Department of Science, Information Technology, Innovation and the Arts

Review of Water Resource (Burnett Basin) Plan 2000 and Resource Operations Plan

Appendix E–Assessment of alternate environmental management rules (surface water)

April 2013

Great state. Great opportunity.

Queensland Government

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Preface

This report is part of a suite of documents contributing to the environmental assessment for the Burnett Basin Water Resource Plan (WRP) review. These reports have been prepared by the Department of Natural Resources (DNRM) and Department of Science, Information Technology, Innovation and the Arts (DSITIA).

The objective of these reports is to provide an environmental assessment of the key flow-related surface water and groundwater dependent ecosystems of the Burnett Basin. A key aim is to identify environmental risks associated with a range of potential water allocation and management scenarios. Management recommendations will address these risks and propose strategies to protect the ecological values of the plan area.

The outcome of the project is presented in the following stages:

Environmental assessment report

Appendix A—Assessment of critical water requirements for selected ecological assets

Appendix B—Risk assessment for selected ecological assets

Appendix C—Assessment of existing environmental management rules

Appendix D—Assessment of groundwater-dependent ecosystem reporting nodes in the Coastal Burnett Groundwater Management Area

Appendix E—Assessment of alternative environmental management rules

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Executive Summary

As part of the review of the Water Resource (Burnett Basin) Plan 2000 (Burnett WRP 2000), an assessment of alternate water sharing and environmental management rules was conducted to identify how the alternate rules changed the risk to selected ecological assets in the Burnett Basin.

The assessment was conducted on ecological assets selected under the Queensland Government's Environmental Flows Assessment Program (EFAP) using the methodology that was applied in the Environmental Assessment (DNRM 2012a). Assets that have a specific link to low flows include the Australian lungfish (*Neoceratodus forsteri*), White-throated snapping turtle (*Elseya albagula*) and waterholes as refugia. The selected assets that have a specific link to high flows are banana prawns (*Fenneropenaeus merguiensis*), sea mullet (*Mugil cephalus*), barramundi (*Lates calcarifer*) and river mangroves (*Aegiceras corniculatum*).

Previous studies found that the *Neoceratodus forsteri* require flow variability and persistence for successful spawning, egg development and recruitment (Espinoza et al. 2012). The alternate rules aim at providing these flows between September and March. While the risk assessments of the alternate rules suggest that there was no overall change in the risk profile when compared to current management rules, the alternate rules cater for low flows during critical months of the year. However the inclusion of additional unallocated water did increase risks.

Elseya albagula was included in this assessment, though not specified in the Burnett Asset Selection Report (Implementation Review Report appendix B), after important biological data became available during scoping and initialisation of this report. Studies have found that as *E. albagula* nest within 1.3 m of standing water levels, the nests are vulnerable to inundation. In addition, the nests are also heavily predated and trampled, further increasing the risk for this species. The alternate rules aim to reduce nest inundation by implementing a seasonal nominal operating level (NOL) for the Ben Anderson Barrage that stimulates nesting higher up the river bank. The risk assessment found that the alternate water sharing and environmental management rules significantly reduce the risk of nest inundation. The alternate NOL also increases upstream/downstream connectivity through maintaining a water level that fosters increased fishway operation. The inclusion of proposed unallocated water further reduced this risk for *E. albagula*.

While there are no specific rules which relate to maintaining waterhole levels, the cumulative effect of other management strategies that may impact waterhole persistence was assessed. It was found that the three largest waterholes across the basin are of sufficient capacity to retain some water through any period of no flow on record. While the persistence of smaller waterholes was not assessed, it is believed that the alternate water sharing and environmental management rules would not negatively impact on their refugial qualities.

High flows contribute fresh water into estuarine environments, influencing the extent and duration of brackish conditions. This in turn influences the productivity of an estuary as particular brackish conditions facilitate increased growth rates and recruitment of various important commercial and recreational species. For each estuary in the Burnett Basin, risk was assessed by examining the response of *Fenneropenaeus merguiensis, Mugil cephalus, Lates calcarifer* and *Aegiceras corniculatum* to brackish conditions under the alternate rules.

The alternate water sharing and environmental management rules did not change the risk profiles for any of these assets when compared to the current management rules. The proposed inclusion of unallocated water, however, decreased the growth of *F. merguiensis* and reduced *L. calcarifer* year class strength (YCS). For the Burnett estuary, it has been suggested that significant changes to the risk profile cannot be achieved unless flows are also passed through upstream water supply schemes. In the Kolan River, removal of all high flow releases also did not change risk and it has been suggested that estuarine flows are being met by local rainfall/runoff events.

While alternate water sharing and environmental management rules did not significantly alter the risk profiles for either the low flow or high flow assets, the alternate rules improve on the existing arrangements by better aligning with the natural flow regime–for example inflow/outflow rules. The alternate rules also reflect the role of flow seasonality in migration and spawning cycles–for example by targeting flows in September to March. The implementation and effectiveness of the existing arrangements (for example the Bucca Weir strategy) was considered to develop the alternate rules to balance the needs of consumptive water users and the environment

The information in this report will be used alongside other studies such as hydrological and socio-economic reports to determine the future allocation and management of the water resources within the Burnett Basin.

1 Introduction

As part of the review of the *Water Resource (Burnett Basin) Plan 2000* (Burnett WRP 2000), the risk to selected ecological assets in response to current and alternate water resource management arrangements have been assessed. An Ecological Risk Assessment (ERA) is a semi-quantitative method for assessing the long-term viability of ecological assets under different management scenarios. It is measured in terms of the likelihood of an adverse ecological impact occurring and the consequences of the impact on the asset.

In the Burnett Basin, selected ecological assets with a critical link to low flows were identified as the Australian Lungfish (*Neoceratodus forsteri*), White-throated snapping turtle (*Elseya albagula*) and waterholes as refugia. Estuarine processes, such as brackish habitat, on the other hand have critical links to high flows. In this instance, the risk was assessed by the response of Banana prawns (*Fenneropenaeus merguiensis*), Barramundi (*Lates calcarifer*), Sea Mullet (*Mugil cephalus*) and River mangroves (*Aegiceras corniculatum*) to changes in brackish estuary conditions. The modelled growth rates of *Fenneropenaeus merguiensis* and *Lates calcarifer* Year Class Strength were also considered.

Appendix A of the Environmental Assessment Report defined the eco-hydraulic requirements for each selected asset. It set an appropriate Threshold of Concern (ToC) that identified the minimum flow requirements needed to maintain the viability of each asset.

Appendix B of the Environmental Assessment Report then assessed the risk of the current management arrangements against the minimum flow requirements for each ecological asset. In particular, it identified instances where the current management arrangements caused an exceedance of the ToC, increasing the risk to the asset.

Appendix C assessed the implementation of the current management rules. It assessed the effectiveness of each rule against its success for achieving a desired ecological outcome. It also made recommendations about how management arrangements could be altered to help reduce the risk to the asset.

This current report consolidates the findings of the previous studies to assess the risk that alternate management rules (Attachment 1) pose on the ecological assets of the Burnett Basin WRP area.

The following principles have been used to guide the development of alternate environmental management rules:

- align with the eco-hydraulic requirements of each selected asset
- reduce instances of the ecological asset exceeding the ToC (i.e. reduce risk)
- be consistent with and able to be incorporated into the water planning framework
- not impact on the ability for water users to take water
- provide positive ecological benefits throughout the basin, not just at discrete locations or associated with just one piece of water infrastructure.

The analysis of risk to selected ecological assets from alternate environmental management rules is the final step in the ERA process.

2 Methodology

The methodology used to assess the risk associated with the alternate environmental management rules follows that used for the assessment of risk for the current environmental management rules (Appendix B). This allows a comparison between both sets of rules to quantify the benefits for the ecological asset and assess the suitability of the alternate rules. It should be noted that the assessment of risk for the alternate environmental management rules take into account changes to water sharing rules as well, hence differences in risk may arise because of these changes.

