Protecting the Robe Lakes While Increasing Water Retention in Lake Hawdon North Upstream

Lachlan Farrington and Ben Taylor

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Correspondence in relation to this report contact

Mr Mark Bachmann
Principal Ecologist
NGT Consulting
(08) 8797 8181
mark.bachmann@natureglenelg.org.au

Cover photo: Lake Fox under low water levels, 16th December 2011 (photo Ben Taylor).

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1. Introduction

A preliminary assessment of the potential for wetlands in the South East and Lower Lakes regions of South Australia to provide increased habitat for migratory shorebirds through restoration (Hunt et al. 2019) recommended Lake Hawdon North (near Robe) for a more detailed feasibility assessment. A feasibility assessment was completed (Taylor, 2020) and confirmed that constructing a regulator on Drain L could extend the period of inundation of Lake Hawdon North and provide associated, significant benefits by increasing summer habitat for waterbirds including migratory shorebirds.

A key consideration in assessing the feasibility of regulating outflows from Lake Hawdon is maintaining the ecological health of the Robe Lakes, which receive water that drains from Lake Hawdon North, and to ensure that any regulation does not have a material negative impact on these lakes.

The Robe Lakes are an estuarine system of five interconnected lakes located at the terminus of Drain L adjacent to the township of Robe. The system consists of, from upstream to downstream, Lake Ling, Lake Battye, Lake Nunan, The Pub Lake and Lake Fox (Figure 1). The Robe Lakes contain important ecological values and also provide significant recreational and aesthetic values to the township of Robe.

Figure 1: The Robe Lakes comprise a chain of connected lakes receiving water from Drain L to the east and water flowing north-west to exit to the ocean north of Lake Fox

The following document provides an overview of the ecological character of the Robe Lakes and outlines the impacts that potential different Lake Hawdon North flow regulation scenarios will or may have on these characteristics. This report provides an assessment of potential negative impacts to Robe Lakes and identifies scenarios that will help manage and avoid negative impacts to Robe Lakes. It is an underlying assumption that ecological character directly translates to parallel recreational and aesthetic values and both are therefore mutual.

2. The Ecological Character of the Robe Lakes

Prior to construction of Drain L, the Robe Lakes were landlocked systems. Conceptual models for similar inland coastal lakes identify the major hydrological drivers as groundwater levels and, to a lesser extent surface water levels (Harding, 2014). Since construction of Drain L, the major hydrological drivers now include drain flows and sea water level/tidal influences. This has resulted in a shift from a salinity regime ranging from fresh (during the wettest of years) through to marine (during drier periods). With the construction of Drain L, freshwater inputs and marine incursions have increased and the system is now more typical of an estuarine system. It is this modified state which forms the basis for defining the Robe Lakes ecological character.

In their modified state (as an estuarine system), the Robe Lakes are influenced by both freshwater inflows from inland and inflows of seawater in the reverse direction through the mouth. In winter, when Drain L inflows are high, the entire Robe Lakes system is flushed with fresh water from Drain L and salinities drop to the level dictated by Drain L water, as data collected by the South Eastern Water Conservation and Drainage Board (SEWCDB) illustrate (**Figure 2**). As Drain L inflows decline through spring and into summer, salinities in the Robe Lakes increase to approach that of the incoming sea water. Hence the key drivers of the ecology of the Robe lakes "estuary" are water level and salinity and how these two parameters vary daily and seasonally (Figure 3).

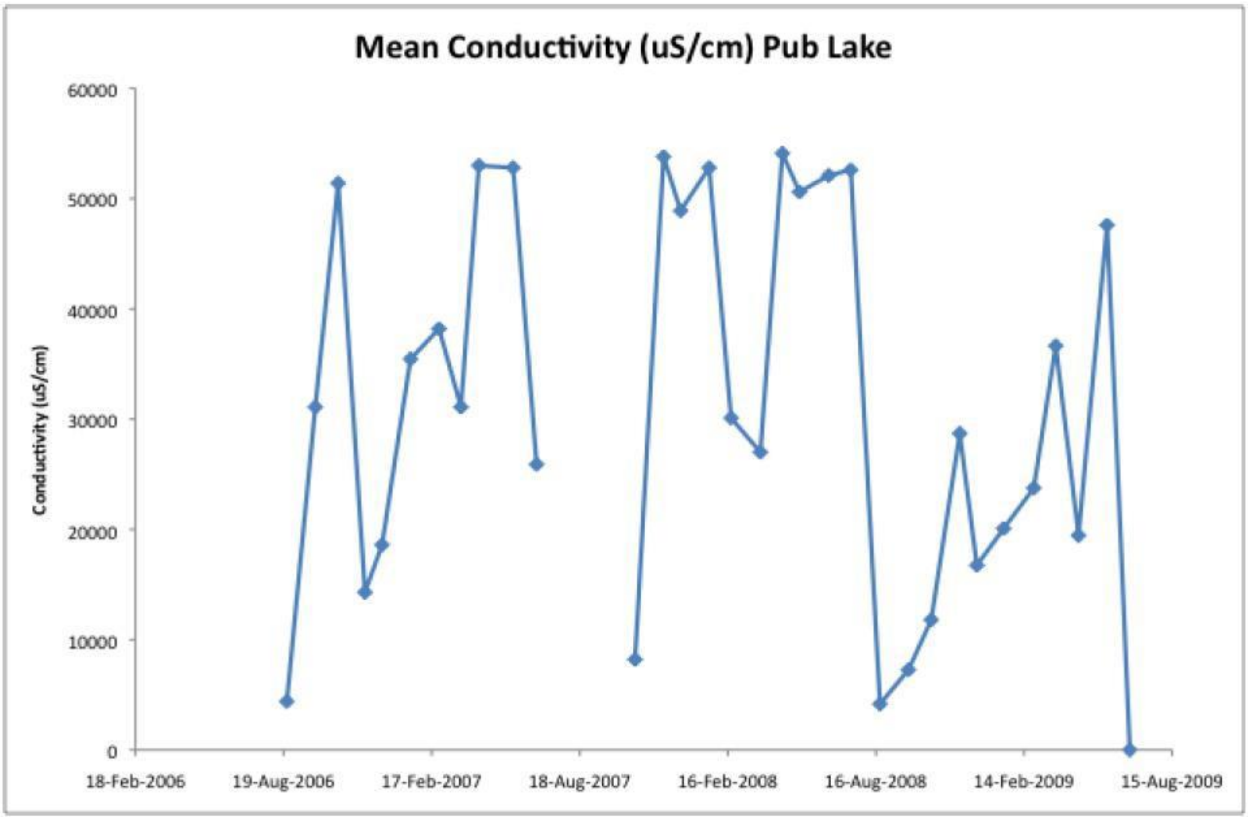


Figure 2. Salinity data for Pub Lake collected by the SEWCDB (source: Hipsey et al. 2014).

