City of Busselton
Geographe Bay

Waterways Management Committee

Agenda

Wednesday 23 October 2024

Our Vision

Where environment, lifestyle and opportunity meet!

Community Aspirations

KEY THEME 1
Environment
An environment that is valued, conserved and enjoyed by current and future generations.

KEY THEME 2
Lifestyle
A place that is relaxed, safe and friendly, with services and facilities that support positive lifestyles and wellbeing.

KEY THEME 3
Opportunity
A vibrant City with diverse opportunities and a prosperous economy.

KEY THEME 4
Leadership
A Council that connects with the community and is accountable in its decision making.

NOTICE OF MEETING

TO: THE MAYOR AND COUNCILLORS

NOTICE is given that a meeting of the Waterways Management Committee will be held in the Council Chambers, Administration Building, Southern Drive, Busselton on Wednesday 23 October 2024, commencing at 9.00am.

Your attendance is respectfully requested.

DISCLAIMER

Statements or decisions made at Council meetings or briefings should not be relied on (or acted upon) by an applicant or any other person or entity until subsequent written notification has been given by or received from the City of Busselton. Without derogating from the generality of the above, approval of planning applications and building permits and acceptance of tenders and quotations will only become effective once written notice to that effect has been given to relevant parties. The City of Busselton expressly disclaims any liability for any loss arising from any person or body relying on any statement or decision made during a Council meeting or briefing.

TONY NOTTLE

CHIEF EXECUTIVE OFFICER

16 October 2024

BEHAVIOUR PROTOCOLS

The City of Busselton values are:

- Listening
- Considered Decision Making
- Appreciation
- Respect
- Teamwork

In accordance with these values, the following outlines the behaviour expectations while attending a Council meeting, Committee meeting, Community Access Session, or Public Agenda Presentation:

- Listen respectfully through the meeting or presentation
- Respect the Council process and comply with directions from the Presiding Member
- Use respectful language when addressing Council, staff, and other members of the public
- Behave in a manner that is respectful and non-confrontational
- Do not use offensive language or derogatory language towards others

The City values the diverse input of the community and seeks to ensure that all members of the community can attend a meeting and have their say.

Elected Members, Committee members and Candidates are bound by the City's Code of Conduct and agree to uphold the values of the City of Busselton and principles of good behaviour, maintaining and contributing to a harmonious, safe, and productive environment.

Anyone who does not behave in accordance with the above values and behaviours may be asked by the Presiding Member to leave the gallery.

CITY OF BUSSELTON

Agenda for the Waterways Management Committee to be held on 23 October 2024.

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1 OFFICIAL OPENING

The City of Busselton welcomes Elected Members, staff, guests and members of the public to the Waterways Management Committee meeting of 23 October 2024.

The City of Busselton acknowledges the Wadandi and Bibbulmun people as the traditional custodians of this region and pay respects to Elders past and present.

Please note this meeting will be audio recorded for minute taking purposes.

2 ATTENDANCE

PRESIDING MEMBER	MEMBERS
	Cr Anne Ryan
	Cr Val Kaigg
	Cr Mikayla Love
	Cr Jarrod Kennedy
	Steve Disley
	Vicki Viela

OFFICERS
Director Infrastructure and Environment
Manager Stakeholder Relations
Manager Parks and Environment
Senior Sustainability/Environment Officer
Community Engagement Officer
Manager Legal, Governance and Risk
Governance Officer

APOLOGIES	
Nil at time of publishing	

3 ELECTION OF PRESIDING MEMBER AND DEPUTY PRESIDING MEMBER

Mr Ben Whitehill, Manager Legal Governance and Risk, will conduct the nomination and voting to elect a Presiding Member of the Waterways Management Committee in accordance with section 5.12 of the *Local Government Act 1995*.

The elected Presiding Member will conduct the nomination and voting to elect a Deputy Presiding Member of the Waterways Management Committee in accordance with section 5.12 of the *Local Government Act 1995*.

4 DISCLOSURES OF INTEREST

DISCLOSURES OF FINANCIAL INTEREST

A declaration under section 5.65 of the *Local Government Act 1995* requires that the nature of the interest must be disclosed. An elected member or employee who has made a declaration must not preside, participate in, or be present during any discussion or decision-making procedure relating to the matter on which the subject of the declaration without the approval of the Council in accordance with the Act.

DISCLOSURES OF IMPARTIALITY INTEREST

Elected members and employees are required, in addition to declaring any financial interest, to declare an interest that might cause or perceive to cause a conflict. If the elected member or employee declares that their impartiality will not be affected then they may participate in the decision-making process.

5 PUBLIC QUESTION TIME

5.1 RESPONSES TO PREVIOUS QUESTIONS TAKEN ON NOTICE

Nil

5.2 QUESTION TIME FOR PUBLIC

Public question time procedures and guidance

Public question time allows members of the public to participate in local government by asking questions of the Council in relation to issues affecting the City. It also assists the City in identifying issues of importance to the community and assists the public to be better informed about how the City is governed.

- The City will allocate a minimum of 15 minutes and a maximum of 30 minutes per Council meeting for public question time.
- Members of the public should register their intent to ask a question at a Council meeting by completing and submitting the Public Question Time form before 4pm the day prior to the relevant meeting.
- Members of the public will be invited to ask their question in order of registration.
- Questions will be limited to three per person. Additional questions may be permitted by the Presiding Member where time permits.
- Where a person is not present to ask their submitted question it will be responded to administratively as general correspondence.
- Questions may be taken on notice, to be responded to at a later time by the CEO in accordance with clause 6.7 of the Standing Orders.
- Public question time is for the tabling of questions, not for members of the community to make statements. For context, the Presiding Member may allow a short preamble.
- Questions containing defamatory remarks or offensive language, or that question the competency or personal affairs of Elected Members or employees may be ruled inappropriate by the Presiding Member subject to the Presiding Member taking reasonable steps to assist the member of the public to rephrase the question.
- There will be no debate or discussion on the response provided.

For further information, please see the Meetings, Information Sessions and Decision Making Processes Policy.

6 CONFIRMATION AND RECEIPT OF MINUTES

7 REPORTS

7.1 Waterway Management Update

Strategic Theme:	Key Theme 1: Environment 1.2 Work with the community to manage and enhance natural areas and reserves and their biodiversity. 1.3 Work with key partners to improve the health of the Vasse River and other waterways in the Geographe catchment.
Directorate:	Infrastructure and Environment
Reporting Officer:	Senior Sustainability/Environment Officer – Danielle Halliday
Authorised By:	Director Infrastructure and Environment - Oliver Darby
Nature of Decision:	Noting: The item is simply for information purposes and noting.
Voting Requirements:	Simple Majority
Disclosures of Interest:	No officers preparing this item have an interest to declare.
Attachments:	1. Lower Vasse River Sediment Removal Stages Map [**7.1.1** - 1 page] 2. Phoslock Trial 2023 Factsheet [**7.1.2** - 2 pages] 3. Toby Inlet Waterway Management Plan [**7.1.3** - 100 pages] 4. Water Treatment Trials 2016 - 2018 [**7.1.4** - 44 pages] 5. Lower Vasse River Waterway Management Plan [**7.1.5** - 80 pages] 6. Independent Review of the Current and Future Management of Water Assets in the Geographe Catchment [**7.1.6** - 77 pages]

OFFICER RECOMMENDATION

That the Committee receives and notes the Waterway Management Update report.

EXECUTIVE SUMMARY

This report provides an overview of the City of Busselton's waterway management activities, particularly management of the Lower Vasse River and Toby Inlet. This includes an update on these waterways, partnership activities and the Lower Vasse River Sediment Removal Program.

STRATEGIC CONTEXT

Regular updates on waterway management aids in the partnership approach to waterway management and provides an additional avenue for updating stakeholders and community in relation to Strategic Priority 1.3: Work with key partners to improve the health of the Vasse River and other waterways in the Geographe catchment. It also relates to Strategic Priority 1.2: Work with the community to manage and enhance natural areas and reserves and their biodiversity.

BACKGROUND

The City of Busselton contributes to the management of waterways in the Geographe region under the context of a partnership approach. Within this structure the City primarily manages the Lower Vasse River and Toby Inlet.

The Lower Vasse River

The Lower Vasse River (LVR) is a stretch of the Vasse River approximately 5.5km in length, which flows through the centre of Busselton. This section is greatly modified, with an estimated 90 per cent of catchment flows diverted to Geographe Bay and was historically impounded by a weir structure downstream. The river is highly eutrophic, with cyanobacterial blooms occurring each year during the warmer months. Isolation of flow, poor water quality, and location have led to the need for specific management of this waterbody.

The Lower Vasse River receives extremely high nutrient loads throughout the year from rural and urban catchments, groundwater, and potentially also from river sediments. Each source individually delivers sufficient nutrients to trigger annual summer microalgal blooms. Targeting all sources of nutrients is important to make substantial and lasting improvements to water quality in the river. The Department of Water and Environmental Regulation (DWER), GeoCatch and other partners have been actively implementing nutrient reduction initiatives throughout the catchment, working with both farmers and urban residents to reduce nutrient runoff. The landscape across the Geographe Bay catchment is saturated in nutrients and will continue to release nutrients to waterways for the next few decades, even if significant reductions are achieved across the catchment. Acknowledging community desires to improve water quality in a shorter timeframe, the City, in partnership with other stakeholders is coupling nutrient reduction from catchment sources with in situ remediation, with a current focus on sediment removal, rehabilitation of riparian areas, and progression of water quality improvement trials with partner agencies, such as recent application of phosphorus-binding clays. These trials require rigorous scientific monitoring and analysis and approvals.

The southwest of Western Australia is experiencing the impacts of climate change much earlier than previously anticipated. In the six months from November 2023 to April 2024 the Busselton region received cumulative rainfall in the range of 0 – 10mm, the lowest in all of Australia for this period. In the preceding decade the area received total rainfall in the range of 50 – 300mm each year for this same period. The drought conditions experienced last spring through autumn resulted in unprecedented drying of the river, exacerbating water quality issues, cyanobacterial blooms, and poor amenity. These conditions also elevated the regional significance of the sections of the river that did retain water, as critical freshwater refuges.

Despite seasonally poor water quality, the LVR provides an important freshwater refuge, habitat and vegetated riparian areas that support native fauna, including many water birds, native fish, turtles, crayfish and the threatened, Carter’s Freshwater Mussel and Western Ringtail Possum. Additionally, the river feeds the Ramsar-listed Vasse-Wonnerup System, holds cultural significance, and is valued by the community for the ecological characteristics and amenity of the river.

The Lower Vasse River is managed in accordance with the *Lower Vasse River Waterway Management Plan* (2019).

Toby Inlet
The City’s current management actions and priorities for Toby Inlet (TI) are focussed on continued management of the sand bar and revegetation of adjacent foreshore reserves, in partnership with the Toby Inlet Catchment Group. Potential management of sedimentation issues including targeted removal of sediments, is identified as a medium to longer term potential priority.

TI had historically experienced severe macro algae blooms and very poor water quality. Following the completion of the *Reconnecting Toby Inlet* study (DWER, 2019), the City has been actively managing the artificial opening of the sand bar to improve water exchange with the ocean. This has led to significant improvements in water quality in the lower part of the inlet (3.6km) but unfortunately does not flush the upper section closer to Caves Road. Each year, from May to October, the ocean outlet is managed for flood mitigation to protect neighbouring residential properties, and from November to April is managed for water quality improvement.

Development in the catchment, hydrological changes, high nutrient inputs and a history of severe macroalgal blooms have led to an accumulation of both sandy sediments and fine, black sulfidic sediments). Sediment deposition can interfere with water flow, fish movement and recreational use, and there are increasing community concerns about deteriorating amenity and unpleasant odours during low water levels, where sediment deposits are exposed even more. Reduced rainfall associated with climate change is also impacting on water flows.

Managing sedimentation was identified as a high priority during the preparation of the *Toby Inlet Waterway Management Plan* (2019). As a result, the City commissioned a study into the extent of sedimentation in TI and how this could be managed. The *Sediment Study* (Ottelia, 2020) concluded that the restoration of habitat values in TI is unlikely to be achieved without the removal of accumulated black sediment. It recommended the staged removal of sediments in priority areas, from Wilson Avenue to the footbridge, equivalent to approximately 60,300m³ of sediments or an average of 80cm deep. The study specifies that different dredging techniques will be required, some of which will require scientific trials.