Four scenarios were modelled based on updated flow and rainfall data for the period 1890 to 2008. These are:

1. Predevelopment (PD) – flows modelled to be unaffected by water resource development (e.g. infrastructure and consumptive take), often referred to as “natural” flows.
2. Base case (BC) – full use of existing entitlements with water sharing and infrastructure operating rules (including environmental management across all schemes. In addition, critical water supply arrangements in Barker-Barambah Water Supply Scheme) as outlined in the current Burnett Resource Operations Plan (Burnett ROP) that could be modelled were included.
3. Alternate management rules (A) – full use of existing entitlements with alternate water sharing and infrastructure operating (including environmental management rules). This also includes setting proposed annual volumetric limits on some area based and water harvesting entitlements.
4. Proposed unallocated water (B) – full use of existing entitlements with alternate water sharing and infrastructure operating (including environmental management) rules and proposed unallocated water volumes as follows:
   - Bundaberg WSS: 15 295ML/a from Ned Churchward Weir (Stage 2)
   - Upper Burnett WSS: 6 300ML/a from Jones Weir (Stage 2)
   - Barker Barambah WSS: 4 250ML/a from Barlil Weir
   - Gregory: 1000ML/a from end of system
   - Isis: 1000ML/a from end of system

It must be noted that the risk assessment presented in this report was based on flow sequences from an updated Integrated Quality Quantity Model (IQQM). Alongside updated stream flow, rainfall and metered extraction data up to June 2008, the IQQM also includes improved modelling methodologies. As a result, the previous risk assessment (Appendix B) and this assessment may appear different in some cases.

3 Low flow assessment

Low flows, including periods of no flow, are typically associated with base flow contributions from groundwater or local rainfall events that increase flow volumes but not large enough to produce flooding. They drive the availability of hydraulic habitat, instream connectivity and sustain aquatic ecosystems through drier periods.

Low flows and water ponded in pools provide ambient habitat for aquatic vegetation. The composition, distribution and growth of macrophyte communities are correlated with flow velocity. In turn the macrophyte communities provide spawning substratum, refugial habitat, and a food source for a variety of aquatic fauna including turtles and lungfish (Brooks & Kind 2002; Duivenvoorden 2008).

Low flows also maintain connectivity through riffle habitat. Characterised by coarse sediments and disturbed, highly oxygenated water, riffles habitats are valued for facilitating movement/dispersal of species and the provision of breeding habitat. For example, *M. cephalus* is a catadromous fish species which traverses riffle habitats through its longitudinal movement to the estuary. The red-eye tree frog (*Litoria chloris*) lays eggs on floating masses or on the underside of leaves (Australian Frog Database 2009) and requires low flows for the successful development of its eggs.

On the other hand, waterholes support aquatic ecosystems by providing habitat and refugia during periods of no flow. The long term persistence of many aquatic species depends on the availability of suitable refugial waterhole habitat (Bunn et al. 2006; Arthington et al. 2010; Beesley & Prince 2010; Sheldon & Fellows 2010). Low flows top up waterholes, increase persistence time, and enable them to function as refugial habitat through extended dry periods.

In the Burnett Basin, the dependence of each selected asset on low flows is varied. For example, *N. forsteri* require small slow moving flows (associated with a change in water level between 0.3 and 0.5m) during late winter to early summer to initiate spawning (Espinoza et al. 2012). These low flows are important for facilitating migration and selection of breeding sites as well as maintaining favourable conditions for egg development.

Similarly, the reliance of *E. albagula* on low flows relates to providing a constant base flow during their breeding seasons. Typically 20% of *E. albagula* nests are found within 1.3 m of the standing water level at the time of nesting. Any changes in water levels greater than 1.3 m during incubation places these nests at risk of inundation. This is important as nest predation has already significantly altered the demographics of the population and nest inundation adds an additional stressor to the species.

For waterholes, changing low flows, particularly the period between flows, may result in more rapid and frequent drying of this habitat. This could be detrimental to species that rely on waterholes for refuge, spawning or feeding habitat.

The following sections examine how the alternate management rules change the risk (compared to the current rules) for each selected asset and discusses this in the context of managing low flows across the Burnett Basin.

3.1 Australian Lungfish (*Neoceratodus forsteri)*

An assessment (Appendix B) of low flows suitable for lungfish found that the current management rules increased the moderate risk profile when compared to the predevelopment scenario. It was identified that this was a result of less suitable spawning flows at each of the Jones Weir Tailwater, Mount Lawless and Ban Ban sites. A map showing the location of these sites is provided as Figure 3 in Appendix A with their corresponding gauging station numbers listed in Table 1 (Site 136008C, whilst not found on the map is located immediately downstream of 136023A–Ned Churchward Weir Headwater).

An assessment of the current environmental management rules (Appendix C) found that the current storage operation and pass flow rules do not align with the eco-hydraulic requirements of lungfish. Furthermore, the current management arrangements are undermined by critical water supply arrangements (CWSAs) which supersede environmental releases during extended dry periods. It was recommended to reassess the management arrangements for each of the following pieces of infrastructure:

- Ned Churchward Weir,
- Claude Wharton Weir
- Silverleaf Weir (compensation rule), and
- Paradise Dam.

3.1.1 Alternate environmental management rules

The alternate environmental management rules aim to provide low flows during key periods throughout the year (details are presented in Attachment 1). Rating curves were assessed to determine the flow rates (in ML/day) that achieve a rise in water level of 0.3 m above the cease to flow point downstream of the infrastructure. The alternate environmental management rules are as follows:

- Ned Churchward Weir–releases to match inflows (an inflow/outflow rule) between 85 to 200 ML/day, up to a maximum release of 200 ML/day, from September 1 to December 31.
- Claude Wharton Weir–releases to match inflows (an inflow/outflow rule) between 50 to 150 ML/day, up to a maximum release of 150 ML/day, from September 1 to March 31. This release period has been extended past December for this location to provide for fish passage for other species.
- Silverleaf Weir–releases to maintain a flow rate at Stonelands (GS136206A) equal to 2/3 of the combined flow rate at West Barambah (GS136213A) and Glenmore (GS136209A) up to a maximum flow rate of

50 ML/day, from September 1 to December 31. This rule is also conditional on a flow rate at Ban Ban less than 50ML/d and a Barker Barambah Water Supply Scheme Medium Priority announced allocation greater than 5%. A minimum passing flow of 5 ML/d at Stonelands is to be provided from Silverleaf Weir during July to December, only when the flow occurring at Ban Ban is 0 ML/d and there is combined inflow of West Barambah and Glenmore>10 ML/d and Medium Priority announced allocation is greater than 5%.

- Paradise Dam–no low flow rule as flow requirements can be achieved through irrigation releases. In addition, the alternate high flow rules also facilitate *N. forsteri* spawning (see chapter 6).

The risk assessment was assessed against the modelling results described in Table 1.

Table 1 Modelling scenarios used in the risk assessments for *N. forsteri*

<table>
<tr><th rowspan="2">Location</th><th rowspan="2">IQQM node number</th><th colspan="4">Scenario</th></tr>
<tr><th>Pre-development</th><th>Base case</th><th>Alternate management rules</th><th>Alternate rules including unallocated water</th></tr>
<tr><td colspan="6">Upper Burnett Water Supply Scheme</td></tr>
<tr><td>Burnett River at Mt Lawless Gauging Station (136002D)</td><td>577</td><td rowspan="2">311b</td><td rowspan="2">312a</td><td rowspan="2">357a</td><td rowspan="2">363a</td></tr>
<tr><td>Burnett River at Jones Weir Tailwater (136094A)</td><td>604</td></tr>
<tr><td colspan="6">Barker Barambah Water Supply Scheme</td></tr>
<tr><td>Barambah Creek at Ban Ban Gauging Station (136207A)</td><td>377</td><td>305b</td><td>329a</td><td>335a</td><td>350b</td></tr>
<tr><td colspan="6">Boyne River and Tarong Water Supply Scheme</td></tr>
<tr><td>Boyne River at Derra Gauging Station (136318A)</td><td>236</td><td>305b</td><td>305a</td><td>-</td><td>-</td></tr>
<tr><td colspan="6">Bundaberg Water Supply Scheme</td></tr>
<tr><td>Burnett River at Figtree Gauging Station (136007A)</td><td>812</td><td rowspan="2">312b</td><td rowspan="2">339a</td><td rowspan="2">343b</td><td rowspan="2">366a</td></tr>
<tr><td>Burnett River at Ned Churchward Weir Tailwater (136008C)</td><td>844</td></tr>
</table>

3.1.2 Results

The change in the number of flow events satisfying *N. forsteri* requirements varied throughout the catchment (Table 2). Locations where more than 30% of years were at high risk included Jones Weir Tailwater, Ban Ban and Mount Lawless. In contrast, sites such as Derra, Figtree and Ned Churchward Weir Tailwater generally had a low number of years at high risk. Flow supplementation at these latter sites reduced the number of years that were at high risk.

There was no change in the risk profile between the base case and the alternate management rules scenario. Also, there was no difference when proposed unallocated water volumes were included, except for the Ban Ban site where there was a marginal increase in the high risk profile.