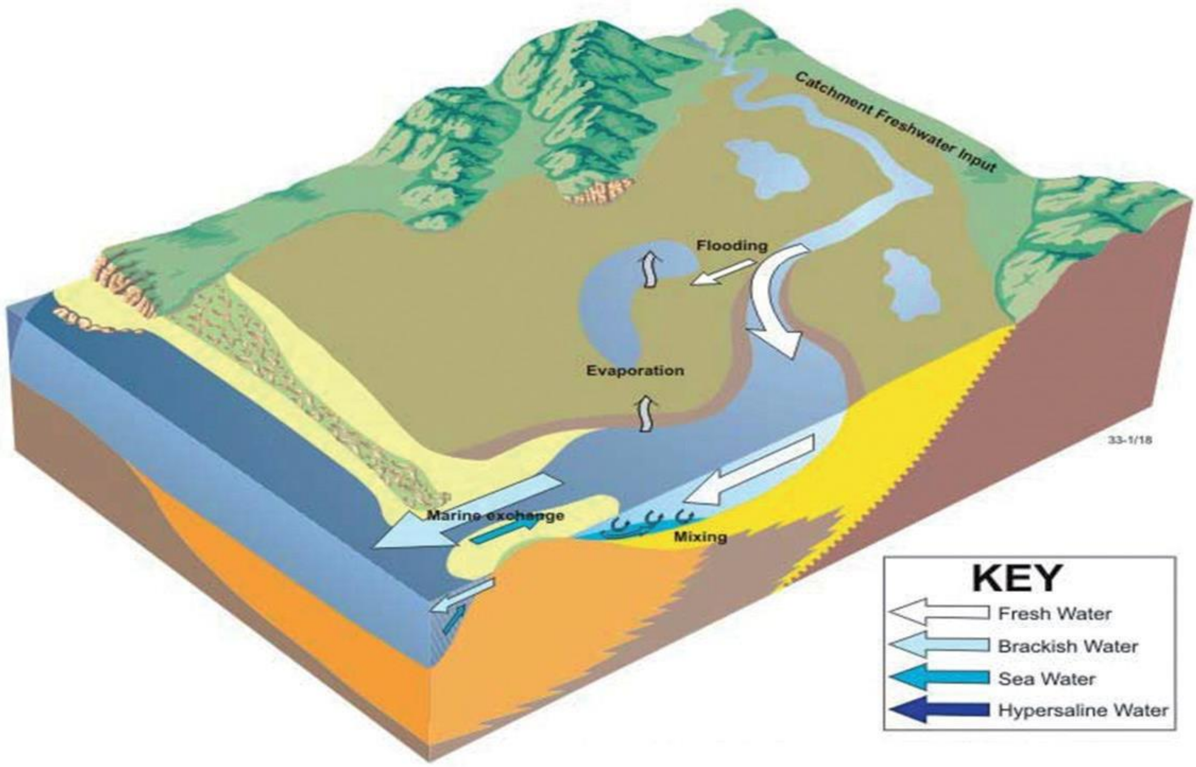


Figure 3: Conceptual model of estuarine hydrology (from Oz Coasts 2008).

Mouth openness is also an important feature of estuaries. In many estuaries, as freshwater inflows from inland decline during the drier months of the year, the mouth of the estuary may narrow or close completely, leaving an isolated coastal lagoon separated from the sea by sand. Seasonal opening and closings are a significant natural phenomena of south eastern Australian estuaries and the process underpins an ecological community now protected under the *EPBC Act 1999* (*Assemblages of species associated with open-coast salt-wedge estuaries of western and central Victoria ecological community – Department of the Environment, 2021*).

The Robe Lakes, and their estuarine character, differs from other natural estuaries in south eastern Australia because the mouth (the outlet of Drain L) never closes. The aspect of the mouth does not lend itself to prevailing swell impact and the geomorphology of the opening (cut through a low cliff into a relatively rocky bay) does not facilitate sand deposition and sandbar establishment. Hence, openness is maintained, even during low rainfall periods such as the Millennium Drought, and seasonal patterns of variable movement of water in both directions are more regular and not punctuated by periods of sustained mouth closure. This regular, seasonal pattern oscillates from high winter or spring flows in Drain L coinciding with low tides and resulting high outflows of freshwater (e.g. Figure 4 and Figure 5) to summer and autumn patterns where freshwater inflows to the Robe Lakes are greatly reduced and mean sea level is also lower than in the winter. However, high tides and swell in autumn, winter and spring can also push seawater in through the mouth of Drain L (Figure 6). Sustained inundation of fringing areas, however, usually occurs under higher inflows of fresher water from Drain L.

Figure 4: High outflow at the mouth of Drain L, 24th August 2013 (photo: Ben Taylor).

Figure 5: Discharge from Drain L causing a plume of freshwater within Guichen Bay, 20th September 2012 (photo: Mark de Jong).

Figure 6: Seawater flowing into the mouth of Drain L during a storm, 17th August 2011 (photo: Ben Taylor).

The interplay of freshwater inflows, seawater ingress, seasonal variation in mean sea level and daily tides creates a pattern of water level and salinity variation within the Robe Lakes and these patterns underpin the flora and fauna found within and fringing the lakes system.

Two key ecological components of the lakes system include:

- provision of habitat for migratory shorebirds (Ferenczi et al. 2020); and
- a fish community that includes estuarine species and is free of introduced species (Hammer *et al.* 2012).