The City applied for external funding to trial mechanically stirring sediments in the lower section of the inlet during high flows in winter to disperse the sediments into the ocean; one of the key recommendations from the study. The application was unfortunately not successful. Future sources of funding are being investigated, noting this work has significant costs and may cause disturbance to the environment and would therefore require detailed planning and investigations prior to implementation. Without significant additional funding and resources, the City is not able to prioritise large scale sediment removal in Toby Inlet. Access to areas of the inlet is also constrained by residential properties along the inlet, further adding to logistical limitations of sediment removal in the inlet.

The Toby Inlet Catchment Group (TIC Group) has been one of the most active Friends of Reserve groups in the district, undertaking annual rehabilitation and revegetation of foreshore reserves near Toby Inlet. Partnership with the TIC Group is vital to the ongoing restoration of foreshore areas along the inlet with the City continuing to provide support to the volunteers.

Toby Inlet is managed in accordance with the *Toby Inlet Waterway Management Plan* (2019).

Structure and Governance

The City's waterway management role sits within the structure of Revitalising Geographe Waterways (RGW), established in 2015, and is coordinated by the Vasse (Ministerial) Taskforce (the Taskforce). The RGW program works across the broader catchment to reduce nutrients entering waterways from urban and rural areas. The program has also expanded its focus to investigate ways to fast-track water quality improvements within the waterways.

The Taskforce is chaired by a representative of the Minister of Water, and is a partnership between the state government, respective local governments, water authorities, and catchment groups. The Taskforce provides strategic direction and support to the lead agencies responsible for delivering projects under the RGW program, and through GeoCatch reports to the community on outcomes of activities undertaken to improve waterway health.

The Independent Review of the *Current and Future Management of Water Assets in the Geographe Catchment* undertaken by Professor Barry Hart (2014), noted the lack of an obvious lead agency for the LVR, and the need for greater support to the TIC. Following a review of possible future management options, the report recommended the establishment of an overall lead agency to coordinate the separate asset management arrangements.

The Vasse Taskforce was formed, and the following interim asset management structure was adopted:

Lead Agency	Asset
City of Busselton	LVR and TI
GeoCatch	Geographe Catchment
Vasse Wonnerup Partnership	Vasse Wonnerup Wetlands
DBCA	Broadwater Wetlands
Water Corporation	Drainage Network

The City committed to be the 'Interim Asset Manager' for the LVR and TI, and as part of that commitment led the preparation of Waterway Management Plans for both. The City does not have a statutory obligation to manage either waterway and could decide to cease being the Interim Asset Manager. However:

- the two waterways are important to the City and our communities;
- the health and management of these waterways intersects the jurisdiction of numerous agencies, and there is no clear single responsible waterway manager. If the City does not agree to play a significant role, it may be at the detriment of the waterways; and
- by showing commitment to management of the two waterways, the City is sending a message to the state government, highlighting the importance of the issues, and showing that the City is prepared to play a significant role.

It is however important to recognise that there are many factors affecting both waterways from diffuse sources and outside the control of the asset manager; and as such a continued partnership approach is required.

In May 2023, the City reiterated its commitment to the role of Interim Asset Manager (C2305/093) but noted that this commitment is contingent upon continued technical and financial support from the state government, and the state government's continued commitment to broader waterway and water quality management in the Geographe Bay catchment.

The complex and difficult nature of the issues, and the high level of scientific and technical understanding required to identify and assess strategies, means that the City is not able to determine what those strategies should be. Instead, the state government, through DWER (Department of Water and Environmental Regulation) and the Taskforce especially, need to play a critical role in determining strategic direction.

Approach for assessing water quality improvement trials
Waterway management programs, works and trials within the Geographe region are assessed and prioritised under the structure of RGW and the Taskforce. The Taskforce has formally endorsed use of the *Vasse Taskforce Water Quality Decision Support Framework* for assessing and prioritising works, programs, and trials. The Framework provides a robust and consistent process for assessing proposals and providing confidence to waterway managers and the Taskforce in prioritising and funding trials and implementing water quality improvement initiatives. The Framework considers factors such as:

- Effectiveness – scientific rationale
- Appropriateness – alignment with waterway management plans
- Environmental impacts – short and long term environmental risks associated with the measure
- Social impacts – social/health risks
- Ease of implementation – practicality of implementation
- Cost – cost effectiveness (including initial, annual applications etc.)
- Maintenance – short and long-term maintenance and product application
- Proponent - experience, reputation and expertise

The LVR and TI are both host to significant ecological values and are afforded regulatory protection which reflects this. Officers are not able to implement water quality treatment technologies or products that have not been rigorously tested and scientifically documented. In May 2023, Council (C2305-093) confirmed the need for a considered approach and demonstrated process to considering water quality improvement trials in the Lower Vasse River and Toby Inlet, informed primarily by advice from the DWER Aquatic Science branch, or other appropriately qualified, experienced and independent technical or scientific specialists.

OFFICER COMMENT

The City and its partners undertake a variety of activities to improve or advocate for the improvements of waterways. A summary of those activities is provided below.

The Lower Vasse River Sediment Removal Program
In May 2023, the Council committed (C2305/093) to the staged removal of nutrient-rich sediments between the Busselton Bypass and the Busselton Butter Factory Museum as the City's short-term priority focus (Stage 3), subject to procurement, funding and regulatory approval, and the review of its effectiveness at improving water quality, before committing to further stages of sediment removal beyond Stage 3.

Sediment removal has historically been viewed by many stakeholders, particularly the community, as an essential component of management of the LVR.

Sediment removal is not anticipated to prevent algal blooms alone. Nutrient concentrations in surface and groundwater inputs individually are sufficient to fuel seasonal algal blooms in the river. Nutrients however may be released from the sediments when there is low dissolved oxygen or when sediments are disturbed, contributing to algae problems. Accumulated sediments may also pose an aesthetic issue, particularly when exposed by low water levels during summer months.

Dredging in natural waterways poses a risk to the natural environment and needs to be managed carefully. Approvals were granted under the Environmental Protection and Biodiversity Conservation (EPBC) Act 1999, Biodiversity Conservation Act 2016, and Aboriginal Heritage Act 1972 with stringent conditions associated with water quality monitoring, management of Carter's Freshwater Mussels and treatment of Acid Sulfate Soils.

Due to the large volumes of sediments, a staged approach is necessary to minimise environmental impacts and logistical constraints. Staging of the dredging process was prioritised on a values basis as opposed to in a linear fashion, with locations for the initial stages of sediment removal selected based on several factors, including severity of annual algal blooms, level of public access, and technical advice and information available at the time. Availability of suitable land for the laydown area and dewatering process was also considered.

Stage 1 of the Sediment Removal Program (SRP) was completed in 2022, with 630 tonnes dry solid removed from the river between the Causeway Road Bridge the pedestrian bridge adjacent to Cammilleri Street. Stage 2 was then completed in 2023, from Causeway Road to the Old Boat Ramp, removing an estimated 700 tonnes of dry solid material.

Sediments were removed from the river as a slurry using a micro-dredge and pumped into mesh geotextile bags, retaining the sediment and returning dewater to the river. The geotextile bags were left to dewater for approximately six months, after which sediments were transported to the Rendezvous Road Waste Transfer Station (Busselton) and treated for Acid Sulfate Soils (ASS) by incorporating lime and sand. Once the ASS neutralisation was verified, sediments were transported to the Vidler Road Waste Facility (Dunsborough) for reuse as daily cover at active landfill cells. Several improvements were made during Stage 2, based on learnings from Stage 1.

There are several ways of measuring success, which all contribute to the assessment of the project. The amount of sediment and nutrient removed from the river can be measured either by comparing the volumes of sediments in situ before and after sediment removal, or by measuring the quantity of sediment transported off site. Additionally, the nutrient load removed can be calculated by measuring the concentration of nutrient contained sediment transported off site.

In situ sediment volume and depth was measured by using pre and post dredging surveys for both stages. There are significant limitations with measuring sediment volumes in situ. Sediment in the LVR has a high organic content and the fine and flocculent nature of this sediment means that it is prone to pluming with minimal disturbance. Due to this characteristic, sediments before and after dredging (an activity that causes high levels of disturbance) will have very different compaction and density rates. Additionally, the need to extrapolate volume data from a limited number of survey points reduces the accuracy of extrapolation of the sediment volumes. Sediments in situ are highly compacted following years or even decades of accumulation, so the final volume once dredged is likely to have a considerably lower density that pre-dredge sediment, meaning that the ability to compare volumes is largely negated. Core sampling was also undertaken, which confirmed the difficulty in relying on measuring sediments in situ.

Recognising the high level of uncertainty highlighted above, it is estimated Stage 1 removed between 33% and 42% (or an average of 37.5%) of sediments in the 180m section of river between the pedestrian bridge and the Causeway Road Bridge.

Another methodology to measure sediments removed from the river is by measuring the volume of slurry pumped and the percentage solids (bone dry) in the slurry. Apex Envirocare used a solids analyser during the Stage 1 works and recorded 630 tonnes dry solids of sediments removed. This is measured continuously and updated during pumping. This method was not able to be used for the Stage 2 works due to damage to the solids analyser during the Stage 1 works. However, the Stage 1 data was used to inform the concentration of solids in the slurry (total dissolved solids, TDS), estimating the removal of 700 tonnes dry solids in Stage 2.

The program has been successful in removing a significant sediment load, approximately 630t and 700t dry weight respectively from the first two stages. The program also removed the following nutrient load (based on total dewatered dredge volumes).

Project Stage	Nutrient	Min (t)	Max (t)	Avg (t)
Stage 1 1,638t	Total Nitrogen	10.2	15.8	11.8
	Total Phosphorus	1.9	3.2	2.7
Stage 2 1,484t	Total Nitrogen	4.5	12.5	9.0
	Total Phosphorus	0.4	2.5	1.2

It is important to note that the intent was never to remove all sediments due to the significant challenges associated with dredging in a natural waterway. Sediments also contain seed and egg banks of aquatic plants and invertebrates; these are important for the system to self-rehabilitate after dredging works.

While the program has been successful in removing considerable sediment and nutrient loads, ongoing water quality monitoring has identified that high concentrations of nutrients were fed back to the river via return water from sediments during the dewatering process. High nutrient concentration in dewater was a risk that was identified during the program inception.

To mitigate this risk, in Stage 1, Phoslock®, a phosphorus-binding clay, was applied to return water prior to re-entry to the river. Phoslock® has successfully been used worldwide to reduce bioavailable phosphorus in aquatic environments. Unfortunately, due to the complex chemical composition of the sediment, Phoslock® was not effective in sufficiently treating the return water. In Stage 2, DWER collaborated with the City and trialled filtering dewater through an off-river treatment system containing Phosflow, beads that are designed to bind the bioavailable phosphorus. A triple filtration system using this product was successful in treating dewater during the trial. However, to scale-up this method to treat all dewater would be prohibitively expensive.

Assessment of the value of the sediment removal program will ultimately be determined by whether the removal of sediments leads to improvements in water quality. The City, in partnership with DWER has developed an ongoing water quality monitoring program to measure impacts from the removal of sediments. It will take several years, proceeding each stage, before meaningful conclusions can be made due to the lag time associated with any potential water quality improvements.

The City has been successful in securing state government part-funding for Stage 3 sediment removal upstream from the Strelly Street Bridge. Stage 3 provides additional constraints due to the proximity of residences, amount of vegetation on the river banks, morphology of the river and the need to manage Carter's Freshwater Mussels.

Environmental monitoring and reporting from Stages 1 and 2 demonstrated effective management of disturbances to water quality during sediment removal works, where no 'stop work' was required. The current sediment removal methodology (of micro-dredge and Geotextile bags) has also proven to be effective in mitigating acid sulphate soil (ASS) risks, and, as stated above, in removing a substantial load of sediment and nutrients from the river. However the undesirable volume of nutrients returned to the river via return water and concerns over whether the current method removes an adequate portion of sediment from the riverbed, has led the City to investigate and prioritise alternative methods for Stage 3, such as, in situ dewatering and direct excavation, which would necessitate rescheduling of sediment removal to occur in summer/autumn, and possibly additional approvals.

The City has requested tenders for both the current method as well as alternatives and is currently finalising assessment of the tender responses. Investigating an alternative method has introduced complexity and potential delays to the stage 3 works, and if details of proposals cannot be resolved satisfactorily or if approvals cannot be secured for proposals, the need may arise to return to the market for re-tender.