Considering the individual node failures, the proportion of years of the simulation period that *N. forsteri* is within the moderate risk category across the basin has increased from 28% of time in the base case to ~30% of time with the alternate management rules (Table 2). The unallocated water scenario increased the percentage of years of moderate risk to ~32%. The increase in risk is due solely to a single year of failure at Figtree in 1995 which extends an existing period of failure and simultaneously occurs at other sites.

Table 2 Percent of years in the simulation period that *N. forsteri* were at different levels of risk both at a site level and overall for the predevelopment and development cases.

Location	Pre-development	Base case	Alternate management rules	Alternate rules including unallocated water
Burnett River at Mt Lawless Gauging Station (136002D) - IQQM node 577				
Percentage of years with low risk	94.9	73.7	73.7	73.7
Percentage of years with high risk	5.1	26.3	26.3	26.3
Burnett River at Jones Weir Tailwater (136094A) - IQQM node 604				
Percentage of years with low risk	78.8	51.7	51.7	51.7
Percentage of years with high risk	21.2	48.3	48.3	48.3
Barambah Creek at Ban Ban Gauging Station (136207A) - IQQM node 377				
Percentage of years with low risk	90.6	67.5	67.5	65.0
Percentage of years with high risk	9.4	32.5	32.5	35.0
Boyne River at Derra Gauging Station (136318A) - IQQM node 236				
Percentage of years with low risk	86.4	87.3	87.3	87.3
Percentage of years with high risk	13.6	12.7	12.7	12.7
Burnett River at Figtree Gauging Station (136007A) - IQQM node 812				
Percentage of years with low risk	100	100	100	100
Percentage of years with high risk	0.0	0.0	0.0	0.0
Burnett River at Ned Churchward Weir Tailwater (136008C) - IQQM node 844				
Percentage of years with low risk	100	100	100	100
Percentage of years with high risk	0.0	0.0	0.0	0.0
ALL SITES				
Percentage of years with moderate risk	6.8	28.0	30.5	32.2
Percentage of years with high risk	0.8	0.0	0.0	0.0

3.1.3 Discussion

The assessment found that while there was no change in risk between base case and alternate management rules for all sites, there was an increase in risk at the Ban Ban site for the unallocated water volume scenario. However, during extended periods of low flow, critical water supply arrangements supersede environmental releases. Apart from Barker Barambah Water Supply Scheme, the base case does not include modelling of critical water supply arrangements. Critical supply arrangements cannot be modelled because they are used only in extreme events and are not predictable in their application. Therefore it is believed that the base case is underestimating the impact of drought on low flows and consequently underestimating risk.

Part of the purpose of the critical supply arrangements has been to protect high priority demands - like urban demands. The alternate water sharing rules provides similar protection for high priority water allocations by first reserving high priority water for future years. Modelling indicates that the reserves used in modelling the alternate rules are sufficient to supply high priority demands through all critical periods in the simulation. This approach removes the need for separate critical water supply arrangements making the environmental releases more predictable, accessible and gives a better indication of risk.

The alternate management rules also align more closely to the eco-hydraulic requirements of *N. forsteri*. For example, the current environmental management rule for Claude Wharton Weir does not provide for releases between August and October, a key breeding period for *N. forsteri* and many other aquatic species. Similarly, in the Barker Barambah Water Supply Scheme, there are currently no specific environmental releases. In this scheme a

compensation flow management rule aims at providing for stock and domestic requirements throughout the year. Under the alternate management rules, environmental releases will be made inline with natural inflows. This provides a more natural flow regime and aims to maintain aquatic macrophyte growth prior and during the spawning season. In the case of Ned Churchward Weir and Paradise Dam, monitoring has shown that near-constant release can cause silt deposition on macrophytes downstream. By varying release rates from the storages based on inflow, it is anticipated that the silt will be removed, providing ideal habitat for *N. forsteri* spawning.

Aligning the alternate rules with the eco-hydraulic requirements of *N. forsteri* will also benefit other species with critical links to low flows. For example, Agassizi's Glassfish (*Ambassis agassizii*) requires stable low flows during the spawning season (spring to early summer), and elevated discharge to cue or facilitate mass upstream dispersal movement. Similarly, the long finned Eel (*Anguilla reinhardtii*) requires longitudinal connectivity for adult spawning migration and juvenile dispersal between September and December. Sea Mullet (*Mugil cephalus*) also requires small flows that create longitudinal connectivity for adult spawning migration and juvenile dispersal. Bullrout (*Notesthes robusta*) also requires low flows in late winter and early spring to initiate spawning.

3.2 White-throated snapping turtle (*Elseya albagula*)

In an assessment of eco-hydraulic rules (Ecological Asset Selection Report), it was found that up to 20% of *Elseya albagula* turtle nest aggregations are found within 1.3 m of the standing water level at the time of nesting (May to July) (data from Duncan Limpus, pers comm. 2010; Hollier 2010). Expert advice suggests that alongside nest predation and trampling, inundation of as little as 20% of nest aggregations presents a threat to the population viability and has therefore been identified as a ToC.

To analyse the risk to *E. albagula*, a node failure was defined as two or more sequential years where the water level of Ben Anderson Barrage rose more that 1.3 m in August to December (incubation period) from the minimum water level in May to July (nesting period). The risk assessment of the current management arrangements found that there appears to be a reduction of risk to nest inundation in the riverine reach above the barrage compared to the predevelopment scenario as upstream storages mitigate fluctuations in water levels (see Ecological risk assessment for selected ecological assets). However, an assessment of the current nominal operating levels (NOL) (see Assessment of alternative environmental management rules) suggests that the risk can be further reduced by reassessing the Ben Anderson Barrage NOL.

3.2.1 Alternate environmental management rules

Alternate environmental management rules aim to reduce nest inundation by implementing a seasonal NOL for Ben Anderson Barrage that firstly provides nesting sites higher up the river bank (a high NOL between May and July). Then reduces the NOL during incubation to create a buffer between the standing water level and the nesting aggregations (a low NOL between August and April). The alternate rules are as follows and also presented in Attachment 1:

- Set the Ben Anderson Barrage NOL at 3 m AHD for May to July.
- Set the Ben Anderson Barrage NOL at 2.2 m AHD for August to April.

In addition, the variable NOL has been selected to maximise fishway operation while still providing storage for capturing inflows. The risk assessment was assessed against the modelling results described in Table 3.

Table 3 Modelling scenarios used in the risk assessments for *E. albagula*

Location	IQQM node number	Scenario			
		Pre-development	Base case	Alternate management rules	Alternate rules including unallocated water
Bundaberg Water Supply Scheme					
Burnett River at Ned Churchward Weir Tailwater - riverine reach upstream of barrage (136008C)	844	312b	339a	343b	366a
Burnett River at Ben Anderson Barrage (storage volume)	852				

3.2.2 Results

The alternate seasonal NOL of 3 m during the nesting season reduced node failures from 7.6% under the base case scenario to ~3.4% (Table 4). The addition of unallocated water further reduced the risk to 2.5% of years primarily due to the increased extraction of water upstream.

Table 4 Percent of years in the simulation period that *E. albagula* were at different levels of risk for the predevelopment and development cases both for the main nesting banks in the Ben Anderson Barrage and the riverine reach upstream.

	Pre-development	Base case	Alternate management rules	Alternate rules including unallocated water
Burnett River at Ned Churchward Weir Tailwater (riverine reach upstream of barrage)–IQQM node 844				
Percentage of years with low risk	86.5%	89.1%	95.0%	95.0%
Percentage of years with high risk	13.4%	10.9%	5.0%	5.0%
Burnett River at Ben Anderson Barrage (storage volume) - IQQM node 852				
Percentage of years with low risk	NA	92.4%	96.6%	97.5%
Percentage of years with high risk	NA	7.6%	3.4%	2.5%

For the riverine reach upstream of the Ben Anderson Barrage, changes to the barrage NOL do not affect this reach as it remains riverine. Further, changes to other environmental management rules (such as the releases from Paradise Dam and Ned Churchward Weir - see section 4.2) reduced the risk of nest inundation from ~11% (base case) to ~5%. The inclusion of unallocated water did not change the risk of inundation in this reach.

3.2.3 Discussion

Nesting aggregations within the Ben Anderson Barrage are considered key habitat to the long term viability of the *E. albagula* populations in the Burnett catchment. Preventing nest inundation needs to be a key water management objective, as the compounding effect of nest inundation alongside nest predation is threatening the viability of the species. Modelling shows that introducing a seasonal NOL in Ben Anderson Barrage may reduce nest inundation. This is a clear and transparent operating arrangement that can be readily implemented. It provides a targeted ecological benefit without significantly impacting on the reliability of the water allocations within this reach of the Bundaberg Water Supply Scheme.