2.1. Migratory shorebird habitat

The Robe Lakes support and provide breeding habitat for a wide diversity of resident shorebirds and waterbirds but are considered particularly important roosting and feeding habitat for two migratory species, sharp-tailed sandpiper (*Calidris acuminate*) and Latham's snipe (*Gallinago hardwickii*). Both species have been recorded in nationally significant abundances (0.1% of the total Flyway population) and a migratory shorebird action plan has been developed covering Lake Fox, The Pub Lake, Lake Battye and Lake Ling (Ferenczi et al. 2020). Key objectives of the Action Plan which underpin considerations with respect to flow regulation in Drain L are (2) reducing or eliminating human and introduced threats, and (3) maintaining and protecting key habitat values. Some specific points relating to water levels and influences on habitat for Latham's snipe, specifically outlined in the Action Plan, include:

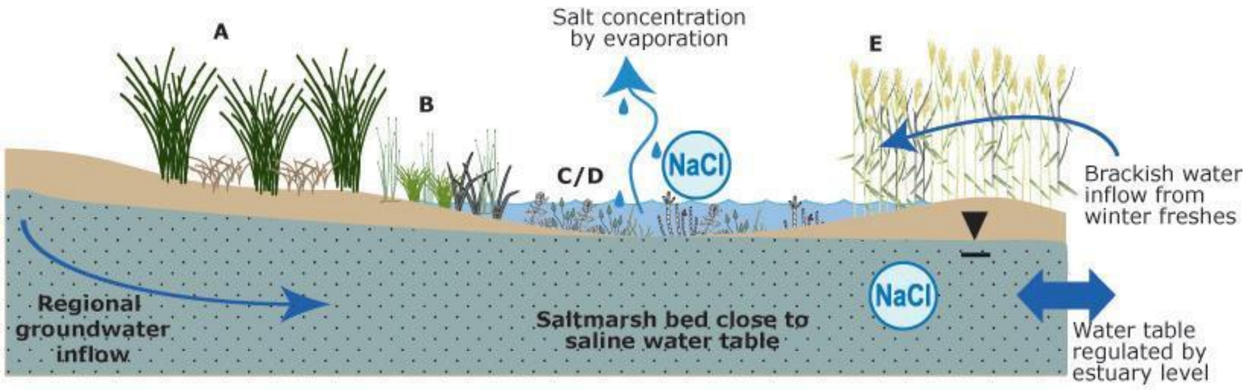
- Latham's snipe prefer Lake Fox although they historically used Pub Lake more in the past;
- high flows and storms cause disappearance of some of the roosting and feeding sites at Lake Fox and The Pub Lake over summer, alternative sites around the lakes remain available;
- Latham's snipe tend to be more abundant in November;
- Birds are observed in areas of open sand mudflats and samphire saltmarshes;
- the extent of saltmarsh appears to have increased and/or encroached onto sand mudflats over time; and
- The South Eastern Water Conservation and Drainage Board (SEWCDB) suggest that flow through the Robe Lakes is important to manage potential algal blooms because of high nutrient levels.

A key and high priority action outlined in the action plan is to:

> *"Regulate water levels in favour of Latham's Snipe and other migratory shorebird species at Lake Fox, The Pub Lake, Lake Battye and Lake Ling. Investigate how the planned construction of a regulator on Drain L will possibly affect the water flows in Lake Fox, The Pub Lake, Lake Battye and Lake Ling (Ecological Associates 2009). If regulator is installed upstream, ensure that environmental water requirements of Lake Fox, The Pub Lake, Lake Battye and Lake Ling are not sacrificed. For example, set a threshold for minimum amount of water that flows past the regulator to meet summer water level requirements of Lake Fox, The Pub Lake, Lake Battye and Lake Ling. Monitor water quality, mouth open-ness, salinity of the lakes as adaptive management in the future."*

In light of this, the extent and availability of sand mudflats and samphire saltmarsh presents as a key consideration in assessing any impacts from regulated upstream flows. A conceptual model of coastal saltmarsh (Figure 7) helps to underpin an understanding of how these habitats may respond to reduced inflows. Typically, saltmarsh is influenced by seasonal inundation, interaction with local water tables and evapo-concentration of salt when inflows and inundation recede. Knowledge around groundwater interactions across the Robe lakes system is scarce, although regional models classify the likelihood of interaction as "very high" (Harding, 2009) and nearby lakes (Robe Lake and Big Dip Lake) are understood to be permanently groundwater gaining systems (Harding, 2018).

Understanding bird behaviour is also important. Shorebirds typically feed on invertebrates in intertidal mudflats and retreat to roost sites during high tide (Lane 1987). Snipe require the upper soil (10 cm) to be soft enough to probe and, unlike some other shorebird species, prefer taller vegetation (Fuller, 2012). Hence, open sand mudflats may not be a critical element of their feeding habitat, more the area of saltmarsh which is reliably moist. However, open mud sandflats are considered important foraging areas for other species and the expansion of saltmarsh at the cost of mud sandflats requires further validation as to whether it is a sign of disturbance or a natural phenomena



Plant assemblages:

A On rises and higher ground in the floodplain, - *Ghania, Poa spp.*

B *Bolboschoenus, Distichlis, Wilsonia*

C Summer (dry) - Salt flat with samphire *Sarcocornia sp* and *Halosarcia sp.*

D Winter / spring (inundated) - diverse community including: *Chara, Nitella, Selliera*

E *Phragmites australis*

Figure 7: Conceptual model of coastal saltmarsh (salinity regime) (Lloyd et al. 2012).

2.2. Fish community

The fish community of Robe Lakes consists primarily of estuarine and diadromous species including black bream, bridled goby, common galaxias, Australian salmon, lagoon goby, small-mouthed hardyhead, Tamar River goby, western bluespot goby, yelloweye mullet, jumping mullet and sea mullet as well as climbing galaxias, congolli and pouched lamprey which are of conservation concern (Hammer et al. 2012). Hammer et al. (2012) noted that, despite its artificial status, the Drain L estuary appears to be an important and rare habitat type and that, from a native fish perspective, is one of the best functioning estuaries in South Australia. Hence estuarine and diadromous species present as a key management focus in this system.

The movement of diadromous fishes from the sea, through the Robe Lakes estuary and into upstream freshwater habitats is likely important to maintaining the ecological values of inland wetlands such as the Lake Hawdon system. Diadromous species such as common galaxias have been recorded upstream of the proposed Drain L regulator, including within Lake Hawdon South (Hammer et al. 2012). Lake Hawdon South is an important stronghold for the internationally Endangered Australian mudfish (*Neochanna cleaveri*) and, despite research (Hammer et al. 2012), it remains unclear if this population undertakes marine migration. The maintenance of connectivity via baseflows, fish passage around any proposed structures and an open mouth are important considerations in the Drain L catchment.