The City is currently committed to sediment removal in the river. While in situ dewatering and direct excavation will initially add significant complication and potentially project delays, it is hoped that it will in time (once the new method has been established) be more financially viable, time efficient and will remove a greater proportion of both sediment and nutrient loads from the river.

It will be important to continuously review the benefits of sediment removal and how it compares with other waterway improvement techniques. The Council previously resolved (C2305-093), to assess the impacts of sediment removal on cyanobacterial blooms in the river in 2025/2026 using data from three years of water quality monitoring, to then make a decision as to completion of stages 4, 5 and 6; and whether the City seeks to prioritise further funding for sediment removal.

Oxygenation/aeration
Refer to Committee Report detailing proposed Aeration Trial via Agenda Item 7.3

Large scale application of phosphorus binding clay
Phoslock is a commercially available clay which binds bioavailable phosphorus in the water column, making it unavailable to fuel algal growth, and caps the sediment preventing resuspension of phosphorus into the water column. It is used extensively in Australia and worldwide to improve water quality. The application of Phoslock® was trialled in the LVR in the early 2000's. DWER also trialled the application of a newly developed phosphorous-binding hydrotalcite-clay (HT-clay) in 2016/17 and 2017/18. Both trials demonstrated that the clays were effective at improving water quality, with the HT-clay able to reduce algal blooms even after the bloom was established. Phoslock® requires annual applications to maintain the water quality benefits, it is understood however, that over time smaller applications may be required.

DWER secured $100,000 in funding from RGW towards implementing a large-scale application of Phoslock® (HT clay is not currently commercially available) to a section of the river. The intention of the trial was to scope out practical requirements, costs and effects on water quality for ongoing Phoslock® programs in the LVR. Applications of Phoslock® elsewhere highlight the complimentary role that phosphorus-binding clays can play in fast-tracking water quality improvements in aquatic environments, while more long-term, slow-acting, programs are implemented.

Initial results from the summer 2023/2024 large-scale trial of Phoslock® suggest that, although the treatment was successful in binding bioavailable phosphorus to below detection limits, microalgal blooms were still present across summer and autumn. DWER has suggested that algal blooms during the trial were not fed by sediments or surface water but were believed to be fuelled by groundwater contaminated with nutrients. Groundwater feeding the LVR is believed to be contaminated with nutrients from septic tanks from the Busselton Light Industrial Area (Busselton LIA).

Light Industrial Area (LIA) Infill Sewer
The Council Decisions has in May 2023 and in August 2024 (C2407/233) resolved to advocate to the state government to prioritise and fund reticulated sewer in the Busselton Light Industrial Area.

Council Decision C2305-093 (May 2023):
16. Requests the CEO to continue advocating with the State Government for prioritising infill sewer in the Busselton Light Industrial Area.

Council Decision C2407/233 (August 2024):
That the CEO in relation to the Lower Vasse River:
5. Writes to the Minister (noting the asset is vested in the State) outlining the community concern in relation to cyanobacteria and health risks, and the link to illnesses citing research papers (noting the Minister's reference to the NHMRC of 08/04/2024) requesting a higher level of funding to complete, but not limited to dredging, trials, and remediation of the River to alleviate repeat cyanobacterial issues as a matter of urgency.

Groundwater input through leachate from septic systems has been identified as a significant contributor to excessive nutrient concentrations fuelling cyanobacterial blooms in the LVR; similarly, the Wonnerup Estuary is understood to be deleteriously impacted by leachate from local residential septic systems. Modelling from the draft Water Quality Improvement Plan (DWER, 2023) shows that septic systems are responsible for 11.4 per cent of nitrogen and 27.9 per cent of phosphorus discharging into the LVR. A significant portion of the Busselton LIA is currently not connected to sewer infrastructure, with 150 septic tanks discharging leachate to groundwater adjacent to the river. The WA Water Corporation is responsible for managing wastewater in Western Australia, with the state government funding and directing extensions to the sewer network.

The City is a strong advocate of reticulated sewer in both the Busselton LIA and the Wonnerup residential area and has repeatedly appealed for infill sewer in the in these areas. Without delivery of reticulated sewer in in the Busselton LIA and Wonnerup residential area waterway managers will be unlikely to be able to control microalgal blooms and amenity in these areas, regardless of any other water quality and nutrient remediation programs.

The City continues to advocate that the state government prioritise the connection of the Busselton LIA and Wonnerup area to reticulated sewer. The City has formally requested (August 2024) that the Vasse Taskforce work to prioritise and further progress advocating to the state government for installation of infill sewer in these areas. Additionally, the City is currently drafting a letter to relevant Ministers to request that the state government prioritise restoration of the health of the LVR and address community concerns regarding health implications of annual cyanobacterial blooms by:

- prioritisation and funding of reticulated sewer in the Busselton LIA and the Wonnerup residential area; and
- allocation of funding for river restoration works and trials conducted by the City of Busselton.

Statutory Environment

The City's waterway management role sits within the structure of Revitalising Geographe Waterways the Vasse Taskforce. The health and management of these waterways intersects the jurisdiction of numerous agencies, and there is no clear single responsible waterway manager.

The City has committed to be the 'Interim Asset Manager' for the LVR and TI. The City does not have a statutory obligation to manage either waterway and could decide to cease being the Interim Asset Manager. In May 2023, the City reiterated its commitment to the role of Interim Asset Manager (C2305/093-) but noted that this commitment is contingent upon continued technical and financial support from the state government, and the state government's continued commitment to broader waterway and water quality management in the catchment.

Relevant Plans and Policies

The officer recommendation aligns to the following adopted plan or policy:

Plan:
Lower Vasse River Waterway Management Plan
Toby Inlet Waterway Management Plan

Policy:
Environment

Financial Implications

Not Applicable with reference to this report. It is however important to recognise that the continued treatment and management of the LVR and TI has financial implications and requires ongoing funding from the State Government (as well as in part the City).

External Stakeholder Consultation

Not applicable.

Risk Assessment

An assessment of the potential implications of implementing the officer recommendation has been undertaken using the City's risk management framework, with risks assessed considering any controls already in place. No risks of a medium or greater level have been identified.

Options

Not applicable.

CONCLUSION

The City of Busselton performs waterway management in collaboration with key partner agencies, under the banner of RGW and the Vasse Taskforce. As the current Interim Asset Manager, is primarily responsible for management of the Lower Vasse River and Toby Inlet. The City, in accordance with developed waterway management plans, performs both ongoing works, such as bar opening at TI, stormwater management, and riparian rehabilitation, as well as intensive programs such as the sediment removal in the LVR.

The initial two stages of the sediment removal program in the LVR are complete, and learnings from these stages have been used to inform a potential methodology change for Stage 3

TIMELINE FOR IMPLEMENTATION OF OFFICER RECOMMENDATION

Not applicable

Lower Vasse River Sediment Removal Stages - 133473.qgz

Department of **Water and Environmental Regulation**

Department of **Primary Industries and Regional Development**

GOVERNMENT OF WESTERN AUSTRALIA

Phoslock® Application in the Lower Vasse River

Revitalising Geographe Waterways

The Phoslock application will use a similar method to the 2018 HT clay trial

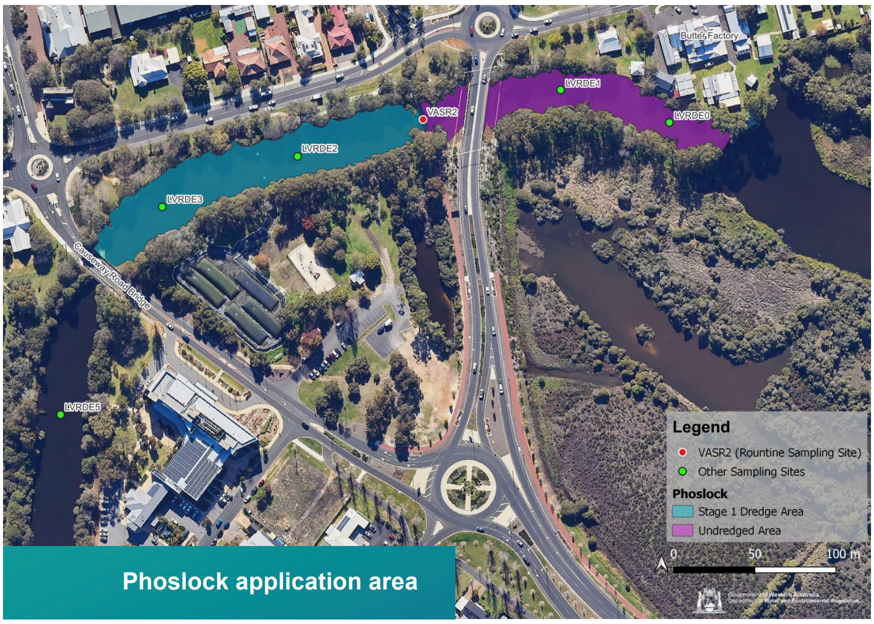
The Department of Water and Environmental Regulation (the Department) is undertaking a broad scale Phoslock® application in the Lower Vasse River between November 2023 and January 2024. The aim of the Phoslock® application is to evaluate if the product is a cost effective treatment to control algal blooms in the river over summer months.

Phoslock® is a commercially available clay product that removes dissolved phosphorus from the water and prevents phosphorus release from the sediment so that it is unavailable for algal growth. It has been approved for use in waterways worldwide and has been shown to be successful.

What work will take place?

Between November 2023 and January 2024, Phoslock® will be applied between the Causeway Road bridge and the Butter Factory in Busselton. The application will add on average 2-3mm of clay to the sediment where it will remain active in binding phosphorus.

The first stage of the application will involve installing a floating curtain at Causeway Road bridge to minimise water flowing into the treatment area. This will be followed by two to three applications of Phoslock® which will be applied as a slurry with a spray boom from a moving pontoon. Water quality monitoring will be undertaken in the river over summer months to measure the changes in phosphorus levels and algal growth.



Phoslock application area

How does Phoslock® work?

Phoslock® is a patented water treatment technology that aims to improve water quality by reducing phosphorus levels in aquatic systems. The main component of Phoslock® is lanthanum-modified clay, which forms a stable compound with phosphorus. Lanthanum chloride is widely used in a range of products and is used to reduce phosphorus concentrations in water bodies in the zoo, aquarium and fishery industries.

Phoslock® comes as dried pellets and is mixed with water in a slurry that is applied to the water surface from a pontoon. The pontoon is moved at a rate that allows around 2-3 mm of clay to be deposited on the sediment. As the clay sinks phosphorus is removed from the water column making it unavailable for algal growth. Phoslock® incorporated into the sediment also reduces the release of phosphorus from the sediment that contributes to algal blooms.

Phoslock® has been trialled a number of times in the Vasse River at smaller scales in the early 2000s. Post application sediment cores show that the applied clay is quickly incorporated into the sediment and covered with organic matter and other sediment.

Sediment coring in the river

Is Phoslock® safe?

Phoslock® is considered safe for waterways when used according to recommended guidelines. The product is designed to specifically target and immobilize phosphorus without causing harm to aquatic ecosystems. In the early 2000s CSIRO developed Phoslock® by modifying lanthanum chloride with a natural clay, thereby reducing potential toxicity and making it safe for use in natural waterways.

In the development of Phoslock®, extensive testing was undertaken to determine toxicity levels and ensure the product was safe to use in natural waters. A rigorous assessment was then undertaken by NICNAS (National Industrial Chemicals Notification and Assessment Scheme), now known as the Australian Industrial Chemical Introduction Scheme (ACIS). Phoslock® was subsequently approved for use in Australian waters by NICNAS and is now listed on the ACIS registry. Phoslock® has also been assessed by the USEPA and approved for use in US natural waters and similarly by the European Union.

Snake-necked turtle in the Lower Vasse

How can I get more information on this project?

For further information on this project visit the rgw.dwer.wa.gov.au or contact the GeoCapes District Office on 9781 0111.

HEALTHY ESTUARIES WA

Revitalising Geographe Waterways

VASSE taskFORCE

GOVERNMENT OF WESTERN AUSTRALIA
Department of **Water and Environmental Regulation**
Department of **Primary Industries and Regional Development**

Toby Inlet
Waterway Management Plan
May 2019

City of Busselton
Geographe Bay

Revitalising Geographe Waterways

VASSE taskFORCE

Document Set ID: 4118022
Version: 3, Version Date: 01/07/2019

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Acknowledgement of Nyungar people and country

The Wadandi Nyungar people are acknowledged as the traditional custodians of Toby Inlet and its catchment. Toby Inlet is a significant place of camping, fishing, hunting, and gathering food. Waterways are fundamental to life and wellbeing, and Aboriginal custodians have a spiritual connection that tasks them with the responsibility to look after these important environments.