It is believed that setting a higher NOL for May and June will result in the turtles nesting higher up the bank. Previous studies have found that 20% of turtle nests are within 1.3 m of the standing water level. However, other factors may influence nesting site selection such as the slope of the bank, the level of vegetation and shading. Above the proposed 3m NOL is a more preferred habitat including riparian vegetation shading. The nesting habits

of the turtles should continue to be monitored to ensure that this management arrangement achieves its intended outcome.

The seasonal NOL may also benefit aquatic macrophytes within the storage by providing a more stable water level. While *E. albagula* are able to feed on fruit from overhanging vegetation, freshwater sponges, some aquatic invertebrates and filamentous algae, Tucker et al 2012 found that the food source for this species changed in storages due to the fluctuating water levels. By maintaining a more stable water level, it is anticipated that the macrophyte growth would be more stable and therefore more suitable food may also be available for *E. albagula.*

Changing the existing NOL will also have other ecological benefits. For example, under the current management arrangements, the fish passage has been operational for ~ 40% of the time over the simulation period. Setting the NOL at a minimum of 2.2 m means that the Ben Anderson Barrage fishway would operate for 100% of the time. Increased fishway operation allows catadromous fish species such as barramundi access to both fresh and salt water habitats at critical points in their life cycle. See section 5 for further discussion on fishway operation.

3.3 Waterholes as refugia

The ecological risk assessment analysed the persistence of three key waterholes in the Burnett Basin: the Bunyip waterhole on Three Moon Creek; Gray's waterhole on the Burnett River downstream of Claude Wharton Weir; and Dr May's waterhole on the Elliott River. The assessment found that the persistence of each waterhole (in days) significantly exceeds the longest period of no-flow recorded over the past 127 years, and as such were not considered at risk (see waterholes section of Appendix B).

However, an assessment of the current environmental management rules (Appendix C) found that the current low flow release rules for Claude Wharton Weir need refining to address issues highlighted in the lungfish risk assessment. These changes may have a consequential affect on the connectivity between smaller waterholes downstream of the weir, while additionally providing flows to Gray's Waterhole.

3.3.1 Alternate environmental management rules

While there are no specific rules that relate to releasing water to maintain waterholes, it is still important to identify how the alternate management arrangements could also change risk. For example, within the Gregory and Isis catchment, the water extraction is unsupplemented, meaning there is no infrastructure that supports the supply of water. As the volume of water taken in these catchments is relatively low, there may be some scope to providing unallocated water in the system (Attachment 1) without negatively impacting either existing entitlement holders or the environment. In other areas, like the Upper Burnett Water Supply Schemes, environmental management rules have been developed around providing low flows for assets like the lungfish. However, these releases also provide a secondary benefit by contributing flows to downstream waterholes. Therefore, the purpose of this section is to assess how the combination of alternate management arrangements would impact on the function of waterholes as refugial habitat in the Burnett Basin.

Table 5 Modelling scenarios used in the assessment of waterhole persistence

Location	**IQQM node number**	**Scenario**			
		Pre-development	**Base case**	**Alternate management rules**	**Alternate rules including unallocated water**
Burnett River at Mt Lawless Gauging Station (136002D)	577	311b	312a	357a	363a
Three Moon Creek at Abercorn Gauging Station (136101C)	083	355b	371a	NA	374b
Elliott River at Dr Mays (137001B)	010	301b	376b	NA	383a

3.3.2 Results

The alternate water sharing and environmental management rules have had minimal impact on the longest period of no flow over the simulation (Figure 1). While there was no difference either at Abercorn or Dr Mays, the alternate rules reduced the longest no flow spell at Mt Lawless. The addition of unallocated water, however, slightly increased the maximum period of no flow at Mt Lawless.

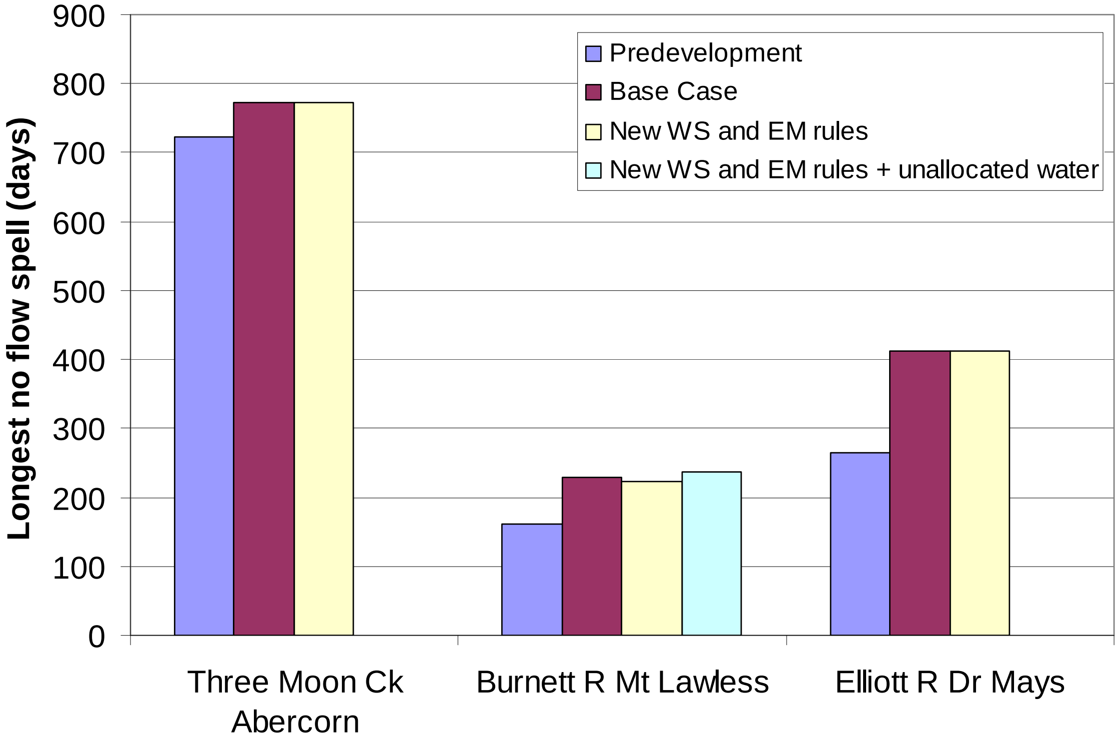

Figure 1 Maximum no-flow spells for waterholes in the Burnett Basin.

These simulated periods of no flow are significantly less than the estimated persistence time for each of the three waterholes (Table 6). Persistence times were the same as those used in assessment of risk for the current environmental management rules (Appendix B).

Table 6 Estimated persistence time for Burnett Basin waterholes

Waterhole	Maximum depth (m)	Persistence (days)
Bunyip Waterhole (Three Moon Creek)	9.6	2 028
Grays Waterhole (Burnett River)	10.3	1 980
Dr Mays Waterhole (Elliott River)	11	2 290

3.3.3 Discussion

Water resource development does not appear to have a significant impact on the persistence and consequential refugial qualities of large waterholes in the Burnett Basin. While there may be some impacts on smaller waterholes (such as those downstream from Claude Wharton Weir), this impact has not been not been quantified. It is recommended that no changes are made to the alternate environmental management arrangements to accommodate waterholes. It is also recommended that smaller waterholes are monitored so that future risk assessments can assess what impacts, if any, water resource development presents.

4 High flow assessment

4.1 Introduction

High flows are defined as any flow with a magnitude between the 1:1 and 1:5 year Average Recurrence Interval (ARI) flow. They have a minimum occurrence probability of 20% in any year. A flow of this magnitude includes flows which approach bank full and may inundate lower flood runners and floodplains. High flows provide assets with opportunities for migration, dispersal, geomorphic maintenance or estuarine brackish habitat. High flows have the velocity and discharge to maintain the existing geomorphic features such as riffles and waterholes through mobilisation of deposited sediment. In addition, the frequency of these flows (< 5 years on average), provides frequent scouring that reduces the encroachment of instream vegetation.

High flows also provide sufficient freshwater influence to maintain estuarine habitat and have been correlated with increased estuarine productivity (Loneragan & Bunn 1999). Estuarine habitats are important nursery and refugial zones for the early life-history stages of many aquatic species (Williamson et al. 1994). Significant freshwater flows to estuaries can also trigger life history responses in fish species including spawning migrations and recruitment (Harris 1986). For example, barramundi require high flows for longitudinal and lateral connectivity for upstream and downstream migration (Pusey et al. 2004).