3. The Recreational and Aesthetic Character of the Robe Lakes

Located at the gateway to the township, the Robe Lakes are a defining geographic feature of Robe. They are visible from the main roads entering into to the town and, in the case of Pub Lake and Lake Fox, they adjoin the peri-urban interface. Lake Battye is a popular waterbody for recreational boating and fishing, and is referred to locally as the “bream lake”. A seemingly healthy population of target species (black bream, Australian salmon, yelloweye mullet and the occasional mulloway) underpin a popular, local recreational fishery. This investigation does not include Lake Fellmongery and Lake Charra, which are also iconic features of the town but are not connected to Drain L and therefore independent of any flow considerations. The general amenity of the Robe Lakes is vulnerable to impact from algal blooms (fuelled by nutrient rich inflows) and also exposure of the lake bed and fringes which can contribute to anaerobic odours. Hence maintenance of water level, as well as connection between freshwater inflows and marine incursions are important for maintaining the recreational and aesthetic amenity of the lakes.

4. Catchment Model

The proposed restoration of Lake Hawdon North (LHN) involves constructing a regulator on Drain L approximately 9 km upstream of the Robe Lakes. The regulator would be operated to extend the duration of shallow inundation of Lake Hawdon North through summer. This would lead to reduced inflows to the Robe Lakes for a period commencing in late winter or early spring, depending upon the rainfall and flow, in a given year. To ensure the ecological character of the Robe Lakes is maintained, the regulator will allow a particular volume per day to pass through to the Robe Lakes with the remaining water used to achieve restoration targets for LHN.

In order to understand the implications of the restoration of Lake Hawdon North on inflows to the Robe Lakes, catchment modelling has been undertaken, utilising scenarios and methodology outlined by Department for Environment and Water (2021).

Inflows to the Robe Lakes are measured at the Boomaroo Park gauging weir on Drain L, located downstream of LHN. The catchment model predicts flows to within 1% of actual flows and is therefore an accurate representation of the catchment. The Robe Lakes have a total volume of 0.53 GL when water levels are high and 0.40 GL when water levels are low. Inflows to the Robe Lakes predicted by preliminary modelling, under several scenarios are shown in **Table 1**. Turnover rate, an indicator of flushing, is also shown. Changes to turnover are estimated conservatively by using the volume of the Robe Lakes when water levels are high.

The key points illustrated by this modelling are:

- Average maximum daily flows (in winter) to the Robe Lakes are essentially unaffected by any of the scenarios examined.
- The reductions to average total annual flow to the Robe Lakes are relatively small under all regulated scenarios, ranging from a 17% reduction for a 0 ML/d bypass to 8% for a 100 ML/d bypass.
- Turnover of the Robe Lakes remains high under all regulated scenarios. The 25 ML/day smart regulator bypass scenario reduces Robe Lakes turnover from 3.5 days to 4 days.

Table 1. Average annual flow to Robe Lake and system turnover rate for current and regulated conditions (Department for Environment and Water, 2021).

Scenario	Annual flow, GL	Deviation from current	Turnover rate (days)
Current	55.0		3.5
Regulated – 0 ML/d bypass	45.5	-17%	4.3
Regulated – 25 ML/d bypass	47.8	-13%	4.0
Regulated – 40 ML/d bypass	48.2	-12%	4.0
Regulated – 60 ML/d bypass	48.9	-11%	4.0
Regulated – 80 ML/d bypass	49.5	-10%	3.9
Regulated – 100 ML/d bypass	50.5	-8%	3.8

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Regulated – 80 ML/d bypass	49.5	-10%	3.9
Regulated – 100 ML/d bypass	50.5	-8%	3.8

5. Hydrodynamic Model of the Robe Lakes

In order to better understand the impacts of the modelled flow reductions under regulated scenarios, a TUFLOW 3D hydrodynamic model of the Robe Lakes was originally developed by Taylor et al. (2014), and updated with more recent data (Department for Environment and Water, 2021). The outputs from the catchment model are used as inputs to the Robe Lake hydrodynamic model. The hydrodynamic model was run for a representative 10 year period, 1995 to 2005 across different scenarios encompassing no regulation (current), smart regulation at rates of 25 to 100 ML/d, regulation targeted at optimising levels in LHN and also no regulation under forecast 2050 climate and sea level (No Reg (2050)). This last scenario examines changes to the Robe Lakes that are likely to occur in response to predicted changes to sea level and rainfall under climate change by 2050.

An overview and comparison of outcomes for salinity (depth averaged) and water level under a subset of these scenarios is provided for each of the four lakes of the Robe Lakes system using monthly averages (Figure 8 and Figure 9). Salinities are presented in Practical Salinity Units (PSU). For context, the salinity of seawater is 35.5 PSU. Depth averaged salinity data have been used as the hydrodynamic model indicates the lakes are generally well mixed.