Executive Summary

Background

Toby Inlet is a small estuary near the town of Dunsborough, Western Australia, about 250 km South of Perth. It is narrow and elongated, extending parallel to the coastline of Geographe Bay for approximately 6 km. Catchment development and hydrological changes have led to water quality and sedimentation problems in Toby Inlet. Remnant vegetation in adjacent areas is threatened by weed invasion, disturbance and illegal clearing. Despite these problems, Toby Inlet, and associated wetlands and remnant fringing vegetation retain natural values, which contribute to the amenity of the area and enjoyment by the local community.

This Waterway Management Plan (WMP) was initiated though the Revitalising Geographe Waterways program, in response to community concerns about water quality issues in key water assets in the Geographe Bay Catchment. The community have long been involved in management of Toby Inlet and its catchment, largely through the efforts of the Toby Inlet Catchment (TIC) Group to undertake research, management planning and on-ground works throughout the catchment. However there is a need for greater clarity in management roles and for a lead organisation to support community initiatives.

The WMP was developed using a collaborative approach that has allowed for extensive consultation to inform future management of Toby Inlet that aligns with community priorities, is well-understood and accepted, and has commitment to implementation by stakeholders.

Purpose and scope

The City of Busselton (the City) has developed this WMP to provide future management actions that will work towards realising the vision for Toby Inlet:

> *A healthy waterway and fringing vegetation that is actively managed, protected, valued and enjoyed by the community.*

The study area for the WMP includes the main waters of Toby Inlet, adjacent public reserves and wetland areas upstream to Quindalup Siding Road. The WMP includes a description of the characteristics and management issues for Toby Inlet, and provides objectives for future management. Through a review of available management options and consideration of stakeholder input, a comprehensive series of management strategies, each with specific actions, has been developed to guide works that will contribute to the objectives and overall vision for Toby Inlet.

Management focus areas

Management issues for Toby Inlet have been grouped into nine focus areas, with sixteen associated management objectives. These are summarised here in order of importance as rated during community consultation. The strategies and associated actions are provided in the table below, with the expected outcomes for each focus area. Owing to the interconnected nature of the system, many management strategies contribute to more than one objective.

1. Sedimentation

Extensive sediment deposition is evident in much of Toby Inlet, with deposits in the upper reach seasonally exposed during low water levels. This is a high priority management issue, which results in poor amenity associated loss of open water vistas and unpleasant odours during low water levels. Sediment deposition also interferes with water flow, fish movement and recreational use.

Objectives:

- Reduce catchment sediments and contaminants from existing and new developments entering Toby Inlet.
- Manage existing sediment to improve water quality, water flow and amenity of Toby Inlet.

2. Amenity

The issue of amenity in Toby Inlet is directly related to sedimentation, water quality and ecology. Amenity is also linked to recreation and access, which provide opportunities to enjoy Toby Inlet.

Objective:

- Improve visual amenity, public health and odours so that residents and visitors alike can enjoy Toby Inlet.

3. Water flow

Water flow within Toby Inlet has been significantly altered through drainage and diversion since European settlement. Reduced catchment flows are considered to have two main consequences: reduced winter flushing, contributing to poor water quality and sedimentation; and less frequent connection to the ocean, reducing summer flushing and increasing winter flood risk.

Objective:

- Optimise all water flow in Toby Inlet to balance improvement of water quality, protection of ecological values and public amenity, while maintaining flood protection.

4. Water quality

Water quality in Toby Inlet, associated wetlands and catchment tributaries has declined due to increased loads of sediments and nutrients, and poor flushing. Elevated nutrient levels typically cause increased growth of algae, including microscopic algae (phytoplankton) and filamentous algae (macroalgae), which impact amenity and can pose a public health risk. Macroalgal blooms in particular have been problematic. They are unsightly and can cover large areas of water, restricting access, and support breeding of nuisance midges. Decomposition of the algae reduces oxygen levels in the water and contributes to accumulation of sulfidic organic sediments.

Objectives:

- Reduce and manage nutrients and other pollutants entering Toby Inlet to improve water quality and lessen the frequency and severity of algal blooms.
- Minimise any additional nutrients entering Toby Inlet from new developments and agricultural intensification.

5. Toby Inlet Ocean Exchange

The status of Toby Inlet's connection to the ocean directly affects water quality and water levels. When the sand bar at the mouth of the inlet is closed during summer, water quality is poor and conducive to algal growth. When the sand bar is open, tidal flushing dilutes the nutrient concentrations and reduces residence time, limiting algal growth. When the sand bar is closed during winter, water levels in Toby Inlet can become high enough to cause localised flooding problems. Declining water quality has likely increased the demand for the Inlet to be opened, and this will be an important ongoing component of managing Toby Inlet.

Objective:

- Actively manage the Toby Inlet mouth to maximise ecology, water quality and recreational values.

6. Ecology

Toby Inlet and associated wetland area retains many important ecological attributes, which contribute to regional biodiversity and are valued highly by the local community. Remnant vegetation in the study area has natural value, provides important habitat and supports ecological functions. Key threats to vegetation are weed invasion, unauthorised clearing within public reserves and unmanaged access. The aquatic habitats of these systems are closely linked to the fringing vegetation and support diverse populations of aquatic fauna and waterbirds.

Objectives:

- Restore, maintain and protect the ecological values of Toby Inlet.
- Reduce the impacts of threatening processes on the ecological values of Toby Inlet.

7. Recreation and Education

Toby Inlet provides significant recreational opportunities, including fishing, swimming, paddling, birdwatching, exercising and passive enjoyment; and also opportunities for people to learn about the ecology and history of the area. Poor water quality and sedimentation issues restrict access for recreation within the water, and poor visual amenity and odours affect other activities. Unmanaged access has degraded fringing vegetation and caused some bank erosion. There is significant potential for improving recreational and educational opportunities in and around Toby Inlet.

Objectives:

- Improve and manage public access for recreational purposes that support the amenity and ecological values of Toby Inlet.
- Facilitate appropriate water based recreational activities with consideration to the ecological values and water quality of Toby Inlet.
- Raise community awareness of Toby Inlet’s recreational, cultural and ecological values.

8. Heritage

Toby Inlet holds significant cultural value for the Wadandi people due to the abundance of resources and the natural protection from weather conditions. The area has been important for hunting and camping for many years both pre- and post-settlement. Aboriginal people are well aware of the decline in health of the inlet and the relationship to drainage changes and land development. A key issue raised by Aboriginal representatives was minimising additional access and infrastructure for recreation, while retaining access for Aboriginal people.

The area around Toby Inlet was an important part of early European colonisation. Quindalup was the primary settlement established in 1866, with a school, supporting local timber export. There is also a history connected to whaling.

Objective:

- Understand, protect and preserve the heritage values of Toby Inlet.

9. Governance

An independent review of waterway management highlighted the need for Toby Inlet to have a designated manager, and for greater clarity of management roles for various organisations. The Toby Inlet Catchment Group has been instrumental in past management, but implementation of an existing management plan has been limited by a lack of funding and support from relevant organisations.

The review also recommended that research and monitoring need to be a component of future management. This would facilitate ongoing assessment and reporting of progress and allow for adaptive management based on outcomes and new knowledge.

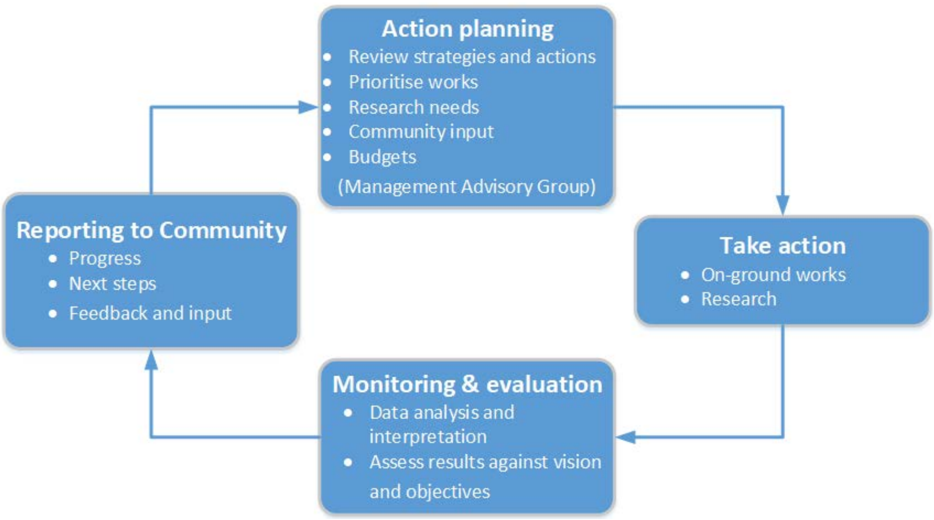
Objectives:

- Develop and maintain partnerships and a collaborative approach between stakeholders and the community when managing Toby Inlet.
- Involve the community in the future management of Toby Inlet.
- Adopt evidence based decision making in the long term management of Toby Inlet.

Implementation

The lead role of the City in the future management of Toby Inlet will be recognised through endorsement and adoption of this Waterway Management Plan. Other key stakeholders will continue to have important roles in many aspects of implementation, and there is an ongoing need for community reporting and feedback. A framework for implementation is provided that defines roles and responsibilities for management and an adaptive cycle for management.

Implementation process for the Toby Inlet Waterway Management Plan:



Management Strategies and Actions for Toby Inlet and expected outcomes for each focus area

Focus areas: Water Quality (WQ); Toby Inlet Ocean Exchange (TIOE); Ecology (E); Water Flow (WF); Sediments (S); Amenity; Recreation and Education (ARE); Culture and Heritage (CH); Governance (G).

Management Strategy	Management Actions	Expected outcomes (related focus area)
Optimal management of Toby Inlet ocean exchange	• Maintain Toby Inlet ocean outlet, the Station Gully culvert and the Station Gully outlet in accordance with the Operational Procedures (Appendix 2). • Monitor the status of the outlet through a telemetered system to determine when opening of the sand bar is necessary. • Ensure the culvert between Station Gully and Toby Inlet remains open to improve water quality in the upper reach of Toby Inlet, east of the ocean outlet.	Sand bar management (TIOE) Defined management (G) Reduced algal growth (WQ, A) Less sediment exposure (S, A) Improved amenity (A, RE) Enhanced fish movement (E, RE) Optimising Water flow (WF)
Investigate sediment removal	• Define priority areas for sediment management and determine sediment composition and volume for these areas, building on previous sediment investigations. • Assess potential outcomes and impacts of sediment removal from priority areas and undertake a cost/benefit analysis of strategic sediment removal. • Assess whether sediment agitation would facilitate mobilisation and flushing of sediment deposits on Toby Inlet.	Evidence-based decision-making (G) Less sediment exposure (S, A) Improved amenity (A, RE) Manage existing sediment (S) Optimising Water flow (WF)
Prevent further sedimentation	• Improve understanding of sediment sources and transport through water quality monitoring. • Develop an education approach to reducing sediments inputs from the catchment. • Identify and ensure management of potential erosion problems from new developments and changes in land use during the planning process, through implementing the Better Urban Water Management framework. • Investigate key sediment sources in the catchment and potential for works to stabilise drains and increase sediment trapping within the drainage network.	Reduce catchment sediments (WQ, S) Minimise development impacts (S, G) Evidence-based decision-making (G)
Rehabilitate exposed sediment deposits	• Identify areas of exposed sediments that could be revegetated to improve habitat and amenity and stabilise sediments. • Undertake trial revegetation of samphire in exposed sediment.	Creation of new habitat (E) Covering unsightly sediment deposits (S, A)
Reducing nutrient sources from the catchment	• Completion of scheduled infill sewerage works in residential areas adjacent to Toby Inlet. • Review the sewerage works once completed, and address any lack of connection to sewerage infrastructure through education campaigns or incentives if deemed necessary. • Ensure Geographe Bay catchment management initiatives extend to the Catchment of Toby Inlet, including: implementation of best management practices; and community education to reduce inputs from gardening and livestock activities in urban and special rural areas.	Reduce inputs of nutrients and other pollutants (WQ) Reduce catchment sediments (S) Reduced algal growth (WQ, A) Minimise development impacts (WQ, G)