In the Burnett Basin the asset selected to represent species and processes dependent on high flows is estuarine brackish habitat. Appendix A defined a Threshold of Concern (ToC) for brackish flows as an event that results in achieving brackish condition in the estuary. For these assessments, brackish conditions are achieved when the salinity levels are 15‰ (parts per thousand) at the midpoint of the estuary–called a Brackish Flow Event (BFE).

While many factors contribute to brackish habitat, like flow duration, flow magnitude and river morphology assessments identified a relationship between peak flow and brackish conditions in each of the estuaries in the Burnett Basin (Appendix A). For example, a BFE in the Burnett River has been identified as a flow with a peak magnitude of 10 000 ML/d entering the estuary.

Additionally, the assessment looked at growth of *F. merguiensis* and *L. calcarifer* Year Class Strength (YCS, seasonal strength of population recruitment in an area). These assessments have been included to provide a comparison about how total volumes of water entering the estuary have changed under different management scenarios. For YCS, node failure was defined in terms of consecutive years of poor recruitment in relation to the *L. calcarifer* lifespan.

The risk to the estuary under the current management rules (Appendix B) when compared to the predevelopment scenario for the indicator assets found that there was a reduction in the frequency of BFE's in the Elliott, Kolan, Burnett and Gregory estuaries. Additionally, the assessment for the Elliott and Burnett estuaries, found there was an increase in the sequential years without a BFE, exceeding the ToC for *F. merguiensis*.

An assessment of the current environmental management rules (Appendix C) found that storage operation and medium/high flow release rules do not align with the flow requirements that provide brackish habitat. For example, the high flow release rule from Paradise Dam operated infrequently, and would only operate when there was a substantial overtopping event.

The following sections examine how the alternate management rules change the risk to the reoccurrence of brackish habitat for the viability of *F. merguiensis*, *L. calcarifer*, *M. cephalus* and *A. corniculatum*. It also assesses growth of *F. merguiensis* and *L. calcarifer* YCS. The results are then discussed in the context of managing high flows across the Burnett Basin.

4.2 Alternate environmental management rules

An assessment of the current environmental management rules (Appendix C) found that storage operation and medium/high flow release rules currently do not align with the flow requirements that provide estuarine brackish habitat. It was recommended that the rules be reassessed by:

- Reviewing infrastructure operating rules for Paradise Dam to ensure flows transmitted to the estuary.
- Removing the Bucca Weir release rule as the 380 ML/d release is insufficient to extend estuarine brackish habitat.
- Changing season and height of Bucca Weir NOL to provide for more flows during the summer months.
- Reviewing to align medium/high flows from Bucca and Fred Haigh Dam with an inflow/outflow rule.

Alternate environmental management rules were assessed to identify if the risk profile could be changed by:

- Paradise Dam – implement an inflow/outflow rule capped at 14 000 ML/day from September to December (when the level in Paradise Dam is above 63.45m AHD).
- Changing season and height of Bucca Weir NOL to 14 m from September to March.

Despite Appendix C recommending implementation of an inflow/outflow rule for Bucca Weir and Fred Haigh Dam to provide for estuarine brackish habitat, the risk assessment (Appendix B) suggests that the risk is negligible. It is thought that changing the Bucca Weir NOL should provide sufficient freshwater inputs during the summer months without increasing risk. These alternate rules have been assessed against the pre-development and base case scenarios (Table 7).

Table 7 Modelling scenarios used in the risk assessment of estuarine brackish habitat

Location	IQQM node number	Scenario			
		Pre-development	Base case	Alternate management rules	Alternate rules including unallocated water
Burnett River at Ben Anderson Barrage Tailwater (no gauge)	952	312b	339a	343b	366a
Kolan River at Kolan Barrage Tailwater (no gauge)	737				
Elliott River at Dr Mays (137003A)	010	301b	376b	NA	383a
Isis River at End Of System (no gauge)[1]	012	305b	377a	NA	386a
Gregory River at End Of System (no gauge)[2]	107	364b	378b	NA	388a

4.3 Results

4.3.1 Estuarine brackish habitat

Banana prawns (*Fenneropenaeus merguiensis*)

In the Burnett River, the alternate management rules increased the low and high risk profiles (0.9%) and decreased the moderate risk category for *F. merguiensis* when compared to the base case (Table 8). However, the proposed unallocated water scenario increased the moderate risk category such that it is slightly higher than the base case.

[1] See Schedule 1 of the Burnett WRP for site location map
[2] See Schedule 1 of the Burnett WRP for site location map

For all other river systems except the Isis River, there was no change to the risk profiles for estuarine brackish habitat either through alternate management rules or addition of unallocated water (Table 8). In the Isis River, there was only a slight increase in the moderate risk category when compared to the base case.

Barramundi (*Lates calcarifer*)

Assessment of the alternate management rules for the Burnett River found that the moderate risk profile for brackish habitat increased by 1% when compared to the base case (Table 8). There was no change to the risk profile with the addition of unallocated water. Looking at the results more closely, the change was the result of an additional year without a BFE in 2007 (increases the sequence from 3 to 4 years) that exceeded the threshold of concern. As this reflects a change to a single event and considering the longevity of the species, it is reasonable to suggest that there would be no long-term changes to risk for the species. For all other river systems there was no change to the risk profiles for the alternate management scenarios as compared to the existing arrangements.

Sea mullet (*Mugil cephalus*) and river mangrove (*Aegiceras corniculatum*)

The assessment of the alternate environmental management rules found that the BFEs suitable for *M. cephalus* and *A. corniculatum* were similar to the base case (Table 8). For the Burnett River there was one event over the entire simulation period that moved from low to moderate risk category. For all other river systems there was no change to the risk profiles under the alternate management scenarios.

4.3.2 *Fenneropenaeus merguiensis* daily growth

The assessment of the alternate management rules found that the daily growth rate of *F. merguiensis* in the Burnett and Kolan Rivers decreases by 0.7% and 1.1% respectively when compared to the base case. For the Burnett River, this reduction in growth occurred in spring, autumn and winter. In the Kolan River this reduction occurred in autumn only. The proposed unallocated water scenario in the Burnett River further reduced average growth by another 1.4%. For all other river systems there was no change to the risk profiles for growth under the alternate management rules or the proposed unallocated water scenario (Table 9).

4.3.3 *Lates calcarifer* Year Class Strength

Assessment of the alternate environmental management rules shows a decrease in the moderate and high risk years for YCS in the Burnett River (Table 10) when compared to the base case scenario by ~4 and 3% respectively. In contrast, addition of the unallocated water increased the percentage of years of moderate and high risk to ~3 and 6% higher than the base case. In the Kolan River, there was ~ 2.5% increase in the moderate risk years for both the alternate environmental management rules as well as the unallocated water scenario. There was no change in the YCS risk profile for the Elliot, Isis or Gregory rivers.

Table 8 Percent of years in the simulation period at different levels of risk for the predevelopment and development cases the provision of brackish habitat for estuarine ecological assets.

	Burnett River at Ben Anderson Barrage Tailwater (no gauge) - IQQM node 952				Kolan River at Kolan Barrage Tailwater (no gauge) - IQQM node 737				Elliott River at Dr Mays (137003A) - IQQM node 010			Isis River at End of System (no gauge) - IQQM node 012			Gregory River at End of System (no gauge) - IQQM node 107)		
	PD[3]	BC	A[4]	B [5]	PD	BC	A	B	PD	BC	A	PD	BC	B	PD	BC	B
F. merguiensis																	
Percentage of years with moderate risk	6.8	22.2	20.5	23.1	12.0	15.4	15.4	15.4	11.1	18.8	18.8	2.6	2.6	3.4	3.4	8.5	8.5
Percentage of years with high risk	1.7	12.0	12.8	12.8	0.9	5.1	5.1	5.1	0.0	13.7	13.7	0.0	0.0	0.0	0.0	0.0	0.0
L. calcarifer																	
Percentage of years with moderate risk	0.9	4.3	5.2	5.2	0.0	1.7	1.7	1.7	0.9	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of years with high risk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M. cephalus																	
Percentage of years with moderate risk	0.9	4.3	5.2	5.2	0.0	1.7	1.7	1.7	0.9	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of years with high risk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
A. corniculatum																	
Percentage of years with moderate risk	1.7	12.0	12.8	12.8	0.9	5.1	5.1	5.1	0.0	13.7	13.7	0.0	0.0	0.0	0.0	0.0	0.0
Percentage of years with high risk	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

[3] See Methodology section for full description of scenarios
[4] New water sharing and environmental management rules
[5] New water sharing and environmental management rules and unallocated water

Table 9 Total percent deviation in *F. merguiensis* daily growth between the predevelopment and development cases.