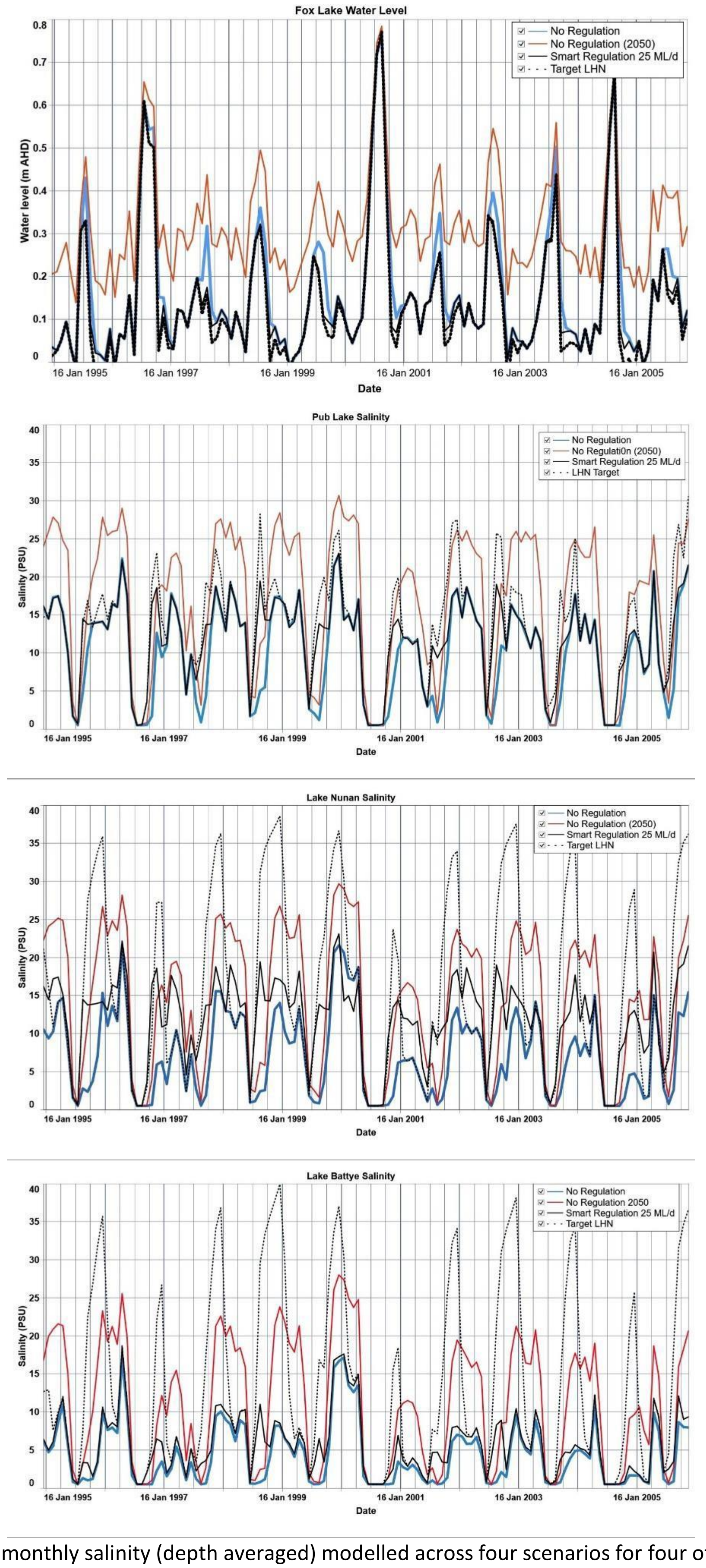

Figure 8: Average monthly salinity (depth averaged) modelled across four scenarios for four of the Robe Lakes from most downstream (top) to most upstream (bottom).

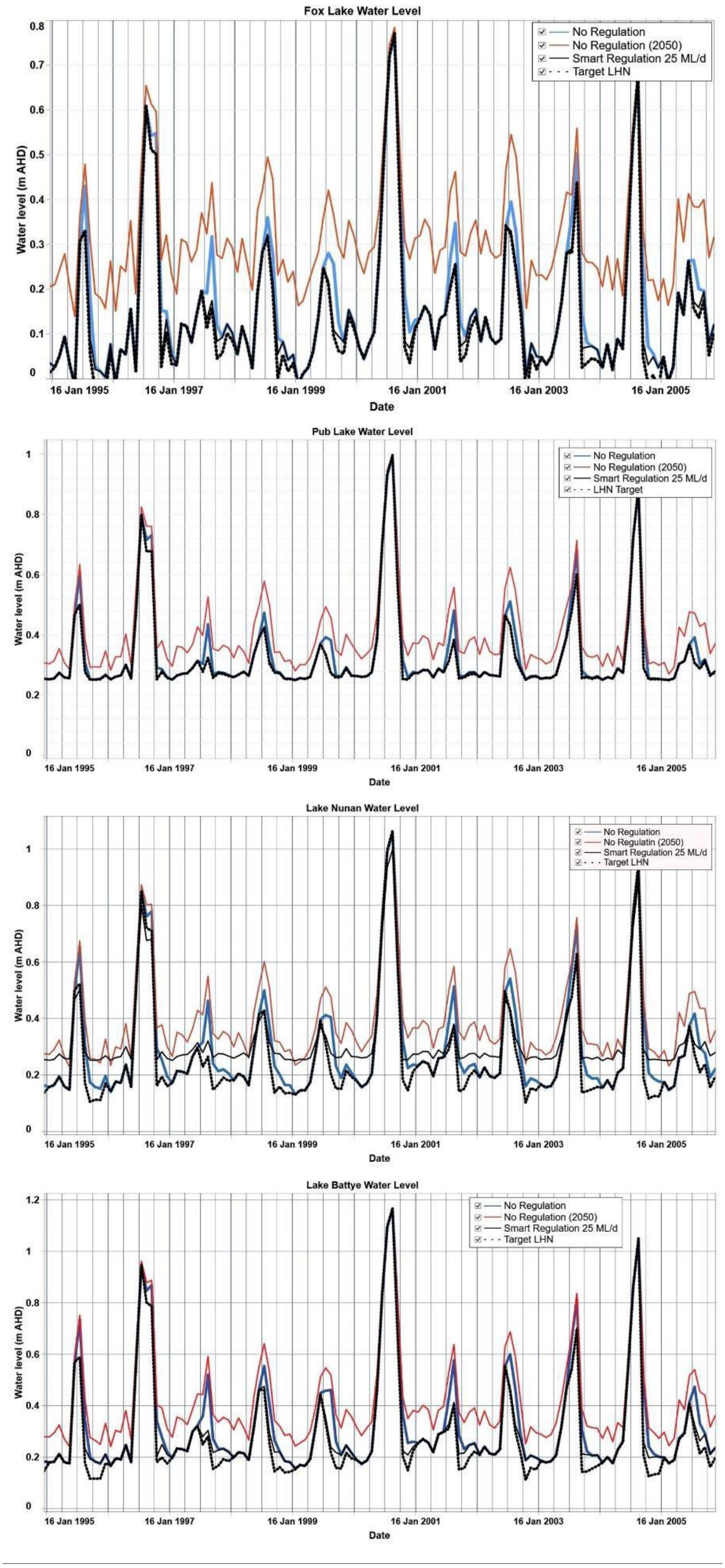

Figure 9: Average monthly water level modelled across four scenarios for four of the Robe Lakes from most downstream (top) to most upstream (bottom).

