a closed vegetation canopy.
 - e. The role of establishing riparian revegetation/canopy as a fire risk reduction strategy.
 - f. The need to manage fire fuel loads and associated hot fire risks where they adjoin fire-sensitive remnant habitat assets.
 - g. The fuel load, seasonal and day timing conditions, and fire conduction methods that support 'cooler' burn outcomes.
 - h. The additional benefits of reducing exotic grass density/fuel loads in riparian areas adjoining farmland, for instance, reducing rodent harbourage habitat.
2. Engage system management stakeholders in implementing the recommendations from the *Grazing regime* section as a pathway towards improving the system's fire regime. In particular, providing support for the reintroduction of controlled grazing to lagoon frontages to reduce exotic pasture dominance and hot/wildfire risk (W4) and to enable reintroduction of cool burning.
3. Engage the landholder of seasonal wetland site (Photo 41, 42, 44, 47, 48) in pursuing the recommendations from the *Grazing regime* section. This includes establishing fencing and introducing controlled grazing to reduce exotic pasture dominance and hot/wildfire risk (W6), and to enable cool burning to be reintroduced.

4. Engage the landholder of system's lowermost reach (Photo 45) and promote exclusion of fire from riparian vegetation corridor to support ongoing recruitment of shade-generating species, like Leichardt trees, to limit channel hymenachne infestation (W12).
5. Engage with the Department of Transport and Main Roads, BSC, and any other management stakeholders associated with the riparian habitat remnants on road and Crown reserves, and state land adjoining the Didgeridoo Lagoon that are exposed to high fire fuel load and associated hot fire risks. Explore the opportunity for these sites to be used as demonstration sites and community engagement in showcasing controlled burns and/or other hot fire risk reduction strategies, like controlled grazing (W7, W8).
6. Form a multi-stakeholder working group to work toward the establishment of formal nature conservation management arrangements, including a managed fire regime and controlled burning program for BHWSS remnant habitat corridors and nodes (M2).

DRAFT

Grazing regime

Why is it a useful tool?

For most Australian landscapes, the conventional wisdom regarding nature conservation-based management is that the impact of grazing animals should be kept out of disturbance-sensitive riparian and wetland areas. In contemporary riparian and wetland habitats of the Lower Burdekin floodplain, this convention is turned on its head because one of the greatest sources of wetland and riparian habitat threat is invasive exotic pasture species that can become dominant in the absence of grazing. These pasture species include a suite of aquatic grasses, such as para, hymenachne, aleman, and other species that occupy better-drained levee soils, like guinea grass.

Collectively, these grasses generate a range of impacts within wetlands and the riparian zone (Figure 7) of floodplain wetland systems, including:

- out-competing native vegetation, including groundcovers and sapling recruitment;
- creating large dry season fire fuel loads that support 'hot' fires;
- smothering open water and shading out native submerged and emergent edge aquatic plants;
- degrading water dissolved oxygen levels by organic loading, reduced instream photosynthesis and less water surface – air interaction;
- degrading fish and waterbird nesting, feeding and egg laying habitats (including dry season-exposed banks used by waterfowl); and
- socio-economic impacts (including creating mosquito breeding habitat, crop weeds, water channel blockages).



Photo 47. This seasonal wetland adjoining the highway (right) receives seepage from an upstream irrigation recycling basin and supports prolific growth of ungrazed exotic pasture species, resulting in hot fire impacts (dead overstory, background).



Photo 48. The landholder of this seasonal wetland is supportive of it being used for grazing-based control of pasture weeds and associated hot fire impacts. While its highway proximity presents some risk management needs, it also provides for high profile demonstration site.

It is within the context of the impacts caused by exotic pasture grasses that grazing, and the lesser disturbance of grazing animals, can be beneficial to the condition and value of riparian and wetland habitats. Ultimately, application of grazing as a habitat management tool requires an appreciation of its impact risks concerning native flora and fauna, bank compaction, and soil erosion, seeking to minimise these while maximising the benefits of reducing exotic pasture dominance. Guidelines for the use of controlled grazing as a riparian and wetland habitat management tool have been developed for the Lower Burdekin region based on a research project involving a range of monitored management trials conducted over a decade ago (Tait 2011). Those guidelines provide a basis for this management plan's recommendations, yet interested readers should refer to that document and the SMP developed for Sheep Station Creek (Econcern 2021) for a more comprehensive treatment of the issue.

Controlled grazing is not a suitable management approach for all sites and is not needed where other methods can be preferentially, or more effectively, applied to control grass weeds, for example, establishing riparian vegetation canopy shading. However, controlled grazing is a useful management tool because it can be used at a landscape scale and fills an important role where other methods may have limitations, such as chemical, and mechanical control, or tree canopy shading established by revegetation. Importantly, all these methods are not mutually exclusive, and the best riparian zone rehabilitation outcome may be achieved by an integrated or sequential application of more than one approach.

In terms of site suitability constraints, the main reasons why controlled grazing may not be suitable at some sites include:

- steep banks/erosion prone soils;
- incompatible adjoining land uses;
- species vulnerable to grazing disturbance and/or presence of good condition or grazing-sensitive habitats; and
- site too small, or shape/configuration has high fencing costs, lacks high water stock refuge, or presents ineffective fencing security.

In contrast to controlled grazing; uncontrolled grazing and associated stock trampling, bank erosion and pugging of wetland and riparian areas; can also present a threat to wetland system ecological values. These threats are relevant concerns where wetland systems fall predominantly within grazing land use areas, but need to be avoided where grazing is applied in a controlled context with agricultural land use areas.



Photo 49. Landholder slashing of guinea grass-dominated lagoon frontages in the lower (above) and upper (right) lagoon systems.



Photo 50. Landholder slashing-based control of grass is indicative of a desire for fire fuel load control and an appreciation of the site's aesthetic amenity. Trial based studies (Tait 2011) suggest controlled grazing could achieve the same outcomes with greater biodiversity returns.

System specifics

As noted in the *Fire regime* section, historically much of the riparian and adjoining floodplain areas of the Didgeridoo Lagoon system were used for grazing purposes. With land use intensification toward irrigated agriculture, most non-cropped areas are no longer grazed. In the absence of grazing and presence of altered hydrology and elevated soil moisture, most water edges and many levee areas previously vegetated with native aquatic plants or grasses are now dominated by invasive exotic pasture species. These include para grass, hymenachne, and aleman grass on water edges/bank margins, and guinea grass on elevated levees. As discussed in other sections of this SMP, the aquatic grasses are major environmental weeds that outcompete critical native aquatic plant habitats; degrade water quality; create channel blockages and fish passage barriers; suppress native vegetation recruitment, and contribute to 'hot' dry season fire fuel loads. Guinea grass growing on elevated levees also contributes to native vegetation impacts via similar processes, particularly its contribution to 'hot' dry season fire fuel loads (see *Fire regime* section).

Grazing animals, including cattle and horses, provide a broad acre tool for reducing the dominance of exotic pasture grasses in riparian areas and for reducing hot fire risks associated with ungrazed grass fuel loads (Tait 2011). As discussed in the *Altered hydrology* section, the reinstatement of dry season water level drawdown would significantly increase grazing animals' access to exotic aquatic grass margins and their associated control effectiveness. Independent of the reinstatement of seasonal hydrology to the system, controlled grazing along the frontage and adjoining floodplain areas of the entire system would serve to re-establish native vegetation, habitat values, and ecosystem processes, including natural recruitment of woodland vegetation and a capacity for non-destructive cool burns (see *Fire regime* section). Remnant floodplain vegetation within the BHWSS in the top of the Didgeridoo Lagoon system's catchment could also benefit from controlled grazing. Currently a range of exotic pasture grasses are establishing within retained natural habitat areas of the BHWSS and – along with late dry season burns in rank native grasses – pose hot fire risks to biodiversity and habitat values of these areas.

During field investigations, the landholder of a small wetland site adjoining the highway expressed support for establishing controlled grazing on it. This historically seasonal wetland now receives seepage from an upstream tailwater recycling storage that keeps part of its basin wet and prone to exotic grass (hymenachne, para) and cumbungi infestation. Being ungrazed, the site accumulates large fire fuel loads before the dry season in most

years, exposing it to ongoing hot fires risks. These risks are frequently realised, resulting in degradation of the remnant wetland vegetation condition (Photo 44, 47,48). Small seasonal wetlands host different plant species to those more commonly associated with the main perennial lagoons and have their own intrinsic nature conservation values that warrant management investment within the broader system.

Recommendations

Note: where recommendations correspond to identified management issues (M) and nominated works (W) in Appendix 1 and 2, the listed number is referenced.

1. Seek resources to provide incentives, for instance, support for fencing infrastructure. Engage with landholders of frontage and adjoining floodplain and seasonal wetland areas of the Didgeridoo Lagoon system to canvas interest and support for establishing controlled grazing sites (W4, W6, W10).
2. Support to engage with grazing stock owners within the system and broader Barratta Creek catchment to identify opportunities for establishing a 'mobile herd' habitat grazing capacity. Also, to provide expertise to monitor habitat condition indicators at nominated trial and demonstration sites.
3. Engage with local government and appropriate state agencies to gain support for using seasonally-applied grazing pressure to reduce fire fuel loads on state land and Crown reserves. Also, to allow for the reintroduction of controlled 'cool' burning.
4. Document results of grazing-based management trials and promote the outcomes and associated learning via publications and landholder forums.
5. Form a multi-stakeholder working group to work towards establishing formal nature conservation management arrangements, including an environmental outcome-focused controlled grazing program for BHWSS remnant habitat corridors and nodes (M2).

Critical wildlife habitat

Under the *Queensland Nature Conservation Act 1992* critical habitat is defined as:

- (1) habitat that is essential for the conservation of a viable population of protected wildlife or community of native wildlife, whether or not special management considerations and protection are required, and
- (2) may include an area of land that is considered essential for the conservation of protected wildlife, even though the area is not presently occupied by the wildlife.

Beyond this statutory definition applied to threatened wildlife species listed under state or federal legislation, the concept of critical habitat can be considered more generally as habitat types or features that are essential to the maintenance of specific wildlife species or groups within a particular landscape or area.

Conserving and improving the wildlife biodiversity that occurs within the Lower Burdekin floodplain is an aspirational goal supported by most stakeholders. Understanding what constitutes critical habitat is important for effective wildlife conservation. Since European settlement in the Lower Burdekin, there has been a reduction in the diversity and population sizes of a range of wildlife species previously occurring in the region, which has coincided with the development of pastoral and agricultural land uses. For example, few younger generation residents know koalas were once common in bluegum forests on the levees of the Burdekin River.

During the author's own lived experience in the region from the 1960s to the present, there are several wildlife species that can be anecdotally reported to have become rare or even extinct from areas within the catchment. These include northern quolls, otherwise known as 'native cats', which occurred in the Mount Kelly area until at least the early 1970s. Spectacled hare wallabies, known as 'pademelons' by Burdekin locals, were once common in coastal floodplain areas until the 1980s, and are now only recorded in rangeland areas on the margin of agricultural production areas. Further, large, diverse (multi species) finch populations are now reduced in species number and population size, and frill neck lizards – once commonly-encountered in habitat remnants – are now a notable record. While the loss of wildlife species can be attributed to a general reduction in available habitat area, habitat fragmentation and feral predators, the loss of critical habitat is often a key cause that can be operating even where areas of remnant habitat remain.



Photo 51. The vulnerable southern squatter pigeon (*Geophaps scripta*) listed under both the *Queensland Nature Conservation Act* (QLD NCA) and the federal *EPBC Act* is recorded in the Didgeridoo Lagoon system (image ian@birdway.com.au).



Photo 52. Numerous reptile species, including several turtles, snakes, lizards and two species of crocodile including the vulnerable estuarine crocodile (QLD NCA) are known from the Didgeridoo Lagoon system.

The intention of identifying this ecological asset type and threats to it is to foster a greater appreciation of what sorts of features can constitute 'critical habitat' in riparian and other habitat remnants of Lower Burdekin floodplain landscapes, and how this knowledge can feed into landscape management decisions that support the conservation of wildlife. A non-exhaustive list of critical habitat features known to be significant on the floodplain and their associated values and management implications are presented in Table 8.