	Burnett River at Ben Anderson Barrage Tailwater (no gauge) - IQQM node 952				Kolan River at Kolan Barrage Tailwater (no gauge) - IQQM node 737				Elliott River at Dr Mays (137003A) - IQQM node 010			Isis River at End of System (no gauge) - IQQM node 012			Gregory River at End of System (no gauge) - IQQM node 107		
	PD	**BC**	**A**	**B**	**PD**	**BC**	**A**	**B**	**PD**	**BC**	**A**	**PD**	**BC**	**B**	**PD**	**BC**	**B**
All seasons	0.143	0.100	0.099	0.097	0.097	0.083	0.082	0.082	0.049	0.047	0.047	0.057	0.057	0.057	0.063	0.061	0.060
% change from PD		-30.1	-30.8	-32.2		-14.4	-15.5	-15.5		-4.1	-4.1		0.0	0.0		-3.2	-4.8
Spring	0.107	0.081	0.080	0.079	0.080	0.072	0.072	0.072	0.043	0.042	0.042	0.045	0.044	0.044	0.045	0.044	0.044
% change from PD		-24.3	-25.2	-26.2		-10.0	-10.0	-10.0		-2.3	-2.3		-2.2	-2.2		-2.2	-2.2
Summer	0.172	0.103	0.105	0.103	0.107	0.086	0.086	0.086	0.089	0.085	0.085	0.102	0.101	0.101	0.110	0.106	0.106
% change from PD		-40.1	-39.0	-40.1		-19.6	-19.6	-19.6		-4.5	-4.5		-1.0	-1.0		-3.6	-3.6
Autumn	0.213	0.159	0.156	0.153	0.155	0.134	0.130	0.130	0.061	0.057	0.057	0.077	0.076	0.076	0.088	0.085	0.085
% change from PD		-25.4	-26.8	-28.2		-13.5	-16.1	-16.1		-6.6	-6.6		-1.3	-1.3		-3.4	-3.4
Winter	0.079	0.057	0.056	0.055	0.046	0.038	0.038	0.038	0.004	0.004	0.004	0.006	0.006	0.006	0.009	0.008	0.008
% change from PD		-27.8	-29.1	-30.4		-17.4	-17.4	-17.4		0.0	0.0		0.0	0.0		-11.1	-11.1

Table 10 Total percent deviation of *L. calcarifer* Year Class Strength for moderate and high risk spells for the predevelopment and development cases.

	Burnett River at Ben Anderson Barrage Tailwater (no gauge) - IQQM node 952				Kolan River at Kolan Barage Tailwater (no gauge) - IQQM node 737				Elliott River at Dr Mays (137003A) - IQQM node 010			Isis River at End of System (no gauge) - IQQM node 012			Gregory River at End of System (no gauge) - IQQM node 107		
	PD	BC	A	B	PD	BC	A	B	PD	BC	A	PD	BC	B	PD	BC	B
Percentage of years with moderate risk	0.0	18.4	16.7	21.1	1.8	14.9	17.5	17.5	0.0	24.5	24.5	5.3	6.1	6.1	4.4	7.9	7.9
Percentage of years with high risk	0.0	7.9	4.4	14.0	0.0	0.0	0.0	0.0	0.0	10.5	10.5	0.0	0.0	0.0	0.0	0.0	0.0

4.4 Discussion

Assessment of alternate water sharing and environmental management rules has found that there is very little change in the risk profiles of the estuarine ecological assets when compared to the current base case. The alternate rules aimed at aligning releases with the eco-hydraulic needs of the estuary, particularly for providing brackish flows during key months. In this instance the alternate rules are focused on inflow/outflow arrangements as these mimic natural flows.

There are many limitations on how environmental releases can be managed to change risk. For example, constructing a release may not represent ecological needs. The rule may require that water be released regardless of prevailing conditions. This may result in water being released even when other flows may already satisfy the needs of the estuary. An example of this is the Bucca Weir strategy in the Kolan River that once triggered continues to make releases even though downstream targets may have been achieved. The implications of these types of rules are that they may:

1. not provide any demonstrable ecological benefit, impacting on the reliability of water allocations;
2. involve complex rules that are difficult to implement; and
3. be constrained by infrastructure.

With these limitations in mind, inflow/outflow rules represent a preferred approach for achieving environmental outcomes.

One of the main reasons why the risk has not significantly changed with the introduction of an inflow/outflow rule is that volume of water entering the lower Burnett is significantly less when compared to the predevelopment scenario. For example the Burnett River is a highly regulated system, with three major water supply schemes above Paradise Dam. A comparison of the predevelopment flows with flows under both the base case and the alternate management rules have found that the BFE do not enter the system as frequently or with the same magnitude as they would have under the predevelopment scenario. Therefore the introduction of an inflow/outflow rule cannot significantly change the risk unless steps are taken to also pass flows through upstream water supply schemes.

One of the significant changes to the current management rules is the proposal to remove environmental releases on the Kolan River. The assessment of existing management rules report indicated that the risk to the Kolan River estuary was low. Assessment of the alternate environmental management rules confirmed that the risk did not change when these rules were removed. One explanation for this is that Fred Haigh Dam is located in the top part of the catchment, and suitable flows to the estuary are actually being achieved from local rainfall/runoff events. Therefore it is recommended that as part of the review, consideration can be given to removing the current environmental rules associated with the Kolan River.

One assumption of the environmental risk assessment has been quantifying brackish flow in terms of flow events. There are a number of factors that influence brackish conditions. For example flow magnitude, volume and estuary morphology affects both the extent and duration of brackish habitat. These risk assessments do not account for how smaller flows provide brackish habitat nor the minimum brackish conditions needed to sustain the function of the estuary. It also does not look at the value of larger flows for achieving a complete freshwater flush through the system.

5 Fishway operation and other release rules

Although not explicitly assessed via the EFAP process, fishway operation was identified as being critical in facilitating longitudinal connectivity in the Burnett Basin. Fish passage is facilitated through the operation of fishways which is dependent in many cases on the Nominal Operating Levels (NOLs) of the storage. A number of weirs in the Burnet Basin were identified as not providing for fish passage during key fish migration months as the NOL was below fishway entrances. It is proposed that the storage NOL is set to at least the level of the fishway entrances as follows:

- Ned Churchward Weir: 13.5 m all year
- Kirar Weir: 149.6 m July to December (key migration period)
- Ben Anderson Barrage: 2.2 m AHD for August to April and 3m AHD for May to July (see section 3.2.1).

The changes to the NOL in Ben Anderson Barrage for example has changed the fishway operation from ~40% of time (base case) to ~100% of time under the alternate water sharing and environmental management rules.

In addition the NOL can also impact on the frequency of storage spills impacting on downstream environments. To facilitate estuary flows it is proposed that the Bucca Weir NOL is set as 12.2 m AHD for April to August and 14 m AHD for September to March

Further description of the proposed changes to NOLs for storages and reasoning behind each change are shown in Attachment 1.

Although it is recommended that no environmental release rules are required for the Kolan River, fish kills have been observed downstream of Bucca Weir where irrigation releases have suddenly ceased. A constant release is recommended to maintain oxygen levels and prevent the pools from stagnating. It is proposed that a 5ML/d release from Bucca Weir would provide connectivity between pools, maintain riffle zones and oxygen levels and provide water to limit desiccation of aquatic macrophytes.