Hydrodynamic modelling shows that regulation that prioritises Lake Hawdon North water levels without considering a minimum daily flow allowance for the Robe Lakes would have a significant impact on salinity at Lake Battye (Figure 8). However, conservative regulation, allowing a minimum of 25 ML/d to pass, is predicted to have much less impact and, for the most part, match salinities that occur under the current, unregulated flow conditions. The duration of winter minimum salinity is modelled to be shorter in duration in 2003 compared to the current flow regime but summer maximum salinities for a given year are similar across all years. Salinity levels maintained through a 25 ML/d scenario are well below those projected for a 2050 high emission future climate scenario. Salinity impacts at Lake Fox, under a scenario of prioritisation of Lake Hawdon North water levels, are much less. Additional scenarios (not shown in Figure 8) only provided minimal or no overall improvement in terms of matching the current, unregulated flow scenario.

In terms of water level, the 25 ML/d smart regulation scenario closely matches the current, unregulated flow regime for all lakes (Figure 9). There was one exception, in winter 1997, where water levels were approximately 10 to 15 cm lower under the regulated scenarios. Water level is consistently higher under a future climate scenario due to a projected sea level rise of 0.24 m for 2050.

6. Implications for Robe Lakes under different flow regulation scenarios

6.1. Effect on ecological character

Reductions in quantity of freshwater inflows to estuaries can lead to increases in salinity and die-offs of salinity-sensitive plants as well as a reduction in nutrient inputs thereby reducing plant and animal productivity. In addition, changes to the timing and volume of inflows (pulsing) can cause destruction or degradation of habitats that are adapted to seasonal pulses of freshwater (Olsen et al. 2006)

Under a flow regulation scenario that prioritises inundation frequency and extent in Lake Hawdon North, without considering a minimum daily flow allowance for the Robe Lakes, these estuarine lakes are likely to be subject to elevated salinities through late Spring and early Summer. Smart regulation allowing LHN inflows up to 25 ML/d to flow through to the Robe Lakes is forecast to provide substantial mitigation against rising salinity, although the time at which levels start to increase is earlier (August vs September) under regulated scenarios for most years. This early increase is most pronounced in drier years (e.g. 2008 - Figure 8). Typically, saltmarsh habitats are only periodically inundated by the highest tides, they grow in sediments or soils that are often waterlogged and extremely saline (with salt concentrations often well above seawater, due to evaporation) (Scientific Working Group, 2011). However, the winter and spring freshwater periods potentially stimulate peak floristic diversity, primarily herbs and charophytes (Figure 7) and likely underpin developing food webs that support foraging opportunities as inflows, and hence water levels, recede and saltmarsh areas are exposed. The level of salinity in the Robe Lakes under smart regulation is still quite moderate, and within the expected thresholds of the contemporary vegetation community, so is unlikely to significantly impact any underlying processes. It is worth noting that salinity increases due to smart regulation upstream are well below what are expected under a 2050 future climate scenario without regulation.

Assuming vegetation assemblages remain unaltered under the 25 ML/d smart regulation scenario, variation in water levels presents as a more pertinent area to explore given how this may modify areas available for foraging i.e. sufficiently moist ground for beak probing by waders and shorebirds. The lakes closer to the sea are shallower, with less defined banks and small changes in water level effect larger areas of the intertidal zone. Modelling indicates that water levels in Lake Fox remain unaffected under a 25 ML/d Smart Regulation scenario, suggesting that access to foraging habitat for wading birds is unaffected by this scenario. The levels of change at both Lake Nunan and The Pub Lake suggest that inundation of foraging areas (shallowly inundated sand mudflats) would be reduced in drier years (e.g. 2008) where, under a 25 ML/d smart regulator scenario, monthly water depth would not exceed 0.3 mAHD compared to 0.4 mAHD under unregulated scenarios. The variation in area under these conditions is shown using elevation contours (**Figure 10**). Modelling also suggests that water levels would recede earlier (one to two weeks) under a regulated scenario but that summer and autumn levels would remain unaffected (**Figure 9**). A more detailed inspection of daily water levels for a given year (1999 for example) shows that the biggest differences occur mid-August to mid-September (**Figure 11**). Given that migratory waders typically utilise these habitats from October to March (Ferenczi, 2020), this slight change to water level regime is unlikely to constitute a major interruption to their behaviour. To the contrary, enhanced inundation of Lake Hawdon North will provide a significant foraging area for migratory birds and one that is likely more resilient to changes forecast under a warming climate (i.e. habitat availability won't be grossly impacted by a rising sea levels).