	• Increase potential for nutrient assimilation in the rural drainage network in conjunction with sediment trapping and through restoration. • Identify opportunities for reducing nutrient, sediment and pollutant sources through upgrades to stormwater infrastructure. • Continue current water quality monitoring within Toby Inlet, and extend routine monitoring to include associated wetlands and catchment tributaries, to ensure information requirements for prioritising and reviewing management initiatives are met. • Support educational campaigns that aim to reduce nutrients in runoff through individual and community actions (e.g. Bay OK) and investigate options to improve nutrient management in public open space. • Minimise future nutrient sources from new development and land use change at the planning stage through implementing the *Better Urban Water Management* framework. • Support implementation of the Vasse Wonnerup wetlands Geographe Bay Water Quality Improvement Plan.	Evidence-based decision-making (G)
Effectively manage foreshore reserves	• Prepare and implement a prioritised works program for weed control and revegetation. • Support community efforts in weed control and revegetation. • Ensure revegetation in high amenity areas is appealing and maintains vistas to increase community support for these activities. • Effectively manage recreational access to protect and enhance the key values of reserve areas. • Create awareness of reserve boundaries through bollards and signage where appropriate. • Develop information resources for landholders to raise awareness of reserve boundaries, the importance of fringing vegetation, weed problems and the restrictions on clearing native vegetation and building jetty structures. • Assess foreshore reserve areas that have no public access and develop appropriate management actions to benefit the broader public. • Develop a policy for jetties that ensures structural integrity and protection of adjacent foreshore areas and prevents establishment of new structures.	Conservation of vegetated habitat (E) Reduce threatening processes (E) Improved amenity (A) Managing access (RE) Maintaining fringing vegetation buffer (WQ) Preventing bank erosion (S)
Understanding fauna	• Support further research on aquatic and terrestrial fauna and bird populations to inform management initiatives and assess outcomes. • Pursue a community science approach to collecting bird data. • Develop information resources to increase community interest and understanding of fauna.	Awareness and understanding of ecological values (RE) Community involvement in management (G) Evidence-based decision-making (G)
Improving facilities for community appreciation	• Seek community input on the *Access Management Plan* for Toby Inlet (SW Environmental 2018), and subsequently develop and implement appropriate access-ways and recreational infrastructure. • Determine requirements for additional parking in support of improved facilities.	Improved public access and amenity (RE) Support for appropriate activities (RE)

	• Enhance bird habitat in connection with existing and potential bird watching sites. • Encourage bird watchers to join a community science approach to collecting bird data. • Support schools in using Toby Inlet as an outdoor learning environment, including provision of information resources and consideration of an outdoor classroom.	Awareness and understanding of ecological values (RE) Community involvement in management (G)
Providing informative resources	• Develop appropriate signage in connection with improved access and facilities to inform the community about: ecological values of Toby Inlet; location and use of access and facilities; cultural and historical values; and management initiatives underway. • Prepare and distribute fact sheets and educational material for key management focus areas, relevant to schools, community members and natural resource managers. • Continue to update the Revitalising Geographe Waterways website with information on Toby Inlet and its management.	Awareness of recreational, cultural and ecological values (RE)
Recognising Aboriginal custodianship	• In partnership with local Aboriginal people, include reference to traditional custodianship of the waterways and land in development of information resources. • Manage future access in a way that avoids additional disturbance and considers protection of potential sites of Aboriginal significance – however activities of local Aboriginal people, such as fishing, camping, the gathering of bush foods and family recreational and educational activities, will not be restricted by implementation of this plan. • Seek to improve partnerships with the Nyungar community to increase their involvement in the management, protection and restoration of Toby Inlet and the study area. • Consult further with Aboriginal representatives in regard to specific works which result from this plan. • Support programs that engage the Aboriginal community in implementation of works associated with this plan.	Understanding and protecting heritage values (CH) Community involvement in management (G)
Conserve historical values	• Identify and ensure appropriate maintenance of sites historical importance. • Develop interpretive material to increase understanding of local history, and to promote, appreciate and access historical sites.	Understanding and protecting heritage values (CH)
Defined and collaborative management	• City to consider securing management order over waterways and adjacent public lands in study areas, to facilitate implementation. • Establish a Management Advisory Committee comprised of representatives from the City, Toby Inlet Catchment Group, Department of Water and Environmental Regulation, Water Corporation, GeoCatch, South West Catchments Council, Wadandi representatives and broader community representatives. • Support the Toby Inlet Catchment Group as active participants in planning, on-ground works, and as a key link to the community.	Collaborative approach to management (G) Community involvement in management (G)

	• Facilitate the development of locally-active Friends of Toby Inlet groups to advocate and coordinate on-ground work in reserves and on private property. • Define and resolve issues around vesting of Unallocated Crown Land.	
Evaluate and adapt management actions	• Continue monitoring of water quality in Toby Inlet. • Review monitoring requirements for catchment tributaries and groundwater. • Undertake assessment of macroalgal growth. • Ensure timely reporting of monitoring and research outcomes to the management advisory group. • Review future management actions in light of monitoring and research outcomes.	Evidence-based decision-making (G)

1 Introduction

The City of Busselton (the City) has developed this Waterway Management Plan (WMP) to guide future management actions that will lead to improved water quality and ecological health for the Toby Inlet and associated reserves and wetlands within the study area. The vision for Toby Inlet, developed in partnership with the community and stakeholders, is:

> *A healthy waterway and fringing vegetation that is actively managed, protected, valued and enjoyed by the community".*

1.1 Background to this Waterway Management Plan

Catchment development and hydrological changes have led to water quality and sedimentation issues in Toby Inlet for many years. Nutrient enrichment has resulted in seasonal blooms of filamentous algae (macroalgae), which reduce amenity and recreation values by blocking open waters and causing foul odours when they decompose. Sediment deposition in the Inlet has created shallower conditions which are exposed at low water levels, reducing visual amenity and contributing to odour problems. Phytoplankton blooms and stranding of fish in shallow pools have occasionally resulted in fish deaths in the Inlet.

This WMP is part of Revitalising Geographe Waterways (RGW), a $15 million program developed to improve water quality and ecosystem health in key water assets. Within the RGW program, the City has been identified as the lead agency for progressing improved waterway management within the Lower Vasse River and the Toby Inlet, and was given responsibility to prepare Waterway Management Plans for these systems. The Department of Biodiversity, Conservation and Attractions was given responsibility to develop an Operational Plan for the Vasse-Wonnerup Wetland Systems.

The RGW program is one of five focus areas of the Vasse Geographe Strategy, a State Government initiative to address water quality in the Geographe Bay catchment (Figure 1). The program also includes two projects directly related to the Toby Inlet WMP: the Reconnecting Toby Inlet hydrological modelling project; and the infill sewage project for residential areas adjacent to Toby Inlet.

The Vasse Geographe Strategy was initiated by an independent review of waterways management (Hart 2014), commissioned by the State Government in response to serious community concerns about water quality issues. The Vasse Geographe Strategy is overseen by the Vasse Taskforce, comprising representatives from:

- Department of Water and Environmental Regulation (DWER)
- City of Busselton (the City)
- Shire of Capel
- Geographe catchment Council (GeoCatch)
- Department of Biodiversity, Conservation and Attractions (DBCA)
- Department of Primary Industries and Regional Development (DPIRD)
- Department of Planning, Land and Heritage (DPLH)
- South West Catchments Council (SWCC)
- Water Corporation (WCorp)
- Busselton Water (BW)

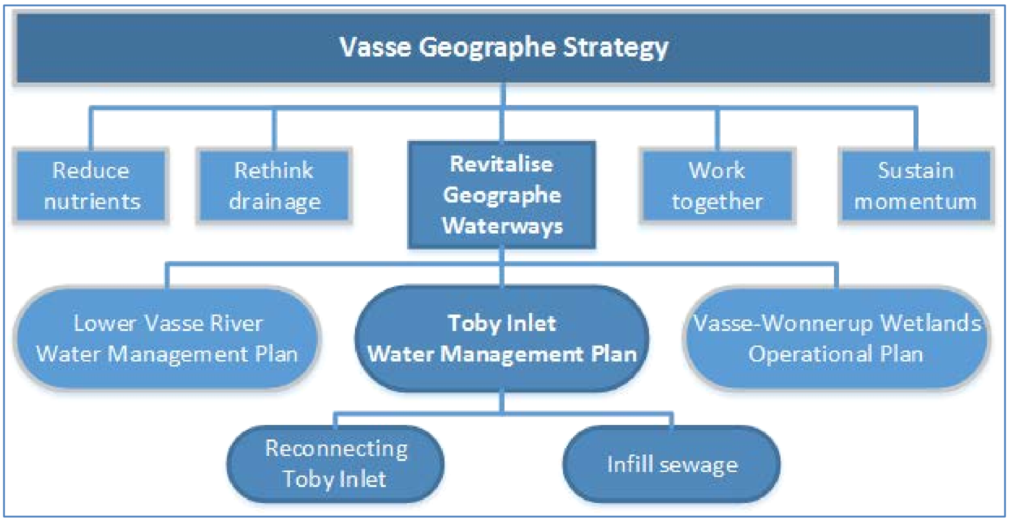


Figure 1. Management framework for the Toby Inlet Waterway Management Plan.

1.2 Study Area Description

Toby Inlet is a small estuary near the town of Dunsborough, Western Australia, about 250 km South of Perth (Figure 2). It is narrow and elongated, extending parallel to the coastline of Geographe Bay for approximately 6 km. It is situated on the Swan Coastal Plain and is connected to seasonal wetland areas upstream. The study area for the WMP is 118 hectares, encompassing Toby Inlet itself, adjacent public reserves, and the wetland area extending upstream approximately 2.7 km from Caves Road to Quindalup Siding Road. Quindalup Siding Road acts as a physical barrier to other wetlands to the east. The study area also includes a short reach of Station Gully Drain between Caves Road and the beach (150 m), which dissects the easternmost section of Toby Inlet (500 m) commonly referred to as the Deadwater. Station Gully Drain is openly connected to the Deadwater, but is only connected to Toby Inlet via a culvert under the access road to the beach.

1.2.1 Landscape and hydrology

Toby Inlet has a catchment area of approximately 33 km^2 including large areas of Swan Coastal Plain, and bounded by the Whicher Scarp to the south. The portion on the coastal plain areas is characterised by deep sandy soils and seasonally inundated flats, which have been subject to extensive clearing and drainage for agriculture. Only around 30% of native vegetation remains in the Toby Inlet catchment, with key remnants occurring in foreshore reserves, on private land adjacent to the wetland areas, and on reserves and private land in the upper catchment.

Artificial drainage, undertaken for much of the Swan Coastal Plain in the early 1900s to improve agricultural value, has changed the hydrology of Toby inlet and its catchment. This included drainage and redirection of flow within wetland areas to the south of Toby Inlet, and diversion of the upper reaches of Station Gully, Annie Brook and Mary Brook into a single drain into Geographe Bay at the eastern end of Toby Inlet (Station Gully Drain). These changes have effectively reduced the original catchment area of the inlet and the volume of water conveyed. The average annual rainfall in the catchment is 651mm (10-year average, BoM 2018), with declining rainfall evident over the last 20 years (Figure 3).

Toby Inlet is intermittently connected to the ocean, either naturally or artificially, at two points: via a channel to the east of Station Gully; and via a culvert to Station Gully, which then flows to the ocean. The connection of Toby Inlet to the ocean is likely to have always been intermittent, but it is thought that reduced flows from the catchment have decreased natural breaching of the sand bar.

Figure 2. Toby Inlet locality and study area, and routine monitoring sites.