6 Overall conclusions and recommendations

The assessments of risk to ecological assets through the application of the alternate management rules to be included in the draft new Burnett WRP has found that:

- The *N. forsteri* assessment highlighted that water resource development has the potential to cause simultaneous failure of a number of nodes in the Burnett Basin. The risk profile showed an increase in the moderate risk category (50 to 75% of nodes simultaneously failing) when compared to the base case. This increase is due to an additional single year failure at one node. In addition, the scenarios tested could not fully include historical critical water supply arrangements which cease or reduce environmental flows during dry periods. Hence, although the risk assessment shows that there is increased risk from the introduction of the alternate rules, the alternate rules better reflect the hydrology of the system.
- For *E. albagula*, the alternate rules reduce the likelihood of nest inundation within the core nesting habitat primarily due to the raising of the Ben Anderson Barrage NOL during nesting season (May to July). In addition, a reduction in nest inundation in riverine habitat upstream of the barrage occurs as a result of the capture of inflows and overtopping flows in upstream storages. The alternate rules are a simplified approach for providing suitable nesting habitat that can be easily implemented.
- For the assessment of waterhole persistence, there was very limited change to the maximum no flow spell duration for any of the three waterholes (Bunyip, Gray's and Dr Mays), with these durations being much less than the maximum persistence times of the waterholes. Therefore the alternate rules did not have any negative impact on the ability of waterholes to serve as refugial habitat during prolonged drought periods
- For the assessment of estuarine brackish species, *F. merguiensis*, *L. calcarifer*, *M. cephalus* and *A. corniculatum.*
  - For the Burnett River, there is no change to the risk to the provision of estuarine brackish habitat of the indicator species. However there was a reduction in the risk profile for *L. calcarifer* YCS for the scenario

including alternate water sharing and environmental management rules. There was, however, a larger increase in risk for *L. calcarifer* YCS from the unallocated water scenario. There is a slight reduction in banana prawn growth associated with the alternate water sharing and environmental management rules, with this trend increasing with the addition of unallocated water. It is suggested that the cumulative impact of upstream infrastructure has affected the reoccurrence and duration of estuary flows. Therefore, it is difficult to implement an inflow/outlfow rule that would provide more brackish flow events without also implementing similar rules in upstream water supply schemes.

- For Elliott and Kolan Rivers there is no change risk for the provision of estuarine brackish habitat as well as *F. merguiensis* growth, and a slight increase in the risk to *L. calcarifer* YCS in the Kolan River when compared to the base case. In the Kolan River particularly, it is suggested that local rainfall/runoff events are sufficient for creating regular brackish conditions that support the functioning of the estuary.
- For the Isis and Gregory Rivers there was virtually no change in risk for the provision of estuarine brackish habitat, *L. calcarifer* YCS or *F. merguiensis* growth.

While the alternate rules may not have changed the risk profile, they do still have merit. The alternate rules attempt to consolidate ecological understanding of ecological assets across the Burnett Basin while operating within the constraints of existing infrastructure as well as considering the effects of upstream water supply schemes. The alternate rules:

1. Make ecological sense and can be easily communicated
2. Simplifies the existing rules making it easier to implement
3. Do not make unnecessary releases and matches ecological requirements (e.g. Inflow/outflow rules match the incoming flows and provide for natural flow variability)
4. Utilises irrigation releases improving efficiency
5. Works conjunctively with other management strategies–e.g. raising infrastructure operating levels increases overtopping events and better aligns water levels with fishways
6. One rule can meet the needs of multiple flow requirements (e.g. Paradise Dam releases satisfy the high flow requirements of the estuarine ecological assets whilst also providing for low flows for assets such as the Australian lungfish)

The implications are that when compared to the existing rules, the alternate rules are more likely to provide an important flow when it is needed most. It is recommended that a revision of the management rules continue to support inflow/outflow rules.

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Attachment 1–summary of alternate environmental release rules

Table 11 Low Flow Assets

Rule type	Appendix A – biological rules	Appendix B – risk assessment	Appendix C- assessment of existing rules	Description of current ROP rules	Appendix E – alternate scenario
***Neoceratodus forsteri* ecological asset**					
Upper Burnett Water Supply Scheme - Claude Wharton Weir					
Releases	0.3 m rise in streamflow above the cease to flow, persisting for 30 days between August and December.	Water resource development has reduced low flows, increasing risk to low flow assets. The flows required are within the operational capacity of the impoundment. Recommend: Low flow releases should be introduced that mimic natural events.	Releases were generally smaller volumes and were insufficient to stimulate spawning and did not align with spawning period. The critical water supply arrangements limited releases in some years. Recommend: Low flow releases be made to support lungfish spawning and fish migration (September to March).	Low flow: 1. Jun: inflows > 74ML/d, release 74ML/d; 2. Nov: inflows > 109ML/d, release 109ML/d; 3. Dec: inflows > 305ML/d, release 305ML/d. Note: applies when storage above NOL and not under critical water supply arrangements.	Low flow release for September to March (aligning with lungfish spawning requirements): All inflows that exceed 50ML/d are to be released to a maximum of 150ML/d. No change to the risk profile at this point. Recommend: Support rules that align with ecological requirements during key months.
Barker Barambah Water Supply Scheme - Silverleaf Weir					
Releases	0.3 m rise in streamflow above the cease to flow, persisting for 30 days between August and December.	Water resource development has reduced low flows, increasing risk to low flow assets. The flows required are within the operational capacity of the impoundment. Recommend: Low flow releases should be introduced that mimic natural events.	No specific low flow release for lungfish spawning, however compensation flow release maintained throughout the year. This release is not targeted at low flow assets. Recommend: current arrangements are reviewed to identify whether a release rule could be adopted that aligns with both ecological outcomes and stock and domestic needs.	Compensation flow releases: 1. If the flow at Stonelands is <15ML/d for 90 consecutive days, then passing flow is to be maintained at Silverleaf Weir to ensure a minimum flow of 15ML/d at Stonelands if flows at West Barambah are greater than 2ML/d. The total number of days for this release is seven days; and 2. If the flow at Stonelands is <15ML/d for 120 consecutive days, then a passing flow is to be maintained at Silverleaf Weir to ensure a minimum flow of 15ML/d at Stonelands. The total number of days for this release is seven days. There are no additional restrictions on supplemented entitlement holders when low flows are released.	1. **Compensation flow:** A minimum passing flow of 5ML/d at Stonelands is to be maintained during July to December, only when the flow occurring at Ban Ban is 0ML/d and there is combined inflow at West Barambah and Glenmore >10ML/d. 2. **Low Flow**. A flow at Stonelands (GS136206A) equal to 2/3 of the combined flow rate at West Barambah (GS136213A) and Glenmore (GS136209A) up to a maximum flow rate of 50 ML/day is to be maintained between September 1 to December 31when the combined flow rate is >15 ML/d. Releases are not required when there is a flow rate > 50ML/d at Ban Ban. Releases are not permitted when the Barker Barambah Water Supply Scheme medium priority announced allocation is less than 5%. Risk at Ban Ban springs was slightly greater for the

Rule type	Appendix A – biological rules	Appendix B – risk assessment	Appendix C- assessment of existing rules	Description of current ROP rules	Appendix E – alternate scenario
					unallocated water scenario only. Recommend: Support rules that align better with ecological requirements during key months.
Bundaberg Water Supply Scheme - Paradise Dam					
Releases	0.3 m rise in streamflow above the cease to flow, persisting for 30 days between August and December.	Water resource development has reduced low flows, increasing risk to low flow assets. The flows required are within the operational capacity of the impoundment. Recommend: Low flow releases should be introduced that mimic natural events.	Releases were generally smaller volumes and were insufficient to stimulate spawning and did not align with spawning period. Recommend: Refine rule to provide for ecological outcome by, for example, extending to other months of the year and increasing magnitude to provide for fish passage and lungfish spawning.	Low flow: 1. Jul: inflows > 20 ML/d, release 20ML/d; 2. Dec: inflows > 75 ML/d, release 75ML/d	Inflow/outflow rule for September to December (aligning with lungfish spawning requirements): If the storage level is above EL 63.45m AHD then all inflows in the previous 24 hours must be released up to a maximum volume of 14 000ML/d. No change to the risk profile at this point. Recommend: Support rules that align with ecological requirements during key months.
Bundaberg Water Supply Scheme - Ned Churchward Weir					
Releases	0.3 m rise in streamflow above the cease to flow, persisting for 30 days between August and December.	Water resource development has reduced low flows, increasing risk to low flow assets. The flows required are within the operational capacity of the impoundment. Recommend: Low flow releases should be introduced that mimic natural events.	No specific release for lungfish spawning. Recommend: Align more closely with principles of increasing flow variability through an inflow/outflow rule between September to December.	Low flow to be provided whenever possible to maintain the downstream pool and riffle sequence.	Inflow/outflow rule for September to December (aligning with lungfish spawning requirements): All inflows that exceed 85ML/d are to be released to a maximum of 200ML/d. No change to the risk profile at this point. Recommend: Support rules that align with ecological requirements during key months.
***Elseya albagula* ecological asset**					
Bundaberg Water Supply Scheme - Ben Anderson Barrage					
NOL	Stabilisation of water level to reduce inundation of nest sites. Water levels not to exceed 1.3 m change between nesting (May to July) and incubation and hatching (July to December).	Over 90% of the nests of *E. albagula* have been found within the barrage. Nest predation has caused substantial impacts to local populations. Age structure is skewed towards older individuals due to poor recruitment. Recommend: Rules should reduce occurrence of nest	Current NOL is nearly three meters below the full supply level of the barrage. This low NOL increases the potential for the water level to fluctuate and therefore inundate nests. Recommend: Review NOL to minimise *E. albagula* nest inundation.	Maintain a NOL of 1m for the entire year.	Raise the NOL during the nesting period forcing turtles to nest higher on bank. Reducing water levels during incubation to provide buffer between standing water level and nest locations. NOL: ▪ August to April:- 2.2m (nesting) ▪ May to July:- 3m (incubation) Recommend: Support implementing seasonal NOLs

Rule type	Appendix A – biological rules	Appendix B – risk assessment	Appendix C- assessment of existing rules	Description of current ROP rules	Appendix E – alternate scenario
		inundation to increase success of recruitment.			