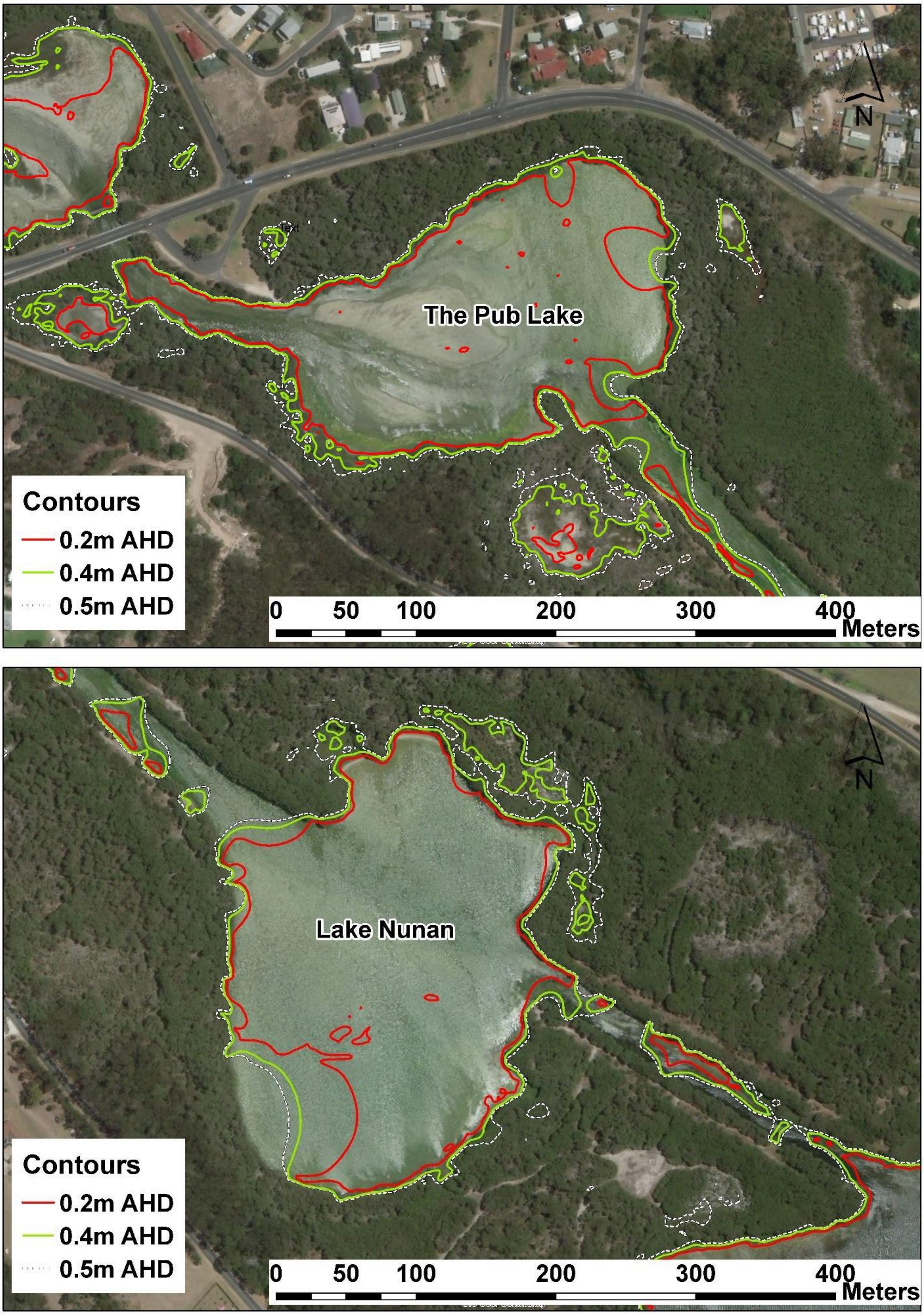

Figure 10: Contour lines showing areas inundated under water levels of particular relevance to scenario modelling.

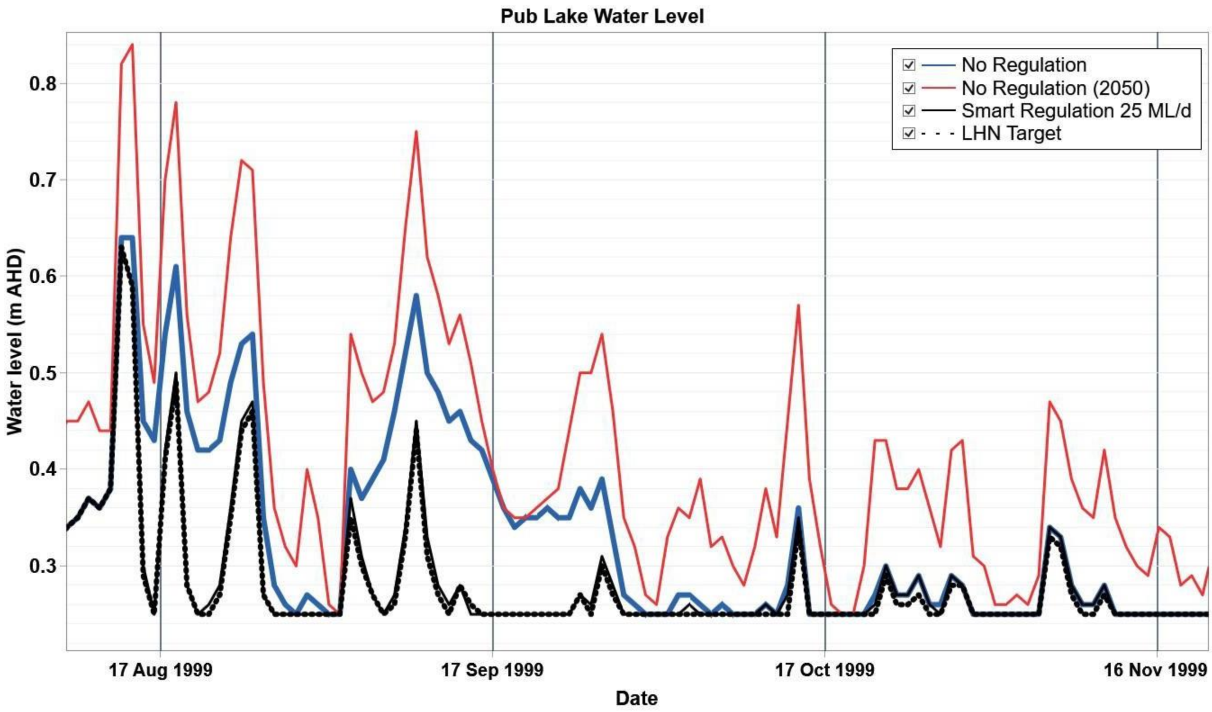

Figure 11: Daily water levels modelled under various scenarios, based on 1999 climate data.

The fish community which resides or passes through the lake system is either euryhaline or diadromous (Hammer et al. 2012). Maximum salinity levels predicted under all scenarios do not present any issues with regard to species specific thresholds i.e. none exceed seawater. The main consideration therefore lies in maintaining connectivity throughout the drainage system, during peak times for recruitment (e.g. spring for *Galaxias maculatus*) (Hammer et al. 2012), noting that the mouth is not anticipated to close. As indicated by **Table 1**, minimum flows in Drain L are maintained as per unregulated conditions provided a smart bypass of 25 ML/day or greater is used. Additional considerations with regard to fish communities relate to stratification, particularly in relation to dissolved oxygen (DO). Warm and/or saline water holds less dissolved oxygen than cold water or freshwater. Hypoxia (<2 mg/L oxygen) develops when there is low inflow or limited water-atmosphere gas exchange (i.e. vertical stratification which leads to a slug of low DO water in the lower parts of the water column) (Hassell et al. 2008). Hypoxia is a major management concern in seasonally closing estuaries (Barton et al. 2008). Winter inflows typically breakdown the stratification, but wind mixing also plays a part. The geographical positioning of the Robe Lakes (running east to west) does present some problems in terms of wind mixing as they are generally sheltered from prevailing south-westerly winds. Hence the contribution of inflows is likely to be the primary driver for water column mixing, although if the mouth is maintained continuously open then the overall vulnerability of the lakes system is somewhat reduced due to tidal exchange and mixing. Hypoxia typically develops in late summer and early autumn when temperatures are higher and phytoplankton blooms occur. Phytoplankton blooms are related to nutrient inputs which, in turn are related to the quantity of nutrients in surface water inflows and their retention (usually in sediments) within the estuary. Peak inflows and water turnover in the estuary are particularly important in maintaining this nutrient budget.