Some of the main implications of management issues surrounding critical habitat include:

- Fire regime – the impact of burning regimes and exotic grass fuel loads on vegetation condition has been widely covered elsewhere in this report. It is important to recognise that uncontrolled burns, particularly hot fires, also impact a range of critical habitat features, including tree hollows, woody debris and shed tree bark.
- Cultural practices – some of the practices that lead to a loss of critical habitat come, not from required production activities, but from held cultural values including an attraction to parkland clearing, 'cleaning up the farm', and removing problem trees. Greater educational extension to landholders on the value of critical habitat features and the wildlife they support could assist in changing some of these practices.

- Habitat rehabilitation beyond overstorey trees – in recent decades the concept of habitat rehabilitation has generally become synonymous with tree planting, particularly overstorey trees. Greater recognition of the importance of critical habitats should lead to the inclusion of a broader range of activities under habitat rehabilitation, including revegetation of components besides overstorey (for instance, mid storey and groundcovers) and establishing physical habitats such as logs, woody debris, and nesting hollows/boxes.
- Recognising regional landscape ecology – a landholder's perspective on the importance of habitat features or their management needs is often constrained to their own property boundaries. Awareness of the broader landscape ecology can inform better management by promoting recognition of the regional importance of site features. For instance, contributions of tree stands to functional wildlife corridors and/or regional uniqueness/importance of habitat features on a property.

System specifics

Where discussion relates to values, management issues or nominated works listed in Appendix 1 or mapped in Appendix 2, the designated (V, M or W) number is referenced.

Examining Table 8 (below), all listed critical habitat features other than 'closed rainforest' are identified to be of relevance to biodiversity conservation management within the Didgeridoo Lagoon system. Even the closed rainforest critical habitat feature has analogues in the denser fire-sensitive riparian vegetation communities of the lower system, and in the more complex remnant riparian vegetation nodes of the middle system. The key management needs for these features have mostly been covered in preceding sections of this SMP, particularly sections addressing:

- reinstatement of seasonal hydrology (see *Altered hydrology* section);
- reducing impacts of aquatic and woody weeds (see *Aquatic weeds* and *woody weeds* sections)
- addressing physical and poor reach condition fish passage barriers (see *Fish passage barriers* section);
- improving the extent, condition, and structural diversity of riparian and adjoining frontage vegetation (see *Lack of riparian vegetation*, *Fire regime* and *Grazing regime* sections); and
- addressing the causes of high fire fuel loads and associated hot fire regime impacts (see *Fire regime* and *Grazing regime* sections).



Photo 53. Location of the Didgeridoo Lagoon system within the broader remnant vegetation landscape of the Lower Burdekin floodplain.

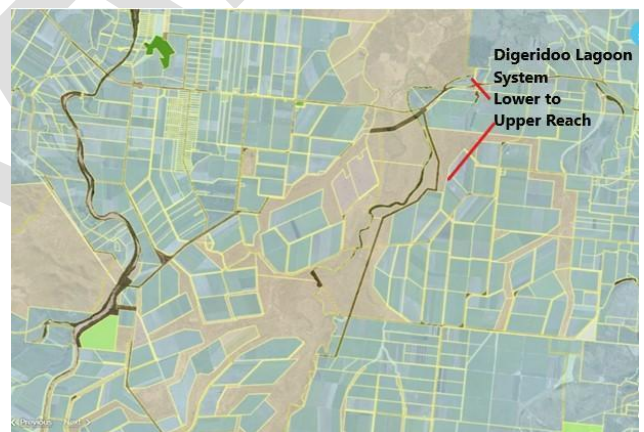


Photo 54. The land tenure context of the Didgeridoo Lagoon system, illustrating its overlap with a network of retained state land corridors within the BHWSS. These link from the Houghton River in the west across the floodplain to the east.

The landscape ecology context of the site is a biodiversity conservation management planning consideration that needs further development. The health of wetland systems within the catchment of the Cape Bowling Green Bay Ramsar wetland are important because they contribute to the wellbeing of this internationally-important wetland, which acts as a biophysically-connected, receiving environment at the bottom of the floodplain drainage system (see *Background* section). Biophysical connections at a local catchment and site scale also need to inform system management planning to serve 'critical habitat' and biodiversity conservation outcomes. Examining the location of the Didgeridoo Lagoon system within the broader remnant vegetation landscape of the Lower Burdekin floodplain (Photo 53, 54) reveals some important contextual landscape features:

1. The Didgeridoo Lagoon system and retained frontage vegetation areas provide a habitat corridor between extensive areas of retained floodplain woodland within the BHWSS in the south, and with an extensive areas of core coastal remnant vegetation associated with the Jerona pastoral property in the north.
2. The southern upper catchment portion of the Didgeridoo Lagoon system is located within a regionally-connected floodplain scale remnant habitat network.

During the development of the BHWSS, thousands of hectares of remnant floodplain habitat were set aside nominally for nature conservation purposes. A significant part of the Didgeridoo Lagoon system's upper catchment is comprised of this reserved area. Despite being 'reserved', this area has never been bought under any formal nature conservation tenure or management arrangements. Although having very high nature conservation values, the area's condition is subject to longer term decline due to a lack of effective, fire, woody weed, and grazing management (M4). As noted earlier, wallaby populations within the reserved area and wildfire risks to adjoining cane farms also serve to create management conflict with adjoining land users. In the absence of visible management, the area also suffers from inappropriate management practices such as waste dumping, vegetation clearing and hot fire regime burns. Addressing the biodiversity conservation management needs of this area is beyond the scope of this individual SMP, though the strategic merits of having a floodplain-scale system management plan would serve the outcomes of the Didgeridoo Lagoon system and other SMPs, like Collinson's Lagoon. This integrated approach and associated outcomes would serve downstream receiving environments, including the Ramsar wetland. This is explored further in the *Innovative Management* section.



Photo 55. Land tenure of the lower Didgeridoo Lagoon system including blue=freehold, green=reserve, brown=leasehold, clear = road reserve or Crown watercourse.



Photo 56. The land tenure context (left) of a remnant habitat landscape (above) can help define critical habitat conservation opportunities. State land infers a public interest, and this includes biodiversity conservation outcomes.

One of the constraints encountered when attempting to serve critical habitat and biodiversity conservation outcomes across wetland system catchments and regional landscapes is land tenure. Where land is privately owned freehold, the support of landholders is essential to deliver conservation outcomes. Where landholders are not supportive of such initiatives, biodiversity conservation will depend on their attitudes, knowledge, development aspirations, and the constraints of a generally poorly-enforced government regulatory framework. A desirable system-scale biodiversity conservation outcome for the Didgeridoo Lagoon system would be for the collaborative support of landholders to manage and improve the condition of remnant habitat on the predominantly freehold land that constitutes the middle and lower lagoon system. These collaborative efforts would retain and consolidate a regional wildlife habitat corridor between the retained floodplain habitat areas of the BHWSS in the south, and retained coastal habitat areas of the Jerona pastoral property in the north (Photo 53, 54, 55, 56). In the pursuit of such a catchment-scale outcome, the land tenure context of a remnant habitat landscape can help define critical habitat conservation opportunities. State land infers a public interest, and this includes biodiversity conservation outcomes. With management stakeholder support, state land areas can provide valuable nuclei and/or corridor linkages as sites where management approaches can be demonstrated and broader initiatives on private land can be engendered.

Recommendations

Note: where recommendations correspond to nominated works (W) in Appendix 1 and 2, the listed works number is referenced. As identified above, most identified critical habitat management needs have been addressed by recommendations in preceding plan sections. Some specific critical habitat recommendations are presented below.

1. Engage system management stakeholders in the pursuit and implementation of recommendations in the *Altered hydrology*, *Aquatic weeds*, *Fish passage barriers*, *Woody weeds*, *Fire regime* and *Grazing regime* sections of the SMP. These are the primary pathways towards improving critical habitat conservation outcomes within the Didgeridoo Lagoon system.
2. Extension officers use the release of this SMP as a basis for engagement with landholders and other management stakeholders of the Didgeridoo Lagoon system to determine support for delivering collaborative management efforts. These efforts serve system-scale biodiversity conservation outcomes around the central concept of a regional wetland/wildlife habitat corridor linkage from retained floodplain habitat areas of the BHWSS in the south, and retained coastal habitat areas of the Jerona pastoral property in the north.
3. Engage state land management stakeholders, including adjoining landholders, BSC, and state government agencies to explore options for developing formal Vegetation Regeneration and Public Access and Use Options Management Plans for the Crown reserve (W7) and road reserve (W8) adjoining the highway lagoon. Also, for the state land/Crown watercourse on the lagoon reach upstream of the highway lagoon as part of serving a system-scale biodiversity conservation outcome.
4. NQ Dry Tropics act as a lead organisation in the engagement of Sunwater; state government agencies, including DES; BSC; Gudjuda Reference Group, and other relevant community stakeholders. The objective is developing a supported and funded proposal to establish formal nature conservation management arrangements for the retained remnant floodplain habitat corridor and node network within the BHWSS. This includes appropriate tenure designation, weeds, feral and fire management programs, and public access infrastructure and management.

Table 9. Examples of 'critical habitat' within the Lower Burdekin floodplain and implications for management

Critical habitat	Why important	Wildlife groups that benefit	Management implications/opportunities
Tree hollows	Provide nesting and nursery sites that are protected from the elements and predators.	Arboreal mammals (gliders, possums), microbats, hollow nesting birds.	Fire management to avoid uncontrolled burning loss of old trees. Avoidance of old tree clearing. Establishing artificial nest boxes can benefit dependent species.
Fringing 'riparian' communities	Has greater structural complexity, diversity, and associated feeding (fruit, nectar) and nesting resources than surrounding woodlands (or agricultural landscapes).	Migratory passerines, (songbirds), honey eaters, parrots, raptors.	Rehabilitation of riparian forests in agricultural landscapes will support populations of dependent species reduced during development habitat losses.
Riparian – Ecotone margins	Greater diversity of habitat and food resources available, as includes both the riparian and the adjoining woodland vegetation.	Arboreal mammals (gliders, possums), nectivorous birds, raptors.	Clearing to margin of riparian zones often results in loss of ecotone woodland component in retained vegetation. An ecotone is essentially the boundary between different vegetation assemblages or ecosystem types. Natural recruitment is possible where there are remnant trees. Best opportunities are in broader development set-back corridors.
Mid/understorey trees	Provides a broader range of food resources (wattle gum, broad leaf tea tree nectar, associated insects) than what is provided by overstorey canopy trees alone.	Arboreal mammals (gliders, possums), nectivorous birds, insectivorous bats.	Need to challenge commonly desired parkland clearing aesthetic of 'cleaning up' 'useless scrub' trees, often mid-storey vegetation (like broad leaf tea tree). Need to include in targeted revegetation species.
Aquatic plants of seasonal water level zone	Include important food and nesting resources for waterfowl, prey sheltering, egg laying, cover habitat for fish and aestivation habitat for turtles	Waterfowl, waterbirds, fish, aquatic reptiles, crustaceans, aquatic insects	Stream and lagoon draw down now more limited, or no longer occurs due to modified hydrology/aseasonal flows. Water management to reduce, reuse or divert aseasonal flows, or manipulate water levels.
Bare lagoon banks	Provides preferred predator safe roosting and resting areas for waterfowl.	Flock-forming waterfowl, like whistling ducks	Could trial use of intense grazing, burning or spraying to create.
Remnant vegetation corridors/landscape linkages	Provides opportunities for disturbance-sensitive wildlife to move between remnant habitat areas in developed landscapes to access food resources, find mates and distribute young to new areas.	Arboreal mammals (gliders, possums), macropods, dasyurids (quolls), reptiles.	The value of small vegetation remnants, even individual trees, can be important in providing this critical habitat and needs to be communicated to avoid incremental loss. Regional wildlife corridor transect most systems (Appendix 1 values).
Exposed sand beds	Provide nesting sites for aquatic reptiles.	Turtles and freshwater crocodiles.	Now a limited resource due to lack of water level drawdown. Control of grass weeds could be used to create.
Closed 'rainforest'	Provides roosting sites protected from exposure to elements and predators and offers food resources for frugivorous (fruit-eating) fauna.	Owls, flying foxes, pigeons, frogs.	Fire sensitive. Existing closed forest reaches/sites warrant protection. Capacity to create with riparian revegetation should be supported at suited sites.
Low ground-covering bushes	Provides shelter from predators and refuge/resting areas for small mammals in open woodland habitats.	Small macropods, like spectacled hare wallabies, rufous bettongs, dasyurids (quolls), ground-nesting birds.	Impacted by pasture improvement, slashing, intensive grazing and culture of 'parkland clearing', 'cleaning up scrub' as desired aesthetic. Fauna survey of sites retaining this critical habitat could demonstrate its value. Also, useful revegetation target.
Logs/woody debris	Provides safe refuges for numerous species of small-to-medium-sized vertebrates.	Reptiles (snakes, lizards), dasyurids (quolls), and invertebrates.	Lost to frequent burning and 'cleaning up' of habitat remnants. Comparison fauna surveys of sites could demonstrate its value. Inclusion in rehabilitation objectives valuable.
Rank grasses	Provides grass seed food sources for granivorous birds.	Finches, pigeons.	Critical habitat supported by grazing spelling/timing.