Table 12 High flow assets

Rule type	Appendix A – biological rules	Appendix B – risk assessment	Appendix C- assessment of existing rules	Description of current ROP rules	Appendix E – alternate scenario
Estuarine ecological assets (*F. merguiensis*, *L. calcarifer*, *M. cephalus*, *A. corniculatum*)					
Bundaberg Water Supply Scheme - Paradise Dam					
Release	Flows sufficient to produce brackish conditions (50% seawater~15‰) for 50% length of the estuary for September to March.	Impacts on *L. calcarifer* YCS and *F. merguiensis* growth in the Burnett River due to loss of higher flows. Impacts on the abundance of brackish flows in the Burnett River estuary and associated increases in risk to *F. merguiensis, L. calcarifer, M. cephalus, A. corniculatum*. Recommend: Provide more flows to the estuary.	Estuary monitoring indicates that high flows create significant spatial and temporal brackish habitat in the Burnett River estuary. Recommend: Consider refining the release volumes, dam threshold levels and timing to provide peak flows of >10 000ML/d during Spring and Summer.	From August to November –The previous 24 hours volume of inflow to Paradise Dam must be released if ROP conditions are met up to 14 000ML/d.	Inflow/outflow rule for September to December: If the storage level is above EL 63.45m AHD then all inflows in the previous 24 hours must be released up to a maximum volume of 14 000ML/d. Alternate rules resulted in small increases in risk. Recommend: Continue to adopt an inflow/outflow rule that better aligns with estuary requirements.
Release			The high flow release was only made when a large flow was already occurring at Paradise Dam. Recommend: Refine the release volumes, threshold levels and timing (seasonality).	For all months: The total volume of flow into Paradise Dam in the previous 24 hours from 0600, is between 12 000ML and 28 000ML; and the rate of flow into Paradise Dam at 0600 of the current day is between 160 and 300 cumecs; and the storage level of Paradise Dam is above EL 67.92m AHD; and a flow of 26 000ML/d has not passed the Figtree Gauge on a previous day in the current water year. Paradise Dam outlet is to be fully opened until a total volume of 26 000ML has passed GS136007A Burnett River at Figtree in the following 24 hours.	When this rule is activated, there is already a significant flow at Paradise Dam. In the case of the estuarine ecological assets, the flow is already being provided by the spilling of the dam. No specific rule was identified to replace this rule. Recommend: The proposed 14 000 ML/d flow rule appears to satisfy the needs of the estuary.
Bundaberg Water Supply Scheme - Bucca Weir					
NOL	Flow sufficient to produce brackish conditions (50% seawater~15‰) for 50% length of the estuary for September to March.	The Kolan River estuary was shown to be at a lower level of risk for brackish habitat when compared to the Burnett River. There were smaller impacts on L. calcarifer YCS and F. merguiensis growth compared to the Burnett River.	The NOL was higher in the late summer period and lower in spring which limited overtopping flows to the estuary during this time. Recommend: Change season and height of NOL to provide for more flows to estuary.	Maintain the following seasonal NOLs: ▪ November: 13.57m ▪ December to January: 15.32m ▪ February to March: 13.57m ▪ April to October: 12.2m	Maintain an elevated NOL across the whole spring and summer period to allow freshwater flows to reach the estuary. ▪ Sept to March: 14m ▪ April to August: 12.2m Recommend: Adopt a seasonal NOL that supports more flows to the estuary throughout the key months.
Releases			Releasing 380ML/d was insufficient to create an extended estuarine brackish	During January to April if the storage level of Bucca Weir is less than EL 16.25m AHD;	As risk was low, alternate rules tested removing high flow release rule in the Kolan River.

Rule type	Appendix A – biological rules	Appendix B – risk assessment	Appendix C- assessment of existing rules	Description of current ROP rules	Appendix E – alternate scenario
			habitat but did assist persistence. Recommend: Refinement of this rule could include inflow/outflow rules for Fred Haigh Dam such that flows are passed through the system more naturally.	and Kolan Barrage is spilling; and the storage in Fred Haigh Dam is greater than 53m AHD, then pass a minimum flow of 380ML/d from Bucca Weir.	The removal of the rule did not increase the risk. Recommend: Support the removal of high flow releases.

Table 13 Other Rules

Rule type	Appendix A – biological rules	Appendix B – risk assessment	Appendix C- assessment of existing rules	Description of current ROP rules	Appendix E – alternate scenario
Upper Burnett Water Supply Scheme - Kirar Weir					
NOL	NIL	NIL	Recommend: Any change should reflect fish way height during key fish migration months.	Maintain a NOL of 151m for the entire year.	Implement a seasonal NOL: 1. July to December: 149.6m and 2. January to June: 144.6m Water level maintained above fishways during key months. Recommend: Maintain proposed NOLs
Upper Burnett Water Supply Scheme - Claude Wharton Weir					
NOL	NIL	NIL	Any change should reflect fishway height.	Maintain a NOL of 91.12m for the entire year.	Recommend: Maintain current NOL as this is at the fishway entrance level.
Bundaberg Water Supply Scheme - Ned Churchward Weir					
NOL		The NOL for Ned Churchward Weir is below the fishway entrance level. In addition, the stable water level rule for Ned Churchward Weir does not protect the provision of shallow habitat required for lungfish spawning.	Suitable lungfish spawning habitat is found both upstream and downstream of the weir. The still waters in the weir do not provide all of the water quality requirements for aquatic macrophytes or lungfish eggs. Recommend: Raise NOL to 13.5 m to match fishway entrance and remove the stable water level rule as its not providing any ecological benefit.	Maintain a NOL of 13m for the entire year.	Maintain a NOL of 13.5 m for the entire year. Level increases access to the fishway. Recommend: Support the implementation of a NOL that increases access to the fishway.
Bundaberg Water Supply Scheme - Ben Anderson Barrage					
NOL	NIL	NIL	Fishway on the barrage only operates for approximately 40% of the time. Recommendation: Raise NOL to improve fishway operation.	Maintain a NOL of 1m for the entire year.	Raise the NOL above the fishway entrance level (1.8 m AHD): ▪ August to April: 2.2m ▪ May to July: 3m This allowed the fishway to operate nearly 100% of the time. Recommend: Adopt NOLs that support fishway access.
Bundaberg Water Supply Scheme - Fred Haigh Dam					

Release	NIL	NIL	The release was never implemented. The maximum release rate has since been determined to be only 460ML/d. Recommend: Align with changes to the NOL of Bucca Weir and inflow/outflow rules to provide flows to the Kolan estuary.	For all months: When the storage level of Fred Haigh Dam is above EL 75.14m AHD, a flow equal to the previous days inflow to Fred Haigh Dam must be passed, subject to a maximum daily release volume of 1 600ML.	Removed high flow releases for Fred Haigh Dam. There was no change to risk for the Kolan estuary. Recommend: Removal of high flow releases for Fred Haigh Dam.
Bundaberg Water Supply Scheme - Bucca Weir					
Releases	NIL	NIL	It was identified following a period of persistent releases, a long periods of no flow contributed to fish kills downstream of the weir. Recommend: The current rule be replaced with a targeted rule that provides a more natural flow regime such as an inflow/outflow rule during Spring and Summer.	For May, if the inflow to Bucca Weir is greater than 158ML/d, then release 158ML/d during this period.	Removed Bucca Weir Strategy as not aligned to asset requirements and rarely implemented. Not specifically tested. Recommend: Replace with a constant release of 5ML/d to maintain water quality and connectivity between pools.
Bundaberg Water Supply Scheme - Kolan Barrage					
NOL	NIL	NIL	The NOL was maintained for the majority of months. Recommend: The current NOL be maintained.	Maintain a NOL of 2m for the entire year.	Recommend: Maintain current NOL as this is above the fishway entrance level.