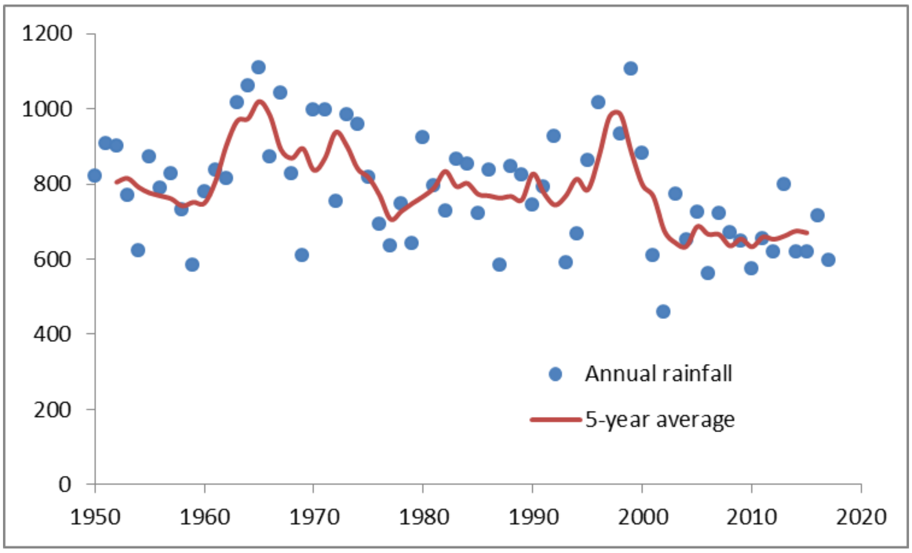


Figure 3. Rainfall records for Cape Naturaliste (BoM 2018). The 5-year average for each year includes two years before and after.

1.2.2 Land use and tenure

From the mouth of the Inlet to 300m upstream of Caves Rd, the study area is entirely within publicly-owned land (Figure 4). Upstream from this point the wetland areas are privately owned, with the exception of a drainage reserve in the central section approximately 800m long and 20m wide (Responsible agency DWER). Public lands include reserves vested in the City, unallocated Crown land (UCL) and road reserves (Appendix 1).

The eastern 1.5km section of Toby Inlet is entirely within public reserve between Caves Road and Geographe Bay, and is managed by the City. West of this, the Inlet is surrounded by residential development. Despite the foreshore being entirely public land, many sections are inaccessible to the public and are managed by adjacent private landholders. Clearing of foreshore vegetation, weed invasion, lawn encroachment and dumping of garden refuse are common problems in these areas. Many residents have established private jetties, which vary in quality and at times debris from these structures floats into the Inlet. Upstream of Caves Road, land use is mainly rural.

Agriculture (50%) and rural residential areas (32%) are the dominant land uses in the catchment. The remaining area consist of existing and future urban development (8%: residential, business and industrial), and reserves and public open space (10%). There is currently considerable urban residential development occurring on coastal plain areas to the south west of Toby Inlet.

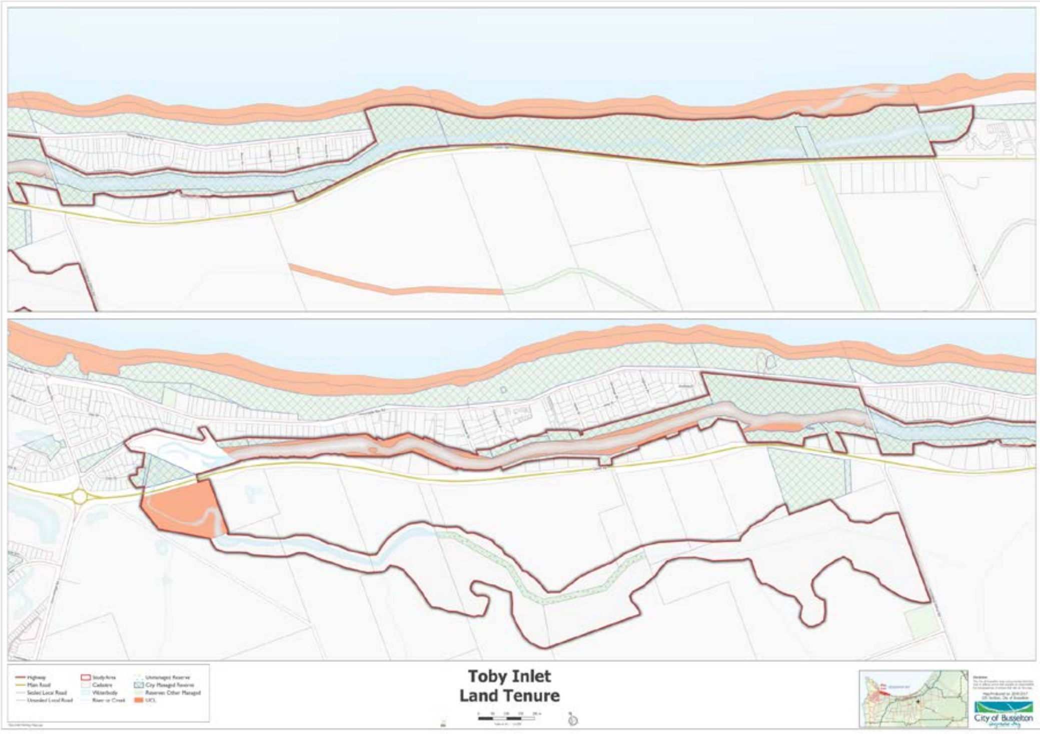


Figure 4. Toby Inlet study area land tenure.

1.2.3 Natural and social values

Toby Inlet study area retains high natural values that are important for conservation purposes, and contribute to the amenity of the area and enjoyment by the local community. The Inlet itself provides habitat for fish, crabs, frogs and aquatic macroinvertebrates that support food webs. The surrounding reserves include important areas of intact remnant vegetation, including areas of the Threatened[1] Coastal Saltmarsh ecological community. Foreshore vegetation and open waters support many species of waterbirds. Remnant vegetation throughout the study area provides habitat for other birds and terrestrial fauna including the Critically Endangered[2] Western Ringtail Possum (*Pseudocheirus occidentalis*) and the Priority 4 Quenda[3] (*Isoodon obesulus fusciventer*, also known as the Southern Brown Bandicoot).

Residential areas adjacent to Toby Inlet in Quindalup benefit from its quiet location away from central Dunsborough and the natural amenity of its proximity to the protected waters of Toby inlet and Geographe Bay. The remnant vegetation, water vistas, birdlife and fishing opportunities are enjoyed by the local community and visitors to the area.

[1] *Environmental Protection and Biodiversity Conservation Act* 1999 (Commonwealth) (EPBC Act)
[2] Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017 (WA); (EPBC Act)
[3] Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017 (WA)

1.3 History of Management

It is important to acknowledge past and ongoing work of the community-based Toby Inlet Catchment (TIC) Group in advocating and undertaking active management of Toby Inlet, associated wetlands and broader catchment. In 1996-97, the TIC Group initiated surveys on vegetation (Weston 1997), terrestrial fauna (HAS 1997), birds (Clay and Clay 1996), and water quality and aquatic macroinvertebrates (Streamtec 1997). The outcomes of this work highlighted degradation of terrestrial and aquatic habitats in the Inlet and its catchment. Data from these surveys was used to prepare the *Toby Inlet and Associated Wetlands Management Plan* (Comer and Clay 1999) for the TIC Group. TIC Group has also prepared the *Toby Inlet Catchment Management Plan* (Clay 2002) to direct catchment scale works to improve water quality and manage flora and fauna.

The Toby Inlet Steering Committee was formed in 2003, which included community members from TIC Group, Dunsborough Coast and Land Care, Sussex LCDC and the Quindalup Strip Preservation Committee; councillors and an officer from the (then) Shire of Busselton; and officers from GeoCatch and the Water Corporation. The TIC Group prepared the *Management Plan for the Toby Inlet Foreshore and Waters* (Clay 2005), supported by the Steering Committee and adopted by the (then) Shire of Busselton.

The issues, objectives and actions in the 2005 management plan remain relevant. Since the adoption of the 2005 management plan, further work has been done to monitor water quality; determine needs and outcomes of opening the sand bar; understand sediment characteristics in the inlet; and to assess and improve the health of foreshore vegetation.

1.4 Process for developing the Waterway Management Plan

The WMP has been developed using a collaborative approach that has allowed for extensive consultation to work towards future management of Toby Inlet that aligns with community priorities, is well-understood and accepted, and has commitment to implementation by stakeholders. Key stakeholders that have contributed to this WMP are:

- City
- Community members
- Aboriginal people
- Toby Inlet Catchment Group
- Dunsborough Coast and Land Care
- GeoCatch
- Department of Water and Environmental Regulation
- Water Corporation

The process for developing the WMP is shown in Figure 5. The consultation process has contributed directly to identifying and developing the management issues, vision, management objectives, management strategies and actions for the WMP. Activities undertaken for consultation are outlined in the following sections. The consultation process and the overall WMP have been informed by review of existing information about Toby Inlet and by new information gained through projects undertaken during the planning process. It is important to note the adaptive nature of this WMP. It has been prepared at a point in time, using the information currently available. Implementation will require an ongoing process of monitoring and evaluation to guide future actions.

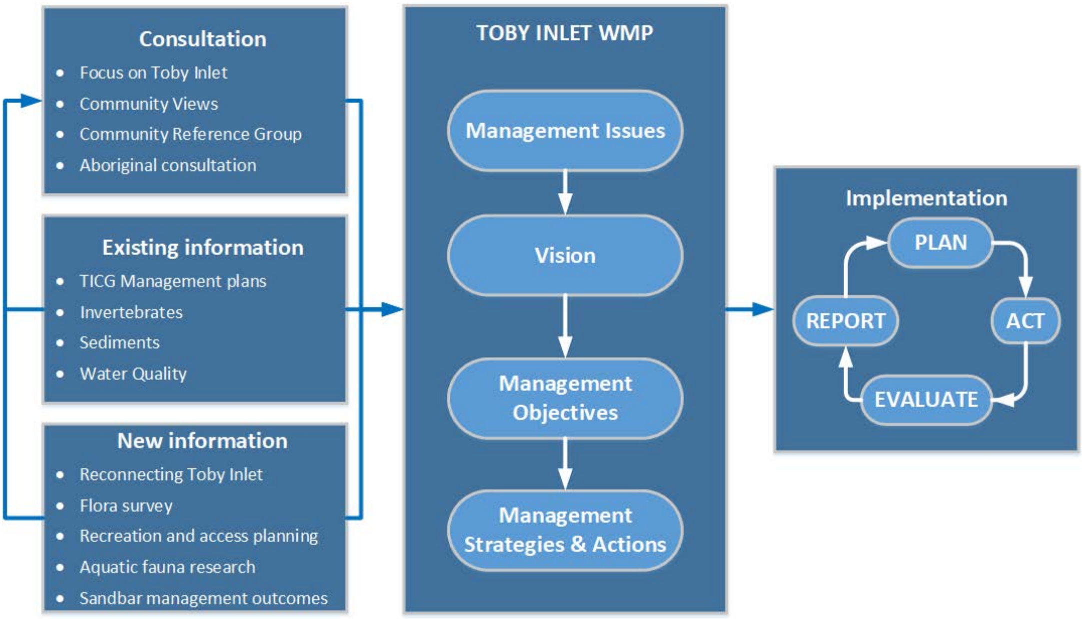


Figure 5. Process for developing the Waterway Management Plan for Toby Inlet.

1.4.1 Community consultation

Consultation with stakeholders was an integral part of preparing this WMP. The aims of consultation were:

- To understand community issues and concerns about Toby Inlet;
- Gain input, ideas, feedback into future management of the Toby Inlet;
- To get support from the community on proposed actions; and
- To raise community awareness and understanding of local water quality issues.

Early consultation events were widely advertised to attract a broad representation from the community. The first of these, *Focus on Toby Inlet* in June 2015, provided information on current understanding of Toby Inlet and sought to identify issues of most importance to the community. The *Community Views* event in March 2016 was also open to whole community and facilitated rating of management issues, valued characteristics and desired change (Figure 6; AHA 2016). These results reflected a high level of importance on issues related to the health of Toby Inlet and associated amenity (82%). Other issues rated as important were recreation and access, heritage, flood and management. The outcomes of this consultation were used to formally identify key management issues, as outlined in Section 2 of the WMP. Information provided by the community and suggested management actions were used to develop draft management objectives, and were considered when reviewing management options.

Following initial consultation, a Community Reference Group (CRG) was formed to provide ongoing input to WMP. This group was formed by inviting participants of earlier events to nominate for ongoing involvement. It also included representation from the Department of Water and Environmental Regulation and GeoCatch, as key supporting partners in development of the WMP. Facilitated workshops with this group were held to develop the vision, management objectives (AHA 2017a, 2017b) and management strategies and actions (AHA 2018) for the WMP.