Shed tree bark	Important refugial habitat for arboreal reptiles (like geckos) and numerous invertebrates, insects, spiders, etc.	Geckos, microbats, invertebrates.	Lost to frequent/hot burning. Target for fire regime management.
Flow-connected coastal drainage depressions	Provides migratory pathway for diadromous fish to move between estuarine and freshwater habitats of the catchment.	Diadromous fish, like barramundi, mangrove jack, mullet, milkfish.	Impacted by aseasonal flows and cumbungi/anoxic reach establishment. Key system-scale rehabilitation target for most catchments.

Climate stress

Types and impacts

The most recent and 6th Intergovernmental Panel on Climate Change report provides compelling evidence that the greater than 1°C global heating the planet has experienced since 1890 is unequivocally the result of human activity, and is proceeding at a rate that is unprecedented over millennia (IPCC, 2022). In Australia, CSIRO modelling examined the future impact of global heating on regional climate patterns. These outputs can be interpreted at a local government boundary scale: [Future Climate Dashboard | LongPaddock | Queensland Government](#).

Based on the globe's current greenhouse gas emissions trajectory, predicted impacts of most relevance to wetland system management include:

- Temperatures in Australia will increase by between 2.8 and 5.1°C by 2090 compared to 1986-2005; heatwaves will become more intense, more frequent and of longer duration; and the number of days of severe fire danger are likely to increase in southern and eastern Australia.
- Rainfall amounts are expected to decrease over southern Australia, accompanied by more frequent and more severe droughts. While rainfall trends for northern Australia are more uncertain, however greater variability and more frequent, intense, extreme rainfall events are projected.
- Fewer, but more, severe tropical cyclones are projected.
- Global sea levels are expected to increase by 45cm to 82cm by 2090, though these levels may be higher if a tipping point is reached which commits one or more land-based ice sheets to irreversible melting.
- Extreme high sea-level events will occur more frequently, increasing the risks of saltwater intrusion, flooding, and erosion in coastal areas.
- In line with global trends, seawaters around Australia are becoming more acidic (>30% since pre-industrial), as the oceans absorb much of the CO₂ released by human activities.

(NCCARF 2019) [Climate change and sea-level rise in the Australian region | CoastAdapt](#).

These projected changes – many of which have been increasingly realised over the past decade – have severe consequences for nature and human society, including agricultural production systems. For wetland system management, the following issues are nominated for consideration in the Lower Burdekin region:

Temperature and water quality

Risk – Higher water temperatures, increased rates instream bacterial decomposition of organic matter resulting in, lower dissolved oxygen (DO) levels; more widespread and frequent summer fish kills; and water quality fish passage barriers.

SMP focus – Greater extent riparian vegetation shading of waterway margins; reduced weed infestation/organic loads into waterway; and role for supplemented /pumped flows to increase DO during critical periods.

Catchment water quality

Risk – Higher intensity rainfall (potentially coming off the back of extended/more extreme dry seasons); higher rates of runoff (potentially in drought stressed catchments); increased soil erosion and contaminant load carrying capacity; and loads exported more directly to receiving stream and wetland systems.

SMP focus – Improvement in contributing catchment condition, particularly vegetation condition; soil erosion pressure points; and increased focus of designed drainage modulus controls (litres/hectares/second) in constructed farm drainage networks, including re-establishing/improving runoff detention function (for example, constructed basins, vegetated drainage lines).

Flood resilience

Risk – Higher intensity rainfall; higher rates of runoff; greater flood peaks; greater frequency of channel break out flows (and associated erosion) across agricultural floodplains; and potential for erosion and undermining/undercutting of stream banks.

SMP focus – Improving condition (contiguity and width) of riparian vegetation corridors to shade-out channel blocking weed growth; secure stream channel stability and baffle the velocity of channel break out flows; retain and re-establish floodplain overstorey vegetation to baffle overland flow velocities; manage floating aquatic weed and aquatic grass abundance to prevent channel blocking/infrastructure-destroying debris dams; retain natural wetland flow detention areas; and re-establish runoff flow detention within contributing catchment areas.

Fire regime

Risk – Extended dry seasons; higher air temperatures; lower soil moisture conditions; reduced cool burn season; more extreme, hotter fire outcomes, with greater consequent death of mature trees and impacts to fire-sensitive vegetation; degradation of vegetation structure; and loss of habitat values.

SMP focus – Reducing fire fuel loads in understorey of valuable riparian and wetland/floodplain habitat remnants by promoting canopy closure and/or controlled grazing; promoting cultural change away from farm 'clean up' burning; promoting controlled, cool burning regimes for remnant habitat landholders; incorporating fire breaks in property/farm layouts; and engaging fire wardens in ecological fire management principles.

Fauna refugia

Risk – Drier climate; failed wet seasons; higher air temperatures; reduced soil moisture; poor plant fruiting/flowering, which places fauna species, like bats, birds and tree-dwelling mammals, under behavioural, physiological and/or nutritional stress, including lack of shelter, overheating, and lack of food.

SMP focus – Retention, protection (from fire, weeds, clearing, stock pressure) and rehabilitation of dense, structurally complex, floristically diverse, or highly productive habitat remnants. This includes riparian and floodplain forests adjoining streams, lagoons or wetland basins, and habitat nodes including fire refuges within variegated/developed landscapes.

Invasive species

Risk – Terrestrial ecosystems include native vegetation stressed in terms of growth vigour and/or attained structure by a climate trending towards a bio-climatic envelope outside its adaptive range, namely, too hot, dry, or wet. Other associated stressors, like larger cyclonic, flood, and extreme fire disturbance, present openings for opportunistic weeds or novel insect pests to gain a dominant niche. In aquatic ecosystems, the risk encompasses aquatic habitat quality being degraded outside of optimal conditions for native aquatic species. This includes the water being too hot, having low dissolved oxygen, and/or turbidity, which present advantageous conditions for opportunistic and generalist feral fish species, other novel aquatic pest species, or pathogens to gain a dominant niche. Higher temperatures, failed wets (no flushing flow), and elevated water nutrient status (no flushing dilution) support a longer and more vigorous growing season for aquatic weeds.

SMP focus – Management investment in the condition of terrestrial and aquatic ecosystems to increase system resilience by reducing pest and weed species abundance and maintaining active vigilance regarding identification and proactive control of 'sleepers', or new pest species, within the system.

Revegetation species providence

Risk – Seed or seedlings produced from local providence native plant stock may become stressed during their growth, in terms of their vigour, by climate trending toward a bio-climatic envelope outside its adaptive range, namely, too hot, dry or wet. Stress can also be caused by disturbances like larger cyclonic, flood, drought, and extreme fire events occurring at a frequency, or for a duration, greater than the species has evolutionarily developed adaptive capacity.

SMP focus – Encourage vigilant observation by landholders and NRM practitioners working within the region of the vigour and potential die back of species comprising local vegetation communities across age classes. This includes areas that have undergone revegetation. Trial and compare the growth success of locally-occurring species from seed stock providences from outside (north, inland) the local latitudinal and longitudinal range.

Landward migration of coastal wetland mosaic

Risk – Sea level rise will increase the landward reach of tidal incursion within coastal wetlands. If protective barriers are created or increased to prevent this occurring, existing brackish environments below barriers will become marine, and important brackish habitats will be lost from the coastal wetland mosaic, potentially in conjunction with a reduction in fish passage connectivity. The ultimate transgression of such barriers could also create highly disturbed environments where freshwater vegetation dies in response to rapid salinity changes.

SMP focus – Identify opportunities, including incentives, to encourage the unimpeded incursion of tidal influence into the lower end of coastal wetland systems. This could include by supporting new bund development within upper reaches of coastal wetland basins in exchange for controlled breaching of existing lower reach bunds. This would allow for the staggered incursion of sea level rise into existing lower freshwater reaches of coastal wetlands, creating a brackish habitat, and facilitating an overall landward migration of the coastal wetland habitat mosaic.

Mitigation as well as adaptation

While the management issues identified above include various proposals to increase wetland system resilience to adapt to emerging climate stress, it is also important to consider the roles that wetland systems can play in mitigating climate change. Principal amongst these is carbon sequestration and storage. Woody wetland vegetation, including that associated with riparian zones and/or floodplains and organic material in wetland soils, represent stores of carbon. Adding to the biomass of either through planting or regeneration of woody vegetation, or the deposition and long-term burial of organic material in wetland soils, represents carbon sequestration. Conversely, wetland environments that promote organic decomposition and associated methane

production contribute greenhouse gas (GHG) emissions to the atmosphere. Reducing GHG emissions, preserving existing stores of carbon, and sequestering additional carbon help to mitigate global warming. This knowledge needs to inform all natural resource management actions in a world facing climate crisis.

System specifics

Considering the landscape, land use and condition context of the Didgeridoo Lagoon system, seven of the nine issues described above are relevant for system management planning that intends to build climate stress resilience. These issues include:

- temperature and water quality;
- catchment water quality;
- flood resilience;
- fire regime;
- fauna refugia;
- invasive species; and
- mitigation versus adaptation.

Summarising the identified SMP focal points discussed for these issues above, a Didgeridoo Lagoon system that is managed to have resilience in the face of climate stress would have the following features:

- Ability to withstand large, floodplain-inundating flows driven by channel breakouts of the Burdekin and Haughton River and Barratta Creek, without significant damage to channel integrity or erosion of adjoining floodplain areas. Flow-baffling bands of mature riparian and floodplain vegetation along the Didgeridoo Lagoon system's bank margins, and adjoining frontages, would help to secure channel bank integrity against erosive forces. Further, open channel flow capacity would be maintained by shaded weed-choke exclusion, and breakout flow velocities reduced. Pressure points for potential channel erosion between the highway and the downstream system would be rock armoured. Any available floodplain land, including road corridors within the BHWSS, would have revegetated floodplain vegetation established across overland flow paths to help baffle overland flow velocities.
- Lagoon margins and intervening creek channels shaded by developed riparian vegetation canopies. This shade would maintain cooler water temperatures, particularly during hot summer months, and exclude aquatic grasses from bank margins. This would help to reduce organic loading and water dissolved oxygen level degradation and help maintain flow capacity.
- A seasonal hydrological regime that allows for dry season lagoon water level drawdown, and intervening channel drying that promotes an open channel and wetland basin condition prior to the annual wet season. During this time, water flows and fish passage are not impeded; dried organic material is exported to depositional environments; and water quality is not degraded by aquatic floating and grass weed chokes, including associated organic loading and biological oxygen demand (BOD).
- Specific design features within the BHWSS-constructed drainage network in its contributing catchment area to effectively cope with extreme rainfall events in a way that controls rates of runoff. This avoids erosion to channels and adjoining farmland and limits the transport of mobilised contaminant loads directly to receiving wetland systems. Such designs would incorporate bank stabilising and high flow-baffling riparian vegetation; in-channel vegetation; and constructed features, like bund walls and controlled flow outlets, that enable scheme sub catchment areas to function as broad detention basins. These basins stage runoff to reduce high flood peaks at the bottom of the system, capture contaminant loads in first flush events, and lower the overall slope and discharge rate of the drainage network.
- Proactive controlled burning and fire regime management. Fire fuel loads in or adjoining areas of remnant vegetation, including BHWSS remnant vegetation areas, would be actively managed by slashing, grazing and/or controlled burning. Proactive management to reduce hot wildfire risks associated with extended dry season and elevated temperatures would include promoting riparian vegetation canopy cover and closure along the main lagoon and channel margins to reduce grass understorey. Also, implementing controlled grazing and/or cool burning of fire fuel loads in lagoon frontage areas, riparian zones and undeveloped land adjoining production areas that are dominated by an exotic pasture (guinea , para grass) understorey; and maintaining functional fire breaks between extensive areas of unmanaged fire-prone remnant vegetation and vulnerable assets.
- Regional wildlife habitat corridors that link to adjoining remnant habitat areas and contain recognised wildlife refuge habitats. These have been consolidated through targeted regenerative activities, like revegetation, controlled grazing, weed, fire control, and are actively protected from threats. For example, riparian vegetation areas that incorporate denser refugial habitat nodes and better condition

floodplain vegetation stands within the BHWSS that are poorly represented in the post development landscape.