Despite the implications for dissolved oxygen stratification in estuarine systems, salinity is also important for providing spawning opportunities in some estuarine fish species. In particular, the recreationally popular black bream relies on a salt water/freshwater interface (salinity stratification and a gradient between 15-30 PSU) for ideal spawning conditions (Sherwood and Backhouse, 1982, Williams 2013). The concentration of zooplankton communities required for larval development in this species is also optimal within this salinity range (Williams 2013). While the importance of the Robe Lakes as a fish nursery remains relatively unknown, the potential impacts of flow regulation on maintaining inflows capable of establishing a salt-wedge dynamic are an area which requires further consideration.

Hence the role and impact of changes to inflows relate to maintaining oxygen replenishment through the water column, the amount of nutrients entering and being flushed through the system and seasonal development of salinity stratification. With respect to changes in inflow under modelled scenarios, 3D modelling suggest the water column remains consistently mixed under all scenarios and that flow during summer and autumn are largely unaltered.

In addition, and providing connectivity with the drain and "estuary" is maintained, the increased area of wetland habitat achieved through hydrological restoration of Lake Hawdon North is likely to contribute a significantly larger area for small-bodied and juvenile fish species to proliferate. This in turn will also providing enhanced foraging opportunities for piscivorous waterbirds (Taylor, 2020).

6.2. Effect on recreational and aesthetic character

Modelled water level data indicates that there will be no significant change in capacity for boat use in Lake Battye, i.e. less than 20 cm drop in water level at any given time, and water levels that are equivalent to the current, unregulated arrangement will typically be maintained. Given the mouth of the system is presumed to stay open under all conditions, it is also presumed that there will be sufficient tidal ingress to mitigate hypoxic conditions under low inflow conditions.

A key consideration, which also relates to biological health involves nutrient inputs and eutrophication. Ferenczi et al. (2020) cite that the South East Water Conservation and Drainage Board (SEWCDB) have demonstrated that flow through the Robe Lakes is important to manage potential algal blooms because of a high level of nutrients. In this context, the high turnover rates for the Robe Lakes that the models indicate will be maintained under the restoration of Lake Hawdon North provide comfort that nutrients will continue to be exported and not accumulate within the Robe Lakes.

Given the relatively large area of catchment above Lake Hawdon compared to that between Lake Hawdon North and the Robe Lakes, any effort to retain water within a large wetland like Lake Hawdon North, and therefore utilise ecosystem services, will have a positive benefit on nutrient uptake (via nutrient cycling). Over time this would improve water quality and reduce the nutrient load being received by the Robe Lakes.

There are potential water quality risks associated with the restoration of LHN related to the proposed clearance of shrubland that has invaded the bed of LHN, i.e. the potential for decomposing vegetation within LHN to leach carbon and other nutrients, deplete oxygen and effectively cause a "blackwater event" downstream. However, this risk is short-term and it is understood that DEW are developing mitigation strategies. This same risk was effectively managed previously in the South East Flows Restoration Project, completed in 2019.

Two key studies into the effect of South East drain discharge on the health of seagrass beds (Seddon et al. 2003, Wear et al. 2006) found that drain discharge was contributing to declines in seagrass health. Drain L was not considered as part of these studies but the results are likely applicable to Guichen Bay, into which Drain L discharges. Reducing the total volume of Drain L discharge to sea, and potentially improving the water quality of discharge through increased residence time in large wetlands (Lake Hawdon North) upstream is likely to be beneficial for the marine environment.

A final consideration relates to potential exposure of lake beds and fringing areas. Such events can result in the release of anaerobic gases (hydrogen sulfide, volatile organic sulphur compounds and sulphur dioxide) and can contribute to unpleasant odours around the lakes and potentially through the township under certain wind directions. Water level modelling predicts no significant shift in the area of wetland or lake bed being exposed under the proposed scenarios, and therefore will not contribute to any unpleasant odours within the surrounds of the Robe Lakes.

7. Recommendations

Hydrodynamic modelling suggests that regulation of Drain L flows and prioritising water levels in Lake Hawdon North, without consideration of a minimum daily flow requirement for the Robe Lakes, would cause significant, seasonal increases in salinity in Lake Battye but would not significantly impact water levels throughout the lakes system. A refined smart regulator scenario, whereby all inflows to LHN of up to 25 ML/d are released to support the requirements of the Robe Lakes, appears sufficient to mitigate salinity impacts in Lake Battye. Water level fluctuations are also unlikely to affect the extent of waterbird foraging habitat under this scenario. Furthermore, negative impacts to the recreational and aesthetic amenity of the lake system are unlikely under a 25 ML/d smart regulator scenario.

Future climate scenarios, without regulation of Drain L upstream, suggest that projected increases in sea level result in increased penetration of sea water into the lakes and a subsequent increase in the salinity of the lakes system and also substantial inundation of waterbird foraging and roosting ground. In this respect, the hydrological rehabilitation of Lake Hawdon North, by providing alternative nearby habitat for wading birds, is a positive mitigating strategy but one which can still be achieved without bringing about short-term negative impacts to the Robe Lakes.

Under a scenario of regulated flows in Drain L, monitoring of the Robe Lakes is recommended. A minimum requirement would be salinity monitoring in Lake Battye, a measure that the hydrodynamic modelling suggests is the most sensitive to inflow reductions. Real time monitoring that informs regulator operations should aim to maintain Lake Battye salinity below its current maximum (approx. 20 PSU based on modelled daily data not presented here) and release water stored in Lake Hawdon North (if available) if salinity exceeds this. In this way, the proposed regulator can be managed adaptively, ensuring outcomes for Lake Hawdon North are optimised while ensuring the Robe Lakes ecological character is protected.

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