1.4.2 Aboriginal consultation

Aboriginal people are important stakeholders. In recognition of Aboriginal people as the traditional custodians of country, and understanding the particular significance of waterways to Aboriginal people, additional consultation was undertaken to facilitate input to the WMP.

The draft management objectives were presented to the South West Boojarah (SWB) Working Party via the South West Aboriginal Land and Sea Council (SWALSC) in May 2017. An overview of the Revitalising Geographe Waterways Program was also provided at a Working Party meeting in November 2017.

The Aboriginal Heritage Survey was undertaken with representatives of the Aboriginal community (members of the SWB Working Party and the Harris family, as nominated by SWASLC) in February 2018, encompassing the study areas of all three plans included in the RGW program. The Survey was facilitated by Brad Goode and Associates (2018) and included briefings and a bus tour of key sites of the Toby Inlet study area for discussion of scientific investigations, future management actions and the content of the plan. Information from this consultation has been considered in the development of management objectives and actions in this WMP.

The study area is within the South West Boojarah Indigenous Land Use Agreement Area, which is one of six Indigenous Land Use Agreement areas that form part of the South West Native Title Settlement Area[4]. There is a historical camping ground within the survey area, which has been lodged as an Aboriginal Site under the Aboriginal Heritage Act (1972) and is awaiting an outcome.

[4] Current information on the South West Native Title Settlement: http://www.noongar.org.au

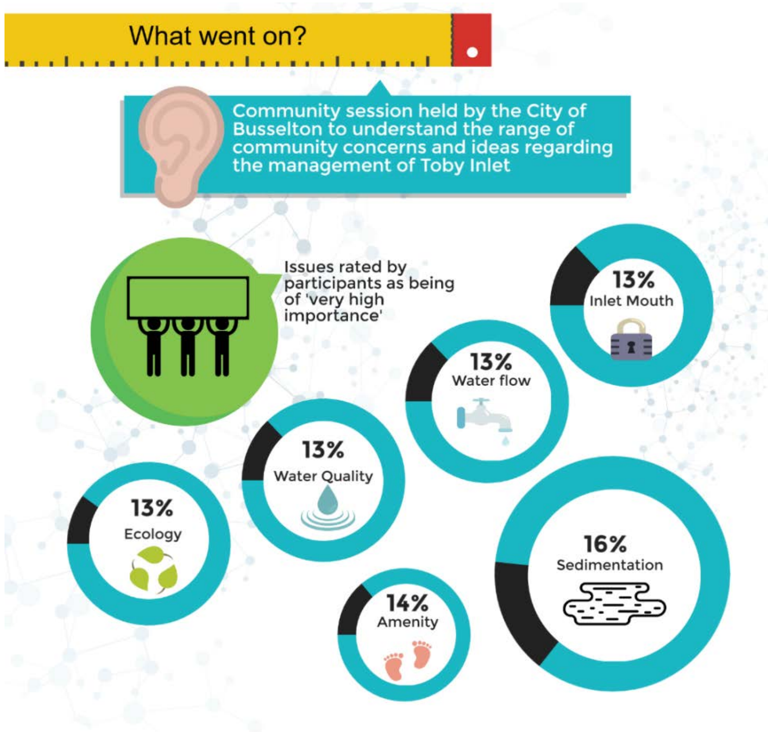


Figure 6. Outcomes from identifying and rating management tissues for Toby Inlet at the *Community Views* consultation session, March 2016.

2 Management Issues

The consultation process lead to the development of nine focus areas for management as follows:

- Sedimentation
- Amenity
- Water flow
- Water quality
- Toby Inlet mouth
- Ecology
- Recreation and education
- Heritage
- Governance

A summary of key management issues and information for these focus areas is provided in this section.

2.1 Sedimentation

Extensive sediment deposition is evident in much of Toby Inlet, with deposits in the upper reach of seasonally exposed during low water levels. Although sediment accretion in estuaries is a natural long-term process, it has been accelerated in Toby Inlet by increased sediment loads from the catchment and by excessive growth of algae in response to nutrient enrichment (discussed further in the section on water quality). Sediments deposits in Toby Inlet broadly comprise two sources: soils from the catchment, transported to and deposited in the Inlet; and accumulation of organic material within the Inlet. There is concern about the build-up of sediment in Toby Inlet for the following reasons:

- Poor amenity due to loss of open water vistas and unpleasant odours of exposed sediment during low water levels.
- Blocking of water flow in the inlet, preventing flushing of nutrients and organic material from the system.
- Reduced depth throughout the Inlet, restricting fish movement and creating potential for fish stranding in shallow pools.
- Smothering of benthic habitats, potentially impacting ecology.
- Reduced depth restricting recreational activities such as use of watercraft.

Areas of deposition downstream of Caves Road are generally sandy to a depth of 0.5m over clay and lateritic rock, and considered to be recent deposition from catchment sources (Norrish 2005, ENV 2007). Sandy deposits are also evident in other parts of the Inlet but these have not been characterised. Aerial photographs of the area show that substantial sediment deposits have been present for more than 20 years (Figure 7). These sediments have been identified as potential acid sulphate soils (ENV 2007, Figure 8) and the implications of this for management are discussed in Section 4.1.

Siltation from catchment sources is associated with clearing and drainage. Clearing of vegetation mobilises soils, and artificial drainage often creates unstable banks and channels, contributing sediment downstream. Earthworks and drainage for residential development results in exposed soils susceptible to erosion, and can be observed in drains within the Toby Inlet catchment (add photo).

Urban development in close proximity to Toby Inlet is often considered a key source of sediment. Diversion of flows may have decreased potential for flushing of sediments through the system to the ocean, exacerbating accumulation of 'sediment slugs'.

In downstream sections of Toby Inlet, accumulation of organic material has contributed significantly to sedimentation. Monosulfidic black ooze (MBO) has been found in the lower reach of Toby Inlet, from a point approximately 700m downstream of Caves Road Bridge (ENV 2007, Ward et al. 2009; Figure 8). MBO commonly forms in areas of high primary productivity, where seasonal growth and decomposition of algae results in accumulation of soft organic material with high concentrations of iron monosulfides (Ward et al. 2009). Growth of phytoplankton and filamentous macroalgae in Toby Inlet has been enhanced by increased nutrient loads from the catchment. MBO presents a risk of rapid acidification when disturbed, causing deoxygenation. Analysis of these sediments did indicate high potential for acidification, but also found that acid neutralising capacity (ANC) may be sufficient to buffer this effect (Ward et al. 2009).

"There used to be little streams 25 years ago. They have all been filled in and the birds and vegetation suffers." Community views report 2016

Figure 7. Comparative aerial photographs of sediment deposition in Toby Inlet downstream of Caves Road, from 2018 (left) and 1997 (right).

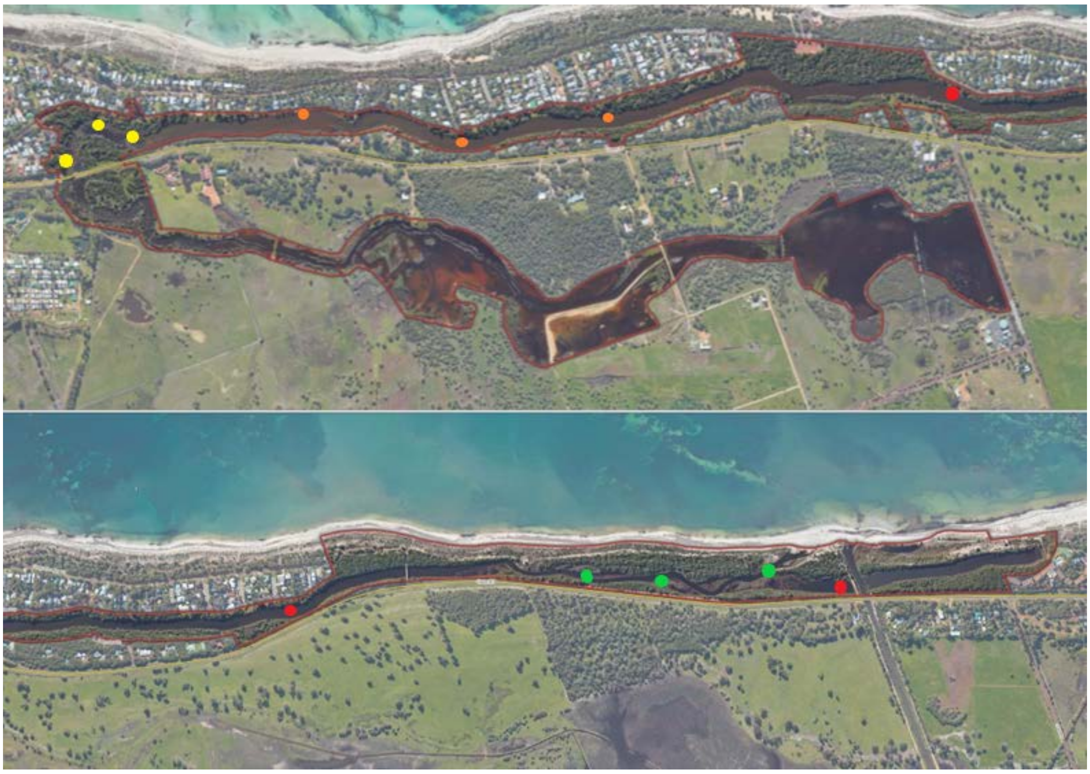


Figure 8. Acid sulphate soil and monosulfidic black ooze (MBO) presence in Toby Inlet sediments. Yellow markers show sand-dominated sediments with potential acid sulphate soils but no MBOs found in 2007 study. Orange sites show MBOs and potential acid sulphate soils in 2007 study. Green sites show no potential acidity or MBOs found in 2009 study. Red sites show MBOs and potential acid sulphate soils in 2009 study.

2.2 Amenity

Amenity describes the attractiveness of a place, and the 'visual' appeal of Toby Inlet was the characteristic most valued by participants in community consultation. Amenity was rated as one of the most important management issues, showing that people are concerned about threats to the amenity of Toby Inlet. The issue of amenity in Toby Inlet is directly related to sedimentation, water quality and ecology. Amenity is also linked to recreation and access, which provide opportunities for the public to enjoy Toby Inlet.

During low water levels, exposure of sediment deposits reduces amenity associated with open water vistas, and can result in unpleasant odours. The loss of amenity is a key reason that sedimentation in Toby Inlet has been identified as the highest-rating management issue.

In relation to water quality, seasonal macroalgal blooms are common in some parts of the inlet due to high nutrient concentration and still conditions. These masses of filamentous algae are unsightly, and cause unpleasant odours when they decompose. The algae also provide good habitat for non-biting midge larvae which may contribute to nuisance populations. As noted in Section 2.1, this material also accumulates in the Inlet and contributes to sedimentation problems.

Phytoplankton blooms occur occasionally in Toby Inlet, but have not been persistent and are usually dominated by harmless species. Isolated blooms of blue-green algae, which create a public health risk, occurred in May 2013 and February 2018, but did not persist. Further decline in water quality has potential to increase algal blooms in Toby Inlet, impacting amenity and recreation.

Quindalup Special Character Area

The Quindalup Special Character Area (SCA) Policy was developed by the (then) Shire of Busselton in 1996 to guide urban development in a way that maintains the natural amenity of the area. The Toby Inlet study area is located within this policy area. The character of the area is described as *a relaxed holiday atmosphere, this is attributable to its low density of housing which is contained within a bush and seaside setting, surrounded by natural environs.* The policy provisions apply to all public and private land within the SCA. The Quindalup SCA Policy notes the extensive remnant vegetation on private and public land in the area as a significant characteristic, and outlines development controls to protect native vegetation.

2.3 Water flow

Water flow within Toby Inlet has been significantly altered through drainage and diversion since European settlement. Notably, the catchments of Carbunup River, Station Gully (aside from interchange at the culvert) and a number of other smaller waterways have been diverted and no longer connects to the Inlet or contribute to its flow. Prior to this, Toby Inlet was connected to the Deadwater and outflow to the ocean was via the current Station Gully outlet (anecdotal). There is also a perception by some community members that construction of dams in the catchment has contributed to reduced flow (including the Dunsborough Lakes development).

Reduced catchment flows are considered to have two main consequences: reduced winter flushing, contributing to poor water quality and sedimentation; and less frequent connection to the ocean. The issue of reduced ocean connectivity is discussed further in Section 2.5.