- Controlled populations of weeds and feral invasive species through sustained management commitments and vigilance to identify and eradicate infestation source areas, novel, or sleeper species, and to maintain the resilience of native terrestrial and aquatic ecosystems. For example, exotic pasture grasses managed to prevent hot wildfire risks, aquatic floating and grass weeds kept below infestation levels.

A Didgeridoo Lagoon system managed to help mitigate global warming would:

- Regenerate or revegetate all land not being used for pastoral or agricultural purposes. The aim is to support maximum standing woody biomass structure for the regional ecosystem type concerned, which could be a potentially greater biomass in the case of intentional agro-forestry land use.
- Have a management regime for hydrological and associated vegetation, like aquatic weeds, that promotes long-term burial of organic material in depositional environments, for example, seasonal drying of bank and lagoon margins and generation of biochar by controlled burning. This regime also reduces the opportunities for creating methane emissions associated with decomposing organic material in depositional environments, such as weed chokes and mats in wet channels loading the water column with organic material.

Recommendations

1. Engage all management stakeholders in:
 - a. understanding projected climate conditions over forthcoming decades and their likely expression on Lower Burdekin floodplain landscapes, including within wetland and production systems;
 - b. identifying local site and individual, along with regional and collaborative, responses and management initiatives that can increase the resilience of natural resource assets of the floodplain to projected climate stress; and
 - c. identifying local site and individual, along with regional and collaborative, responses and management initiatives that can increase the global warming mitigation role of floodplain natural resource management, particularly regarding carbon sequestration and minimising GHG emissions.

> Innovative management

Why we need innovation

Environmental management is an imperfect science that is best progressed by an adaptive approach. This adjustive undertaking allows different methods to be trialled and successes pursued, while mistakes are used as opportunities for learning and can be avoided in future efforts. There has been major improvement in the ecological condition of Lower Burdekin wetland systems due to management investments made over the past two decades. However, as identified through this plan, there are still outstanding environmental management issues confronting most wetland systems and some condition trends remain negative. To achieve further improvements in the environmental condition of wetland systems, there needs to be an ongoing commitment to improving management capacity and outcomes, while recognising the resource constraints for the tasks at hand. Crucially, to take the next step and deliver a new level of improved wetland system management outcomes requires things to be done differently. In some instances, this might involve doing existing approaches better. In other cases, it may call for investigating and applying innovative approaches – essentially drawing on new advanced and original methods.

Much of the environmental management gains achieved for Lower Burdekin wetlands over the past two decades can be attributed to innovation. The use of weed harvesters and excavators to remove neglected aquatic weed infestations; developing a cost-shared weed control program instituted through RMAs; and large reach-scale riparian revegetation outcomes, are all initiatives that Burdekin wetland management stakeholders should be proud of. At the time, these initiatives were truly innovative as it was the first time they had been applied in the seasonal dry tropics, or – in the case of RMAs – in Australia.

During the development of the initial SMP for Sheep Station Creek, 15 other innovative management methods, tools, and approaches were proposed. These are listed below, but are described in full in the Sheep Station Creek SMP (Econcern 2021). Another innovative management method (point 16) that was trialled and developed by NQ Dry Tropics Wetland Team Leader Scott Fry in recent years has also been added to the list. Seven additional innovative management approaches (point 17-23) were also proposed during the development of the Woodhouse Lagoon, Ironbark Creek – Healey's Lagoon and Horseshoe Lagoon SMPs (Econcern 2022a, 2022b, 2022c). The innovative management methods are:

1. Excavated channel weed control via riparian shade tree planting.
2. Alternate channel weed control methods utilising small in-channel machinery.
3. Pumped environmental 'freshening' flow during wet season critical water quality period.
4. Weed control via effective biomass removal and economically viable soil ameliorant product development.
5. Use of mobile herd to deliver controlled grazing outcomes through catchment.
6. Alternate distributary channel fish passage bypass route.
7. Establishing riparian forest and native water lily shading to reduce submerged plant growth.
8. Catchment line of control for floating aquatic weeds.
9. Establishing farm drainage line revegetation/detention function.
10. Use of monitoring drones.
11. Conducting cool burns in cane land habitat remnants.
12. Direct seeding vegetation regeneration methods for exotic grass-infested riparian zones.
13. Instream physical habitat interventions.
14. Fenceless grazing systems.
15. Alternatives to chemical weed control.
16. Use of drones for aquatic weed spraying.
17. Waiving overland flow/water course access/licencing fees for aseasonal flows originating from farm irrigation and/or BHWSS tailwater flows.
18. Intervention and re-use of farm/scheme area irrigation tailwater for off-stream pasture production.
19. Establishing a suitable water quality fish passage preferential flow path through an aquatic grass weed-dominated drainage depression via riparian shading.
20. Alienation of irrigation supply flows from naturally seasonal wetlands.
21. Formation of dedicated catchment management groups to support enhanced aquatic weed and other environmental management of floodplain wetland systems.
22. Use of water management and/or bypass infrastructure to reinstate a seasonal hydrological regime to the wetland system.
23. Using the state land tenure context of the landscape for developing a regionally-significant, protective management, biodiversity conservation planning outcome.

System specifics

Given the overlap in land and water use and condition context of the Didgeridoo Lagoon system with other wetland systems that have SMPs, many of the previously identified innovative management approaches are applicable. Fourteen of the listed 21 points (1, 5, 7, 8, 9, 10, 11, 15, 16, 17, 19 and 23) are incorporated in some form in management recommendations in this SMP, and the complete set have some relevance.

Three management recommendations in this SMP are considered innovative proposals in their scope, but have been previously proposed in previous SMPs in concept. These are:

- (1) The catchment-based line of control 'quasi-eradication' approach nominated for targeted floating aquatic weed species (water hyacinth, water lettuce) within the lagoon system (*Aquatic weeds* section) has been proposed in other developed SMPs. The current low levels of infestation of these floating weed species within the system, and historically within the upper system, and its small size and relative accessibility could make this weed control approach viable, which would not be considered in larger system. The proposed use of drones to identify and monitor control targets and outcomes, and the possible use of drone-based spraying for less accessible target areas, all provide extra innovative elements.
- (2) The proposal to engage with grazing stock owners within the system and broader Barratta Creek catchment to identify opportunities for establishing a 'mobile herd' habitat grazing capacity (see *Grazing regime* section) is a concept originally developed for the riparian areas of Sheep Station Creek (Econcern 2021). The uniqueness of the concept in the context of the Didgeridoo Lagoon system is that the entire system (particularly upstream of the highway) has contiguous frontage areas suitable for grazing, which would enable stock to be moved through sections of the system without transport. This entire area requires grazing-based management of fire fuel loads. It also forms the regional habitat corridor linkage nominated as a focus for collaborative landholder management engagement. Managing controlled grazing through the system could provide a tangible focus for collaborative landholder engagement, and for participatory, adaptive learning in the management of remnant vegetation grazing and fire regime for biodiversity conservation outcomes.
- (3) Developing a supported and funded proposal to establish a formal nature conservation management arrangements for the retained remnant floodplain habitat corridor and node network within the BHWSS (*Critical habitat* section) builds on the idea of using the landscape's state land tenure context for biodiversity conservation planning, as proposed in the Horseshoe Lagoon SMP. The innovation is in the scope, including geographical scale of the proposal, which is discussed further below.

During the development of the BHWSS, some 10,000ha of floodplain remnant vegetation was set aside nominally for nature conservation purposes and to fulfil management recommendations made in the original CSIRO ecological study that preceded the development of the BRIA (Flemming *et al* 1981). Habitat retention and corridor planning was innovative for the time in meeting regional landscape planning principles and being based on comprehensive fauna surveys (Tait 1990, ACTFR 1994).

While the retention of any remnant habitat on alluvial landforms with development potential is rare, the floodplain-scale retained habitat within the BHWSS is unique within Australia. No other irrigation scheme in Australia has such an extensive, diverse, connected network of intentionally retained floodplain and wetland habitats. State assessments recognise the area to be of regional biodiversity significance; contain 'of concern' regional ecosystems; have very high condition, high ecosystem diversity, and high ecosystem value; and to represent medium habitat value for endangered, vulnerable or near threatened (EVNT) wildlife species. This study would nominate much higher than regional values, recognising the total cumulative size of retained areas; their connectivity via dedicated corridor retention, both laterally across the floodplain (from the Haughton to Burdekin Rivers) and longitudinally along drainage lines (from inland rangeland areas to the coast); observations of EVNT taxa not recognised by state assessments; and the uniqueness and natural heritage of this system of planned habitat retention within a government-developed irrigation area. Part of this site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Despite the planning and management history and values of the BHWSS-retained habitat areas, the area remains poorly managed and subject to ongoing degradation from pervasive threats of weeds, fire, feral animals, and inappropriate use. In terms of system management planning outcomes, implementation of nature conservation-based management of the BHWSS-retained habitat areas would deliver a Lower Burdekin floodplain-scale outcome, with concomitant benefits for biophysically-linked environments at the bottom of the system, including the Cape Bowling Green Bay Ramsar wetland.

Recommendations

1. As per recommendations in the *Aquatic weeds* section, engage aquatic weed management stakeholders in trialling a catchment-based line of control 'quasi-eradication' approach for targeted floating aquatic weed species (water hyacinth, water lettuce) within the lagoon system. This trial would be planned to follow a high flow flushing event and would endeavour to eradicate floating weed refuges/reinfestation sources for targeted species, working from the top of the catchment downstream, with two or more closely repeated control events. Given the accessible size of the system, drones could be employed for identifying post-flood flow weed refuges and for monitoring eradication effectiveness, including timing and sources of reinfestation if it occurs. If access and/or a favourable cost benefit analysis supports it, small weed refuge eradication may also present a viable target for drone-based spraying.
2. As per recommendations in the *Fire regime*, *Grazing regime* and *Critical habitat* sections, engage with grazing stock owners within the system and broader Barratta Creek catchment. The aim is to identify opportunities for establishing a 'mobile herd' habitat grazing capacity and to provide expertise to monitor habitat condition indicators at nominated trial and demonstration sites. This approach forms part of an

integrated proposal to managed hot fire risk, enable cool controlled burns, and develop a collaboratively-managed catchment-scale wetland/wildlife corridor linking BHWSS remnant habitat areas in the south with Jerona pastoral property remnant habitat areas in the north.

3. As per recommendations in the *Critical habitat* section, engage Sunwater, state government agencies including DES, BSC, Gudjuda Reference Group, and other relevant community stakeholders. The aim is to develop a supported and funded proposal to establish formal nature conservation management arrangements for the retained remnant floodplain habitat corridor and node network within the BHWSS, including appropriate tenure designation; weeds, feral animals and fire management programs; and public access infrastructure and management.

> Bibliography

ACTFR. 1994a. Burdekin River Irrigation Area Flora and Fauna Survey. Report No. 94/10 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

ANZECC & ARMCANZ 2000, Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

BDTNRM (2005) Burdekin Dry Tropics Natural Resource Management Plan (2005-2010). Produced by the Burdekin Dry Tropics Board for the Burdekin Dry Tropics Community, Townsville.

Burdekin Dry Tropics Natural resource Management Plan 2016-2026
https://drive.google.com/file/d/0B2eYGb5_I-adVXJVOVN2bWcyOFE/view

BBIFMAC (1999) A Community based Natural Resource Management Strategy for the Burdekin – Bowen Floodplain Subregion of the Burdekin Dry Tropics prepared for the Burdekin – Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC).

BSC (2020). Burdekin Shire Council Biosecurity Plan 2020 – 2025. Produced by the Burdekin Shire Council, Ayr.

BSC (2020b). Burdekin Shire Council Aquatic Weed Control Plan 2020 – 2025. Produced by the Burdekin Shire Council, Ayr.

Brizga, S.O., Kapitzke, R., Butler, B., Cappo, M., Connolly, N., Lait, R., Pearson, R.J., Pusey, B., Smithers, S., & Werren, G.L. (2006). Burdekin Basin Draft WRP. Environmental Assessment Report. Phase 1 – Current Environmental Condition. Department of Natural Resources and Mines, Queensland.

Blackman J.G., (1978) The Swamps - A Habitat in Motion. In Exploration North - Australia's wildlife from desert to reef. H.J. Lavery (ed). Richmond Hill Press 1978.

Blackman J.G., Perry, T.W., Ford, G.I., Craven, S.A., Gardiner S.J. and De Lai R.J. (1999). Characteristics of Important Wetlands In Queensland. Environment Protection Agency, Queensland.

Burdekin Region Water Quality Improvement Plan 2016
https://drive.google.com/file/d/0B2eYGb5_I-adNGY0RERCWFB2aDQ/view

Burrows, D., Veitch, V., Loong, D., Perna, C., and Butler, B., (2006). Monitoring of the Health and Fish Passage Issues of Healey's Lagoon Following Removal of an Extensive Mat of Floating Aquatic Weeds. Report No. 06/11 June 2006 Prepared by Australian Centre for Tropical Freshwater Research James Cook University Townsville, Qld 4811

Burrows, D., Perna, C., Davis, A., and Knott, M., (2009). Examination of Fish Passage into Healey's Lagoon and Ironbark Creek, Haughton River Catchment, North Queensland. Report No. 09/09 February 2009 Prepared by Australian Centre for Tropical Freshwater Research James Cook University Townsville, Qld 4811

Carter, J., Tait, J.T.P., Kapitzke, R. and Corfield, J. (2007). Final Report Burdekin Dry Tropics NRM Region Fish Passage Study. 17 November 2007. Prepared by Alluvium Consulting for Burdekin Dry Tropics NRM.

Carter, J & Tait, J 2010, Freshwater Fishes of the Burdekin Dry Tropics, Townsville.

Christian, CS, Paterson, SJ, Perry, RA, Slayter, RO, Stewart, GA and Traves, DM 1953, 'Survey of the Townsville - Bowen Region, North Queensland, 1950', Land Research Series No. 2, CSIRO, Melbourne.

Connolly, N., Kahler, C, Mackay, S, Fry, S. and Cameron, R. 2012. Variations in wetland condition across Land Zones in the lower Burdekin. Aquatic weed distributions determined by underlying differences in water and salinity regimes. A report prepared for the NQ Dry Tropics NRM. Department of Environment and Heritage Protection, Queensland Government.

Coastal Ecosystem Management – Lower Burdekin Floodplain (GBRMPA 2013)
http://elibrary.gbrmpa.gov.au/jspui/bitstream/11017/2901/2/Case_study_water_planning_Burdekin.pdf

Davis, A.M., et al., (2013) Environmental impacts of irrigated sugarcane production: Herbicide run-off dynamics from farms and associated drainage systems. Agric. Ecosyst. Environ. (2011), doi:10.1016/j.agee.2011.06.019

Davis A.M. et al. (2014) Water Resource Development and High Value Coastal Wetlands on the Lower Burdekin Floodplain, Australia. In: Wolanski E. (eds) Estuaries of Australia in 2050 and beyond. Estuaries of the World. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7019-5_13

Davis, Aaron M., Pearson, Richard G., Brodie, Jon E. , and Butler, Barry (2017) [*Review and conceptual models of agricultural impacts and water quality in waterways of the Great Barrier Reef catchment area*](#). Marine and Freshwater Research, 68 (1). pp. 1-19.

DES (2021). Department Environment and Science, Queensland Government, [Regional ecosystems descriptions](#), licensed under [Creative Commons Attribution 4.0](#) sourced on 10 January 2021

DPI (1993). The Condition of River Catchments in Queensland. *A Broad Overview of Catchment Management Issues*. Queensland Department of Primary Industries Integrated Catchment Management 1993.

Draft Environmental Values and Water Quality Objectives for the Estuarine and Coastal areas of the Lower Burdekin region (Burdekin Dry Tropics NRM)

Fleming PM, Gunn RH, Reece AM, McAlpine JR (Eds.) (1981): Burdekin Project Ecological Study. CSIRO and Department of National Development and Energy. Australian Government Publishing Service, Canberra.

Freshwater wetlands of the Barratta Creek catchment management investment strategy. Report prepared by EConcern and TropWater for the Burdekin Dry Tropics NRM (Tait, J. and Veitch, V. 2007)
https://researchonline.jcu.edu.au/cgi/users/login?target=https%3A%2F%2Fresearchonline.jcu.edu.au%2F29261%2F1%2F29261_Tait_2007.pdf

Hooker, N 2010, Native Grasses for Revegetation in the Townsville Region, Coastal Dry Tropics Landcare Inc., Townsville.

Hunter HM, Eyles AG and Rayment GE (1996) Downstream Effects of Land Use. Queensland Department of Natural Resources.

Hunter, H.M., Hargraves, P.M. and Rayment, G.E. (1998) 'Pesticide Residues in Surface Waters of the Burdekin River Irrigation Area' Draft Report Department of Natural Resources, Resources Sciences Centre.

Hunter, H.M. (2012). Nutrients and herbicides in groundwater flows to the Great Barrier Reef lagoon: processes, fluxes and links to on-farm management. ISBN: 978-1-7423-0969. September, 2012

Intergovernmental Panel on Climate Change [IPCC]. (2022). *IPCC Sixth Assessment Report: Impacts, adaptation and vulnerability*. <https://www.ipcc.ch/report/ar6/wg2/>

Keating, B.A., Bauld, J., Hiller, J., Ellis, R., Weier, K.L., Sunners, F. and Connell, D. (1995) 'Leaching of Nutrients and Pesticides in Queensland Ground Waters,' in Hunter, H.M., Eyles, A.G. and Rayment, G.E. (eds) *Downstream Effects of Land Use*, Department of Natural Resources, Brisbane.

Loong, D., Butler, B., Burrows, B., Aaron Davis, A., and Faithful, J., (2005). Limnological Assessment and Benchmarking of Key Sentinel Wetlands in The Burdekin Catchment, North Queensland ACTFR Report NO. 05/09. Draft Report to the Burdekin Dry Tropics Board as part of the National Action Plan for Salinity and Water Quality for the Burdekin Catchment: Priority Action Project No. 4. Australian Centre for Tropical Freshwater Research James Cook University, Townsville, Qld 4811

Loong, D., Butler, B., and Burrows, D. (2006) Water Quality And Aquatic Health Assessment Of Healey's Lagoon, Haughton River Catchment, North Queensland – Appendix To ACTFR Report No. 06/11 December 2005 Prepared by Australian Centre for Tropical Freshwater Research James Cook University, Townsville, Qld. 4811

Perna, C. 2003. Fish Habitat Assessment and Rehabilitation in the Burdekin Delta Distributary Streams. Report No. 03/22 Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Perna, C., 2004. Impacts of Agriculture and Restoration of the Habitat Values, Water Quality and Fish Assemblages of a Tropical Floodplain. Masters of Science Thesis, James Cook University, Townsville, Australia, 144pp.

Perna, C. and Burrows, D. 2005. Improved dissolved oxygen status following removal of exotic weed mats in important fish habitat lagoons of the tropical Burdekin River floodplain, Australia. *Marine Pollution Bulletin* 51: 138-148.

Perna, C. O'Connor, R. and Cook, B, 2012(a), *Hydroecology of the lower Burdekin River alluvial aquifer and associated groundwater dependent ecosystems*, Department of Environment and Resource Management, Queensland Government.

Perna, C.N., Cappel, M., Pusey, B.J., Burrows, D.W., Pearson, R.G., 2012(b). Removal of aquatic weeds greatly enhances fish community richness and diversity: an example from the Burdekin River floodplain, tropical Australia. *River Res. Appl.* 28, 1093–1104. <https://doi.org/10.1002/rra.1505>

Power, T., (2017) Gooseponds Fish Hotels – Increasing habitat complexity. Summary report for Mackay Regional Council. Catchment Solutions, Mackay

Smith, B., Burrows, D., Veitch, V., Tait, J. and Hudson, D. (2007). Great Barrier Reef Coastal Wetland Protection Program Pilot Program 2005-2007– *Final Report June 2007*. Prepared for the Commonwealth Department of Environment and Water Resources by a consortium including Conservation Volunteers Australia, Wetlandcare Australia, EConcern and the Australian Centre for Tropical Freshwater Research, James Cook University.

Sugar Research Australia (2013). Rat Management in sugarcane. Booklet B14023.

Tait, J. (1990). 'Planning principles for nature conservation in the Burdekin River Irrigation Area.' Report to Queensland Department of Environment and Heritage & Queensland Water Resources Commission

Tait, J.T.P (1999) A Community based Natural Resource Management Strategy for the Burdekin – Bowen Floodplain Subregion of the Burdekin Dry Tropics prepared for the Burdekin – Bowen Integrated Floodplain Management Advisory Committee (BBIFMAC).

- Tait, J and Perna, C. (2001) Fish Habitat management challenges on an intensively developed tropical floodplain – Burdekin River North Queensland. RIPRAP Edition 19 LWRDC's Riparian Lands Management Journal
- Tait, J.T.P (2004) Burdekin Dry Tropics Natural resource Management Plan: Regional Overview. Report for the Burdekin Dry Tropics Board. Econcern.
- Tait, J.T.P (2005a) Sheep Station Creek Draft Catchment Management Plan – *Key Management Issues – Chapter 5 - Riparian and Remnant Vegetation. Draft report prepared for the Lower Burdekin Landcare Association.*
- Tait, J.T.P (2005b) Sheep Station Creek Draft Catchment Management Plan – *Appendix 7 – habitat Complexes Draft report prepared for the Lower Burdekin Landcare Association.*
- Tait, J.T.P (2005c) Sheep Station Creek Draft Catchment Management Plan – Appendix 9: Sheep Station Creek Revegetation Master Plan – A Proposal –Draft report prepared for the Lower Burdekin Landcare Association.
- Tait, J.T.P (2009) Sheep Station Creek Draft Catchment Management Plan – Key Management Issues – Water Quality DRAFT February 2009
- Tait, J.T.P. & Veitch, V. (2007). Freshwater Wetlands of the Barratta Creek Catchment – Management Investment Strategy. Report prepared for the Burdekin Dry Tropics Board by Econcern and Australian Centre for Tropical Freshwater Research (ACTFR) October 2007.
- Tait, J., 2011, Guidelines for the Use of Grazing in the Management of Exotic Pasture Weeds in Wetland and Riparian Habitats. Developed for the Coastal Floodplains of the NQ Dry Tropics NRM Region. WetlandCare Australia, Ballina, NSW.
- Tait, J.T.P. (2013) Coastal Ecosystem Management: Lower Burdekin Case Study. An examination of management arrangements for coastal ecosystems and processes linked to the ecological health of the Great Barrier Reef World Heritage Area on a floodplain dominated by irrigated agriculture. Report prepared for the Great Barrier Reef Marine Park Authority by Econcern July 2013.
- Wetlands in the Great Barrier Reef Catchments Management Strategy
<https://wetlandinfo.ehp.qld.gov.au/resources/static/pdf/management/policy/wetlands-gbr-strategy2016-21v13.pdf>
- Tonkin, Z. and Lyon, J. (2016). 'Is Wood Good for Fish'. In *RipRap* Edition 39. Published by the Australian River Restoration Centre, Canberra.
- Veitch, V., and Burrows, D., (2006). Fish Passage Issues of Healey's Lagoon Following Investigation of Water Quality Issues Impacting on Fish Migration Report No. 06/22 November 2006 Prepared by Australian Centre for Tropical Freshwater Research James Cook University Townsville, Qld 4811
- Veitch, V., Tait, J., Burrows, D.W., 2008. Fish Passage Connectivity Issues Lower Sheep Station Creek: Dry and Wet Season Investigations of Water Quality and Fish Assemblages. Australian Centre for Tropical Freshwater Research (08/02), James Cook University, Townsville.
- Waltham, N.J., Fixler, S., 2017. Aerial herbicide spray to control invasive water hyacinth (*Eichhornia crassipes*): water quality concerns fronting fish occupying a tropical floodplain wetland. Tropical Conservation Science 10. <https://doi.org/10.1177/1940082917741592>
- Waltham, N.J, Coleman, L.,1 , Buelow C., Fry S. & Burrows, D., (2020) Restoring fish habitat values on a tropical agricultural floodplain: Learning from two decades of aquatic invasive plant maintenance efforts. Ocean & Coastal Management Volume 198, 1 December 2020, 105355

> Appendix 1 – Reach values, management issues and nominated works descriptions

Reach values (V)
Short description – V1: Productive, deepwater, perennial lagoon habitat with remnant floodplain vegetation
V1 (a – c) Full description Three larger channel-hosted lagoons occur within the Didgeridoo Lagoon system upstream of the Bruce Highway. These perennial lagoons occur within a sub catchment tributary of the East Barratta Creek catchment, provide aquatic refugia within a seasonally dry landscape, have high productivity, predominantly good integrity fringing riparian vegetation, good instream habitat structure including snags and aquatic vegetation, and support good populations of wetland fauna including fish (including good populations of barramundi), reptiles (including two crocodile and several turtle species) and a range of wetland, woodland and raptor bird species. They form an ecologically significant wetland of state biodiversity significance and are assessed to be of high value in state riverine Aquatic Conservation Assessments, which also identify very high values for condition, ecosystem value, and for context and connection and medium habitat value for endangered, vulnerable or near threatened (EVNT) wildlife species. The lagoon and its adjoining remnant riparian and floodplain vegetation are also assessed to have other matters of state environmental significance including 'of concern' regional ecosystems, areas of mapped essential habitat and wildlife habitat for endangered or vulnerable species. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).
Short description – V2: Good condition remnant floodplain frontage vegetation
V2 – Full description This area of remnant floodplain vegetation adjoining the high western bank of the largest lagoon upstream of the Bruce Highway retains good diversity and structural integrity, including several eucalypt species within the levee woodland and fringing melaleuca paperbarks and livistona palms adjoining the water's edge. This contrast with other frontage areas adjoining the lagoons upstream of the highway, which have been subject to weed invasion, hot fire and clearing impacts, and ecotone areas adjoining the riparian zone of lagoons downstream of the highway which have been predominantly cleared. This area of better condition floodplain vegetation contains matters of state environmental significance, including mapped essential habitat and wildlife habitat for endangered or vulnerable species. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).
Short description – V3: Large regionally connected good condition remnant floodplain vegetation
V3 – Full description This large area of remnant floodplain vegetation was set aside during the development of the BHWSS (previously the Burdekin River Irrigation Area, or BRIA) nominally for nature conservation purposes. It forms part of some 10,000ha of natural floodplain vegetation retained during the development of the then BRIA. State assessments recognise its regional biodiversity significance; its 'of concern'

regional ecosystems; its very high condition, high ecosystem diversity, and high ecosystem value; and how it represents medium habitat value for endangered, vulnerable or near threatened (EVNT) wildlife species. This study would nominate much higher than regional values to this and other retained floodplain habitats of the BHWSS, recognising the total cumulative size of retained areas; their connectivity via dedicated corridor retention both laterally across the floodplain (from the Haughton to Burdekin Rivers) and longitudinally along drainage lines (from inland rangeland areas to the coast); observations of EVNT taxa not recognised by state assessments; and the uniqueness and natural heritage of this system of planned habitat retention within a government-developed irrigation area unparalleled in Australia. Part of this site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V4: Regionally-significant wildlife corridor

V4 – Full description

This corridor of remnant floodplain vegetation, running east to west across the floodplain, was set aside during the development of the BHWSS (previously the Burdekin River Irrigation Area, or BRIA) nominally for nature conservation purposes. It forms part of some 10,000ha of natural floodplain retained during the development of the then BRIA. State assessments recognise it to be of local biodiversity significance; to contain 'of concern' regional ecosystems; to have very high condition, high ecosystem diversity, and medium ecosystem value; and to represent medium habitat value for endangered, vulnerable or near threatened (EVNT) wildlife species. However, this study would nominate much higher than local values to this and other retained floodplain habitats of the BHWSS, recognising their role as a regional corridors – in this case – providing lateral connectivity across the floodplain (ultimately from the Haughton to Burdekin Rivers). There are also observations of EVNT taxa not recognised by state assessments, and the uniqueness and natural heritage of this system of planned habitat retention within a government-developed irrigation area unparalleled in Australia.

Short description – V5: Supplemented flow creek channel and waterholes

V5 – Full description

This flowing creek system in the upper catchment of the Didgeridoo Lagoon system was historically a seasonal drainage line, following floodplain drainage depressions. With the advent of irrigation development and associated tailwater flows within its contributing catchment area, the system has now become a semi-perennial creek channel. It has developing riparian vegetation and channel-hosted waterholes that support a diverse suite of fish, several turtle species, freshwater crocodiles and waterbirds. The system is assessed to have high value in State Aquatic Conservation Assessments. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V6: Lagoon and remnant riparian/floodplain vegetation within Crown tenure

V6 – Full description

This lagoon is the smallest of the three lagoons that comprise the Didgeridoo Lagoon System upstream of the Bruce Highway, and is in the middle. In contrast to the rest of the broader lagoon system that predominantly occurs on freehold land tenure, most of this lagoon and a substantial proportion of its eastern bank occur within Crown watercourse tenure, which could present additional management and public use opportunities. Although not the highest condition of the lagoons upstream of the highway, it shares

many values, including high productivity; representative fringing riparian vegetation; good instream habitat structure, including snags and aquatic vegetation; good populations of wetland fauna including fish, including good populations of barramundi; reptiles, including two crocodile and several turtle species; and a range of wetland, woodland and raptor bird species. It forms part of an ecologically-significant wetland of state biodiversity significance; is assessed to be of high value in state riverine Aquatic Conservation Assessments, which also identify very high values for condition, ecosystem value, context and connection; and provides high value habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. The lagoon and its adjoining remnant riparian and floodplain vegetation are also assessed to have other matters of state environmental significance, including 'of concern' regional ecosystems, areas of mapped essential habitat, and wildlife habitat for endangered or vulnerable species. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V7: Seasonal distributary wetland

V7 – Full description

The Didgeridoo Lagoon system includes parallel shallow seasonal distributary channels which dry through the dry season, and host native wetland vegetation adapted to the seasonal hydrological conditions of the region. These types of habitats provide food, breeding and nesting resources for a range of waterbirds and other wetland fauna, including smaller fish species and frogs. Within the main lagoon system, the availability of these seasonal wetland features has been impacted by aseasonal inflows of irrigation tailwater (and potentially groundwater rise) that have reduced water level seasonality. Impacts have also been caused by infestations of exotic aquatic grasses on the margins of the perennial water bodies. These seasonal wetlands represent a small but important component of the overall wetland complex that contribute to its classification as an ecologically significant wetland of state biodiversity significance, with very high values for condition and ecosystem value, and high value for context and connection. Matters of state environmental significance include mapped essential habitat, and wildlife habitat for endangered or vulnerable species. The site is also assessed to be of high value in State riverine Aquatic Conservation Assessments and forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V8: Crown reserve lagoon frontage and remnant riparian vegetation

V8 – Full description

This area of Crown reserve occurs on the eastern bank of the most downstream lagoon of the three lagoons that comprise the Didgeridoo Lagoon system, upstream of the Bruce Highway. The Crown tenure of this reserve contrasts with the broader lagoon system that predominantly occurs on freehold land tenure, presenting additional management and public use opportunities. This section of the lower lagoon shares most values of the larger lagoon, which is an ecologically-significant wetland of state biodiversity significance, assessed to be of high value in state riverine Aquatic Conservation Assessments. These also identify very high values for condition, ecosystem value, and high value for context and connection, and habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V9: Road reserve lagoon frontage and remnant floodplain vegetation

V9 – Full description

This area of road reserve occurs downstream of the Bruce Highway on the most downstream lagoon of the three lagoons that comprise the Didgeridoo Lagoon System, upstream of the Bruce Highway. The road reserve tenure of this site contrasts with the broader lagoon system that predominantly occurs on freehold land, presenting additional management and public use opportunities. This section of the lower lagoon shares most values of the larger lagoon, which is an ecologically-significant wetland of state biodiversity significance, assessed to be of high value in state riverine Aquatic Conservation Assessments, which also identify very high values for condition, ecosystem value, and high value for context and connection, and habitat for endangered, vulnerable or near threatened (EVNT) wildlife species. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V10: Productive, perennial, deepwater lagoon with remnant riparian forest

V10 – Full description

This lagoon is the largest within the Didgeridoo system downstream of the highway. It was historically a highly seasonal wetland that dried in some years. Since the advent of irrigation development in its contributing catchment, aseasonal tailwater inflows maintain it as a perennial water body. It shares most values recorded for the larger lagoons within the system, but has a more diverse and contiguous fringe of riparian vegetation that adjoins larger tracts of remnant floodplain habitat. It is assessed to be a state significant wetland with very high ecosystem value. It is also assessed as high value in state riverine Aquatic Conservation Assessments. Matters of state environmental significance include mapped essential habitat. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V11: Contiguous good condition riparian vegetation corridor

V11 – Full description

This corridor of diverse and structurally-complex riparian vegetation provides a range of habitat resources for birds and mammals and is one of two corridor linkages between the Didgeridoo Lagoon system and the larger tracts of remnant floodplain habitat associated with the downstream East Barratta Creek system. It has good condition in terms of limited rubber vine or exotic grass weed infestation, and has consequently not been subject to canopy damaging hot fires. The upstream end of this corridor falls within the boundary of a state significant wetland with very high ecosystem value, and it is also assessed to be of high value in state riverine Aquatic Conservation Assessments. Matters of state environmental significance include mapped essential habitat. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V12: High value wetland and remnant floodplain habitat complex

V12 – Full description

This remnant floodplain habitat complex provides a wildlife corridor linkage between the Didgeridoo Lagoon system and the larger tracts of remnant floodplain habitat associated with the downstream East Barratta Creek system. It includes a mix of wetland and woodland vegetation types, and perennial deepwater and shallow seasonal wetland types. This juxtaposition of diverse habitat resources for both terrestrial and aquatic fauna provides the site with relatively high ecological and nature conservation values. It is assessed to be a state significant wetland with very high ecosystem value, and is also assessed to be of high value in state riverine

Aquatic Conservation Assessments. Matters of state environmental significance include mapped essential habitat and habitat for endangered or vulnerable wildlife species. This site also forms part of the Burdekin – Townsville Coastal Wetland aggregation listed in the national Directory of Important Wetlands in Australia (DIWA).

Short description – V13: Coastal wildlife corridor

The remnant and disturbed habitat occurring between the upstream margin of the main lagoon and the lower system habitat linkages to East Barratta Creek (V12 & V11) represents an existing wildlife habitat corridor for natural cover-dependent wildlife species. Distribution is between the large areas of remnant floodplain habitat associated with reserved corridors in the BHWSS (formally BRIA) to the south, and the extensive coastal habitats associated with East Barratta Creek, and ultimately Cape Bowling Green Bay National Park, to the north. Recognition of this corridor connectivity as an existing ecological value serves to guide any future land use intensification away from severing its connectivity and/or guide landscape rehabilitation activities toward consolidating it.

Management issues (M)

Short description – M1: Aseasonal inflows of irrigation tailwater and channel overflow from the BHWSS

M1 (a-d) – Like all wetlands in the seasonal dry tropics, the natural hydrology and associated ecology of the Didgeridoo Lagoon system was highly seasonal and related to the timing and magnitude of the annual wet season. In the contemporary modified system, the hydrology is dominated by inflows of irrigation tailwater and supply channel overflow from the BHWSS in its upper catchment. These aseasional inflows contribute to near perennial outflows from the lagoon to the downstream drainage system and a major reduction in dry season drawdown of lagoon water levels. This altered hydrology has generated major changes in aquatic plants communities (increased fringing aquatic grasses, decreased native communities), water quality (higher turbidity and nutrients), and associated habitat values for wetland fauna.

Short description – M2: Lack of active management – fire, weeds and grazing in high value remnant habitat retained for nature conservation

M2 – During the development of the BHWSS, thousands of hectares of remnant floodplain habitat were set aside nominally for nature conservation purposes. A significant area of the Didgeridoo Lagoon system catchment is comprised of this reserved area. Despite being ‘reserved’, this area has never been bought under any formal nature conservation tenure or management arrangements. Although having very high nature conservation values, the area’s condition is subject to longer term decline due to a lack of effective, fire, woody weed and grazing management. Wallaby populations within the reserved area and wildfire risks to adjoining cane farms also create management conflict with adjoining land users. In the absence of visible management, the area also suffers from inappropriate practices such as waste dumping, vegetation clearing and hot fire regime burns.

Short description – M3: Sustained aseasional inflows from irrigation scheme creating turbidity and nutrient level impacts within lagoon

M3 – Under its natural predevelopment condition the Didgeridoo Lagoon system’s water quality was set by annual wet season inflows, after which the water cleared, and nutrients were processed by seasonal aquatic plant communities during seasonal water level drawdown. Under the modified condition driven by BHWSS inflows, lagoon water quality conditions are often turbid. Tailwater inflow volumes also constitute a large source of additional nutrient loading to the system.

Short description – M4: Lack of seasonal water level drawdown and exotic aquatic grass infestation impacted native aquatic plant abundance M4 – The modified hydrological status of the lagoon system, resulting from inflows from the BHWSS, creates conditions suited for exotic ‘ponded pasture’ grass species hymenachne and para to dominate the water’s edge and shallow zone. These grasses now dominate areas that previously supported native aquatic plants, including emergent, submerged and floating bed, like water lilies. Floating aquatic weeds also periodically infest sections of the lagoon system. Competition from aquatic grasses and floating weeds and a lack of seasonal water level drawdown have all served to reduce the area, abundance and diversity of native aquatic plant communities within the lagoon system.
Short description – M5: Ungrazed exotic grass understorey and resulting hot fires have degraded remnant riparian/floodplain vegetation M5 – Historically, much of the riparian and adjoining floodplain areas of the Didgeridoo Lagoon system hosted relatively open eucalypt and melaleuca woodland vegetation that was used for grazing purposes. With increasing land use intensification toward irrigated agriculture, most of these areas are no longer grazed. Ungrazed pasture grasses such as guinea and para grass create large fuel loads for dry season fires. When burning is conducted with large fuel loads in the late dry season, when cane crops have been harvested and fire risks to crops are low, the resultant hot fires can severely impact fire-sensitive riparian vegetation. These fires can cause the death of mature trees and degrade the canopy extent and condition of riparian, as well as floodplain, vegetation communities, facilitating further density and dominance of invasive understorey grasses. As well as posing further hot fire risks to remnant vegetation, increasing pasture grass density also serves to suppress native seedling recruitment. These combined processes have diminished the condition and diversity of remnant vegetation in the riparian zone and floodplain areas with adjoining farm land throughout the lagoon system.
Short description – M6: Flow conditions through culvert road crossing potentially presents low flow fish passage barrier M6 – A road crossing at the downstream end of the system’s main lagoon used for local farm access presents low flow conditions that potentially represents a fish passage barrier when flows are solely directed through the crossing during base flow periods. Although fish passage is possible when this crossing is inundated during higher flows, some fish species and size classes prefer to move on lower flows when this crossing may present a barrier.
Short description – M7: Public tenure Crown watercourse, including adjoining riparian frontages, condition degrading in absence of management M7 – A substantial portion of this central lagoon, including riparian vegetation and adjoining floodplain areas, is located on a Crown watercourse tenure, which legally is publicly accessible land; although landlocked by private property. Given its public tenure, there is some justification for it to be managed in a way that meets community expectations for the conservation of nature. Currently the area is subject to weeds, hot fire risks, and potential long term condition decline.
Short description – M8: Poor condition of frontage remnant vegetation possibly attributable to rising groundwater M8 – Irrigation-driven groundwater rise is recognised for much of the system’s catchment area. Within this and other frontage areas on the eastern side of the lagoon system, observations over a decade have noted stands of remnant vegetation succumb to die back

with no obvious evidence to attribute it to insect attack or hot fire impact. Other evidence, including salt-scalded soil, suggests groundwater rise may be a contributory factor.

Short description – M9: Loss of ecotonal floodplain vegetation due to historic clearing, exotic grass infestation and hot fires

M9 – As described elsewhere for this system, remnant floodplain vegetation condition has been subject to condition decline associated with historic clearing, weed infestation and hot fires. One specific habitat setting that appears to have been particularly impacted is the riparian zone–floodplain ecotone. An ecotone is essentially the boundary between different vegetation assemblages or ecosystem types. These areas are often of great importance to fauna, including arboreal mammals such as squirrel gliders, because of the greater diversity of habitat and food resources available. Assessment of historical photographs suggest that ecotonal areas outside of the immediate riparian zone have been particularly subject to reduced occurrence and condition throughout the Didgeridoo Lagoon system.

Short description – M10: Public tenure Crown reserve lagoon frontage adjoining road reserve degrading in absence of management

M10 – Adjoining the Bruce Highway there is a portion of lagoon and adjoining riparian frontage that is located on a Crown reserve tenure, which legally is publicly accessible land. Given its public tenure, there is some justification for it to be managed in a way that meets community expectations for the conservation of nature, and could – with local government support – be used for public purposes. Currently the area is subject to weeds and hot fire risks and potential long-term condition decline.

Short description – M11: Aquatic grass infestation and hot fire impacts degrading seasonal wetland and remnant vegetation condition

M11 – This historically-seasonal small wetland now receives seepage from an upstream irrigation storage that keeps part of its basin wetted and prone to exotic grass (hymenachne, para) and cumbungi infestation. The site is ungrazed and large fire fuel loads accumulate before the dry season in most years, exposing the site to ongoing hot fire risks. These are frequently realised, resulting in degradation of the remnant wetland vegetation condition. Small seasonal wetlands host different tree and aquatic plant species to those more commonly associated with the main perennial lagoons and have their own suite of nature conservation values.

Short description – M12: Remnant vegetation and lagoon in large public road reserve subject to condition decline in absence of management

M12 – Adjoining the Bruce Highway there is a relatively broad road reserve that includes portions of main channel lagoon, seasonal wetland channel, and intervening riparian and floodplain woodland. Road reserve is legally publicly accessible land. Given its public tenure, there is some justification for it to be managed in a way that meets community expectations for the conservation of nature, and could – with local and state government support – potentially be used for public purposes. Currently the area is subject to weeds, hot fire risks, and potential long-term condition decline.

Short description – M13: Flow path through removed highway crossing directing erosive force toward eastern bank and creating bank erosion

M13 – During the upgrade of the highway crossing of the Didgeridoo Lagoon system, culverts beneath the old highway crossing were removed along with the crossing. This has contributed to a change in the downstream flow direction under larger events with higher flows now placing more pressure on the eastern bank than occurred previously when the culverts trained flow toward the centre of the channel. This could ultimately lead to the undercutting of the bank and a new breakout distributary channel to the east. This outcome is not desired by the landholder.

Short description – M14: Piped culvert road crossing(s) creating low flow fish passage barriers

M14 (a & b) – This one of two proximal road crossings has pipe culverts that convey water under relatively high flow velocities, however they present a fish passage barrier under a broad range of flow conditions outside of road-inundating flow levels. While much fish migration does occur during high flood inundating flow events, some species and/or size classes depend on movement during recessionary flows, which would be entirely directed through the culvert pipes. The upper lagoon's system contains significant areas of high-quality fish habitat and maintaining migratory fish access to the upper reaches is important for the health and fishery productivity of the system.

Short description – M15: Hot riparian zone fire creating impact on canopy, creating palm forest, and opening channel to hymenachne infestation

M15 – This dense and diverse riparian vegetation corridor has good canopy condition and has been maintained relatively free of dense pasture grass understorey and associated hot fire risks. Current fire management arrangements include the landholder's desire to removed fallen palm frond fire fuel loads from beneath livistona palm stands. This results in local hot fires that further promote the fire-loving palms, while keeping an open, or further opening, canopy structure. Some of the species impacted by the fires include shade-generating species such as Leichardt trees that are recruiting along the channel in response to the perennality of the modified system. One of the species that benefits from a more open canopy is hymenachne, also distributing along the now perennial stream channels. Excluding fire from the livistona understorey could promote more canopy closure and keep the channel free of hymenachne, reducing the need for spray-based control. Fire risks associated with accumulated palm fronds would need to be considered.

Short description – M16: Piped channel outlet to East Barratta Creek creates fish passage barrier under all flows except flood inundation

M16 – This road crossing immediately upstream of the system's confluence with the larger East Barratta Creek system has a single pipe culvert, and associated flood gate cap, that conveys water with high flow velocities presenting a fish passage barrier under all but road inundating flow levels. While much fish migration does occur during high flood inundating flow events, some species and/or size classes depend on movement during recessionary flows which would be entirely directed through the piped outlet. The upper

lagoon system contains significant areas of high-quality fish habitat and maintenance of migratory fish access to upper reaches is important for the health and fishery productivity of the system.

Short description – M17: Lack of ecotonal vegetation backing riparian zone reduces habitat and wildlife corridor function

M17 – Patterns of floodplain vegetation clearing for farm development often entail clearing all the way to the margin of stream-side riparian vegetation. Even where good riparian vegetation corridors are retained, ecotone vegetation (i.e. the adjoining floodplain woodland) is often completely cleared. An ecotone is essentially the boundary between different vegetation assemblages or ecosystem types. These areas are often of great importance to fauna, like arboreal mammals such as squirrel gliders, because of the greater diversity of habitat and food resources available. Allowing for the regeneration of woodland margins adjoining creek 'riparian' vegetation corridors can vastly improve habitat value and corridor function in developed landscapes.

Nominated Works (W)

The below section contains short descriptions only. For more information regarding these nominated works, refer to the mapping and recommendations throughout the SMP.

Short description – W1: Reduction in flow volume and re-use of BHWSS tailwater inflows

Short description – W2: Establishing formal nature conservation management arrangements for BHWSS remnant habitat corridors and nodes

Short description – W3: Resource woody weed and rubber vine control program along the length of supplemented creek riparian C=corridor

Short description – W4: Support reintroduction of controlled grazing to lagoon frontages to reduce exotic pasture dominance and hot/wildfire risk

Short description – W5: Improve low flow fish passage at road crossing

Short description – W6: Establish fencing and introduce controlled grazing to seasonal wetland and adjoining habitat to reduce exotic pasture dominance and hot/wildfire risk

Short description – W7: Develop habitat regeneration management plan and assess public use options for Crown reserve

Short description – W8: Develop habitat regeneration management plan and assess public use options for road reserve

Short description – W9: Engage relevant authorities and resource bank stabilisation works for erosion pressure point

Short description – W10: Support introducing controlled grazing to wetland and adjoining habitat to reduce exotic pasture dominance and hot/wildfire risk and to promote open water habitats

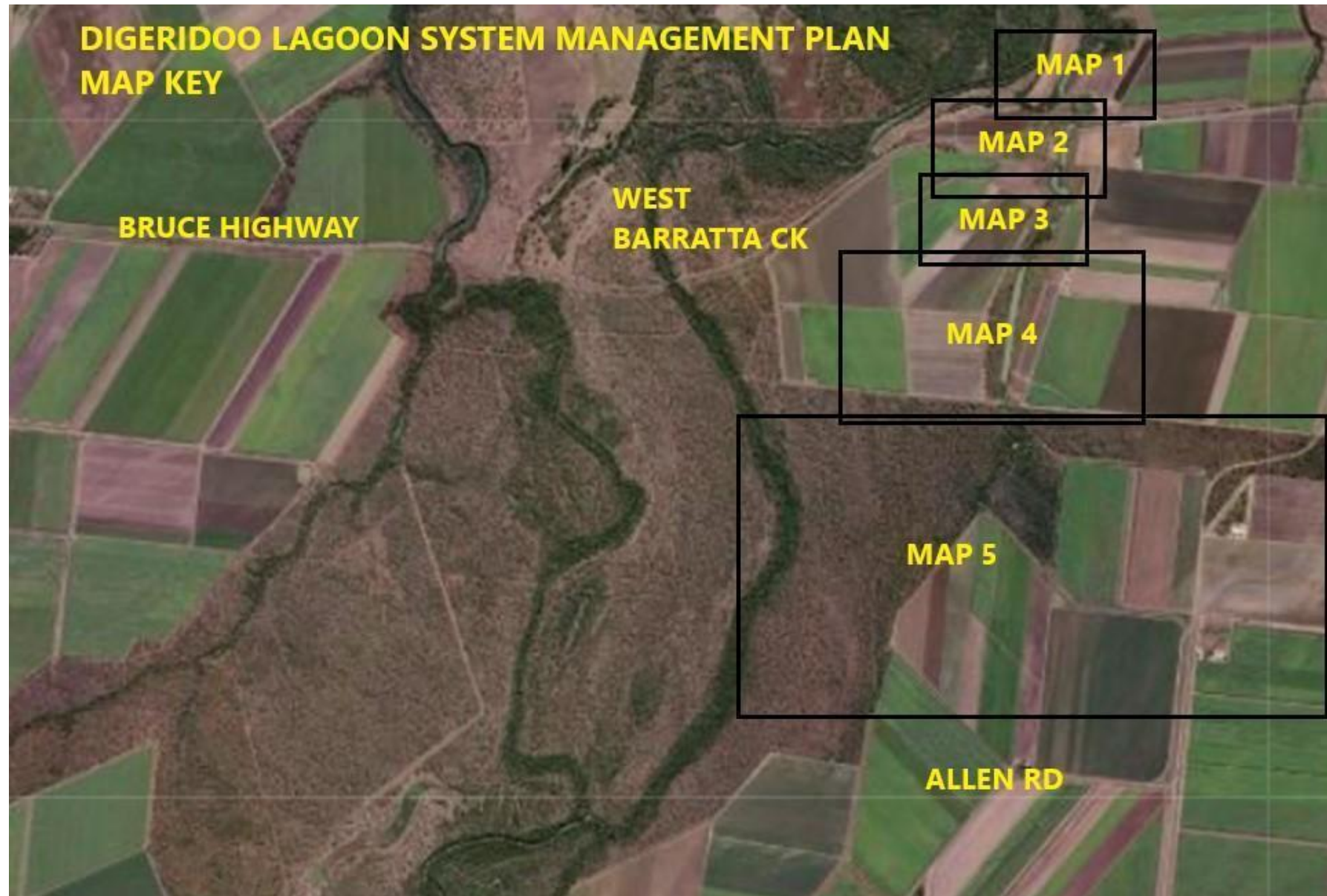
Short description – W11: Replace pipes with box culverts to improve base flow fish passage

Short description – W12: Promote exclusion of fire from riparian vegetation corridor to support recruitment of shade generating species (Leichardt trees) to limit channel hymenachne infestation

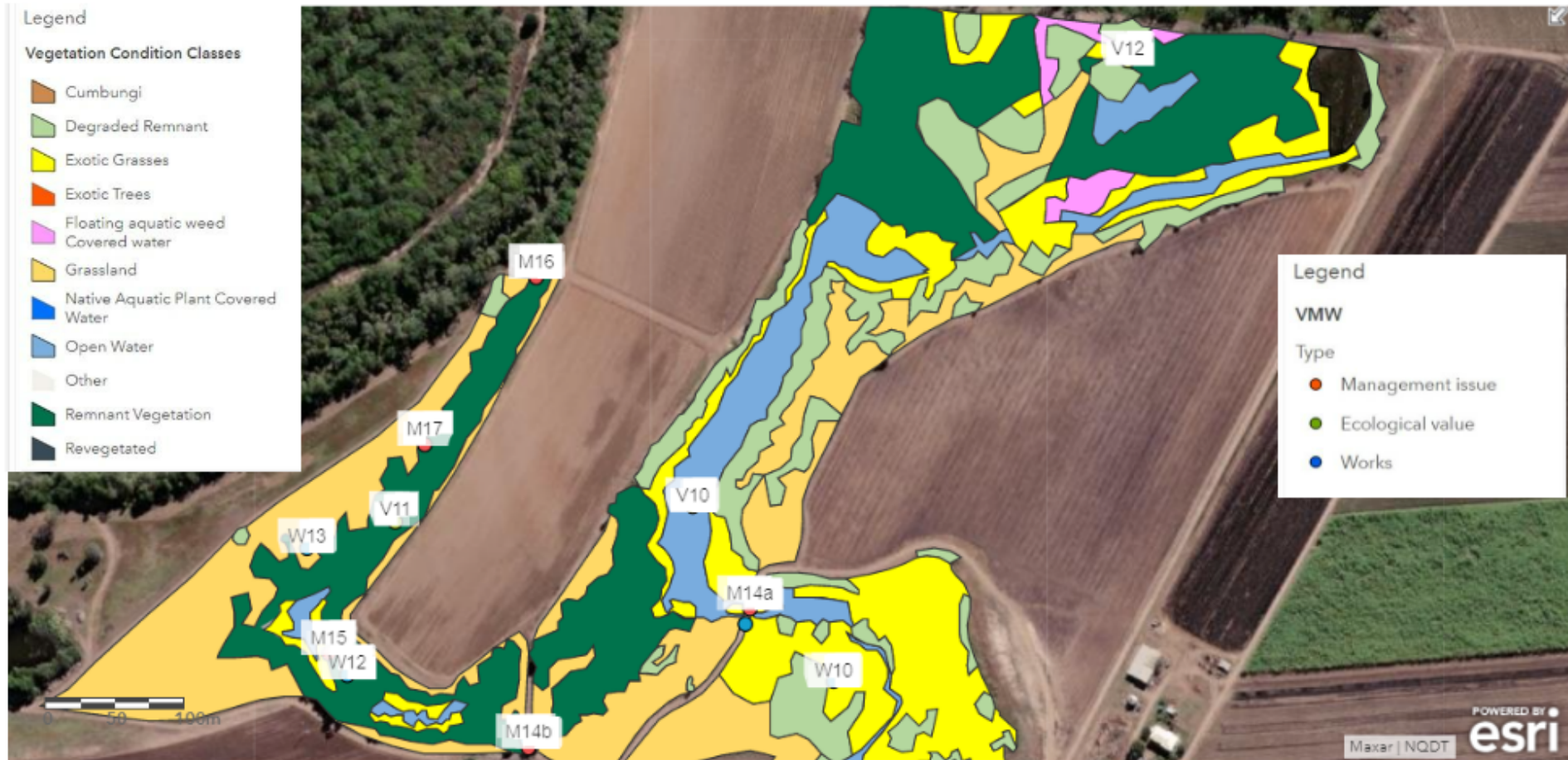
Short description – W13: Support managed regeneration of eucalypt woodland species along margin of riparian vegetation corridor to create ecotone habitat

Short description – W14: Replace piped road crossing with box culvert to reinstate base flow fish passage

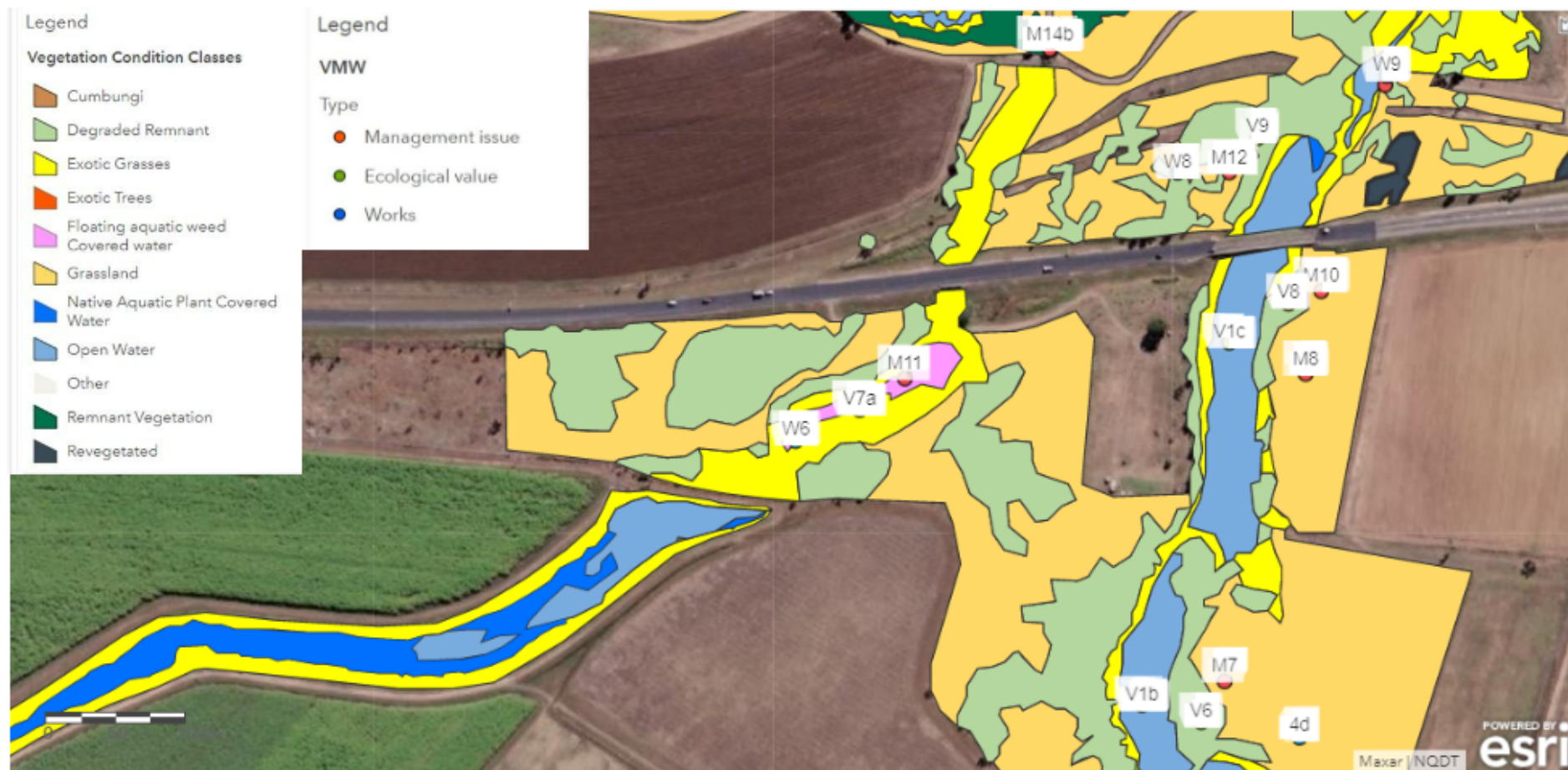
> Appendix 2 – Management plan map sheets separate attachments



MAP1



MAP 2



MAP 3



MAP 4



MAP 5