There is community support for increasing water flows from catchment sources with the aim of mobilising sediment deposits within the Inlet. Altering water inflows may improve water quality through:

- Increasing summer/autumn flow to reduce water residence time and so reduce potential for algal growth.
- Diluting nutrient concentrations by adding lower nutrient-content inflows.
- Increasing winter velocity to scour sediments.

Potential for reconnecting catchment flows to Toby Inlet has been investigated through the *Reconnecting Toby Inlet* hydrological modelling project (Frazer and Hall 2018), and this management option is discussed further in Section 4.3.

2.4 Water Quality

2.4.1 Surface Water

Water quality in Toby Inlet and its tributaries has declined due to increased loads of sediments and nutrients, and poor flushing. Sources of excess nutrients include runoff from agricultural and residential areas, and leachate from septic systems in nearby residential areas (DoW 2010). Elevated nutrient levels typically cause increased growth of algae, including microscopic algae (phytoplankton) and filamentous algae (macroalgae), which impact amenity and can pose a public health risk.

Nitrogen levels in the Toby Inlet are consistently higher than ecosystem protection guidelines for estuaries, particularly in spring and summer (Figure 9a). Concentrations tend to be higher in upstream sites, and are lowest near the ocean entrance in summer and autumn. This may reflect opening of the sand bar in summer autumn period and a limited flushing effect upstream.

Phosphorus concentrations in Toby Inlet are highly variable and while average values are below the ecosystem protection guideline, samples frequently exceed this throughout the Inlet (Figure 9b). Extremely high total phosphorus occurs during summer at the more upstream sites, while concentrations near the ocean outlet are low. This may reflect ocean flushing, but may be due to uptake of phosphorus by filamentous macroalgae.

While nutrient concentrations appeared higher in the most upstream site, phytoplankton growth is greater lower in the Inlet (indicated by chlorophyll a, Figure 9c). Many types of phytoplankton are harmless, but at high densities can have unpleasant odours and form unsightly scums. Some species are toxic to humans and animals, including fish. Phytoplankton sampling by DWER since 2012 shows that the levels in Toby Inlet are mostly below the recreational guideline of 20,000 cells/mL (Figure 9e). However, harmful algal species have been found frequently at low densities. Blooms of blue-green algae have been detected twice since 2012.

Macroalgal blooms are currently more problematic than phytoplankton in Toby Inlet (Figure 10). They are not toxic but are unsightly and can cover large areas of water, restricting access and impacting visual amenity. Macroalgae also provides ideal habitat for breeding of nuisance midges. When large blooms of macroalgae decompose, this reduces oxygen levels in the water and sediments. Accumulation of this material has contributed to the formation of sulfidic sediments, including MBO. Although excessive growth of macroalgae is a serious management concern, no assessment or monitoring of species or biomass has been undertaken.

Fish deaths have occurred in Toby Inlet in late September 2006 (limited information available) and on 6 March 2014 (about 1000 fish). The 2014 incident was a result of stranding of fish associated with extremely low tides draining the lower sections of the Inlet. Fish deaths can be caused by low oxygen conditions, harmful phytoplankton or by stranding in warm shallow waters. Low oxygen levels have been associated with phytoplankton blooms in Toby Inlet, and fish have been observed congregating near the closed mouth of the Inlet when oxygen is low.

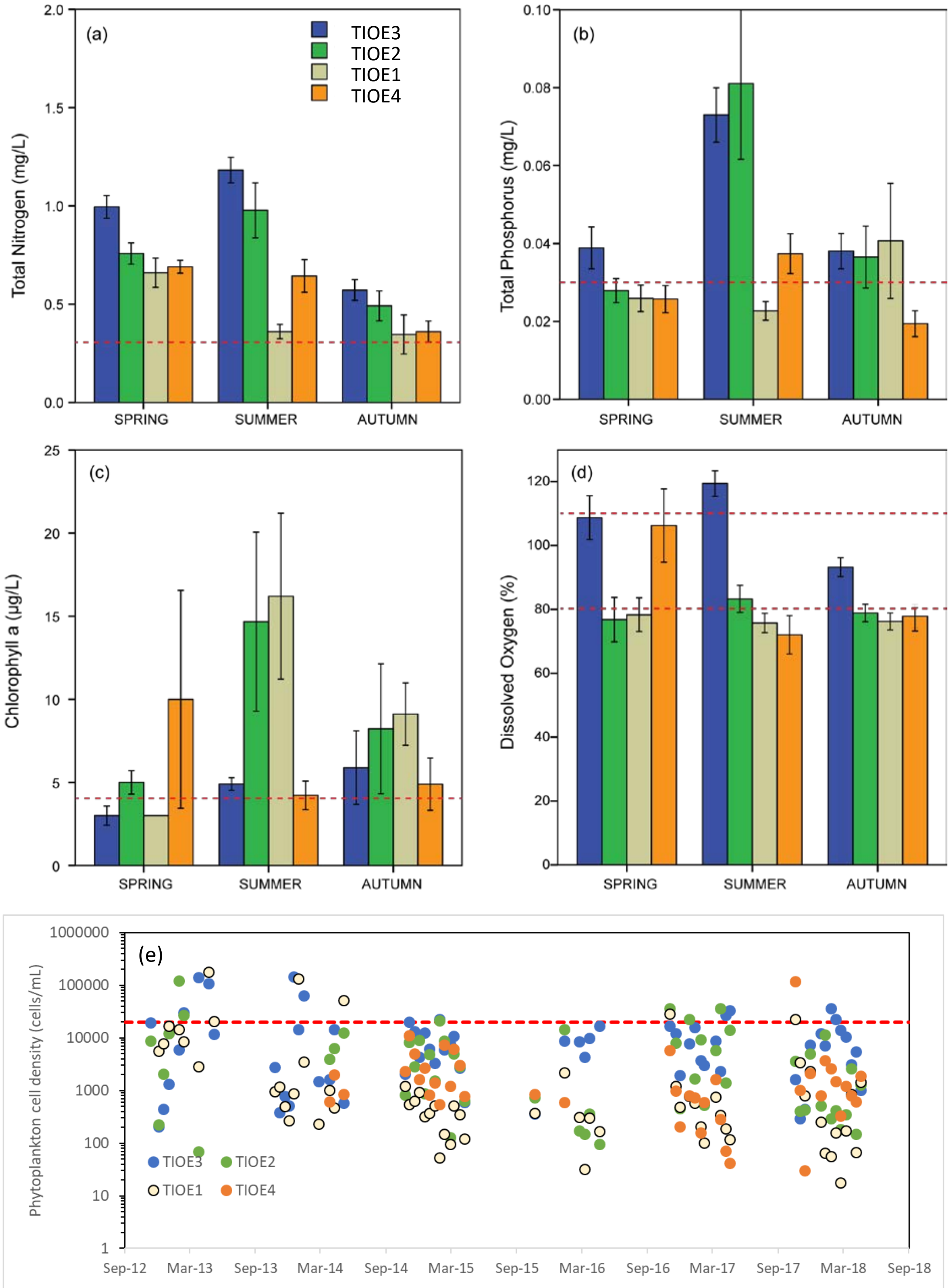


Figure 9. Average concentrations of water quality indicators (a-d) and phytoplankton density (e) in Toby Inlet (data courtesy DWER (DWER 2018). Sites TIOE3, 2 and 1 are located east to west respectively from Quindalup Siding Road to the ocean exchange and TIOE4 is just near the culvert exchange with Station Gully, as shown in Figure 1. Red dashed lines are guideline values for protection of estuarine ecosystems (a-d) and recreational use (e) (ANZECC and ARMCANZ 2000). Note logarithmic scale in (e). Error bars are +/- standard error.

Figure 10. Macroalgae growing in Toby Inlet (DoW 2010).

2.4.2 Groundwater

On the coastal plain, groundwater and surface water are closely related. Summer water levels in wetlands are often expressions of the superficial aquifer. Groundwater quality around Toby Inlet and in catchment areas is not well understood. Though there are numerous monitoring bores in the catchment, sampling has been inconsistent and there has been no analysis of data. This was not raised as an issue during community consultation, but could have implications for future management.

There have been concerns raise by community members in the past (late 1990s) and very recently about salt water intrusion in groundwater in the Dunsborough foreshore area generally, as a possible cause for the declining health of Peppermint trees. Dunsborough Coast and Land Care (DCALC) initiated a groundwater study for Dunsborough foreshore and Toby Inlet in partnership with the (then) Water and Rivers Commission. Fourteen monitoring bores were installed for assessment of salinity, nutrients and pH. However, results of the sampling program are not publicly available.

2.5 Toby Inlet ocean exchange

The common understanding among the community is that reduced water flow from the catchment has reduced the natural opening of Toby Inlet to Geographe Bay. The status of the sand bar has direct influence on water quality and water levels. When the sand bar is closed during summer, water quality is poor and conducive to algal growth. When the sand bar is open, tidal flushing dilutes the nutrient concentrations and reduces the residence time, limiting algal growth. When the sand bar is closed during winter, water levels in Toby Inlet can become high enough to cause localised flooding problems for nearby residential properties.

A memorandum of understanding for artificial opening of the sand bar was signed by key management bodies in June 2000, including the (then) Shire of Busselton, (then) Water and Rivers Commission, GeoCatch and Water Corporation. This specified that the preferred management for Toby Inlet and

Station Gully was as a common ocean outlet. The purpose of opening the sand bar was to prevent flooding of nearby properties and to increase tidal flushing to improve water quality. Managing a single ocean outlet became difficult owing to extensive sand build-up. In early 2005, the (then) Department of Environment trialled excavation of a separate ocean outlet for Toby Inlet with the aim of improving water quality in the Inlet through tidal flushing.

Although water quality is generally improved by ocean exchange, problems have occurred with excessively low water levels during low tides. Very low water levels impede recreational boating activities and lead to greater exposure of sediment deposits, reducing visual amenity and causing poor odours. There is also anecdotal evidence of fish stranding in upstream areas at very low tides.

Declining water quality has likely increased the demand for the Inlet to be opened, and this will be an important ongoing component of managing Toby Inlet.

2.6 Ecology

Toby Inlet and associated wetland area retains many important ecological attributes, which contribute to regional biodiversity and are valued highly by the local community. The vegetation communities within and surrounding Toby Inlet and associated wetlands have intrinsic conservation value and provide important habitats for terrestrial and ecological functions. The aquatic habitats of these systems are closely linked to the fringing vegetation and support diverse populations of aquatic fauna and waterbirds.

The ecology of Toby Inlet provides amenity value and supports recreational activities such as fishing, watercraft use, bird-watching and exercise pastimes. A summary of the ecological components of the Toby Inlet study area and associated management issues is provided below.

2.6.1 Vegetation

The foreshore of Toby Inlet contains large areas of intact vegetation, owing to preservations within reserves, most of which are managed by the City. The management of vegetation and conflicting landscaping and gardens of adjoining properties is a key issue.

A recent survey of flora and vegetation was completed for the City by Ecoedge (2017). The study area contains at least fifty native species within seven different vegetation communities (0), including two vegetation units that fit criteria for the Coastal Saltmarsh threatened ecological community[5]. Weston (1997) described three broad types of vegetation communities: fringing wetland and estuarine, coastal scrub, and forests and woodlands.

There are at least fifty species of weeds present in the study area, and 14 of these are considered environmentally significant (0the most significant of these is Arum lily (*Zantedeschia aethiopica*), which currently occurs as localised infestations at many sites (Ecoedge 2017). Bridal creeper and grassy weeds are also problematic. Grassy weeds continue to invade native vegetation, and there is progressive encroachment of lawns into reserve areas in some locations. There are number of potentially invasive garden escapees that pose a threat in the study area. Dumping of garden refuse

[5] EPBC Act 1999

and direct planting of exotic species within reserves, as well as spreading from private gardens, contribute to this problem.

Other key threats to vegetation are unauthorised clearing within public reserves and unmanaged access.

Despite the presence of a range of environmental weeds, the foreshore vegetation is considered generally in fair to good condition. Forty percent of vegetation is rated as very good to excellent condition. The study area is also in high proximity to a Regional Ecological Linkage. In addition to the conservation value of the flora itself, fringing vegetation of wetland areas is a vital component of wetland health. Functions include:

- supporting terrestrial and aquatic food webs;
- habitat for terrestrial and aquatic fauna;
- foreshore stabilisation;
- maintaining cooler temperatures;
- interception of nutrients and sediments in runoff; and
- nutrient uptake and processing.

Future works to rehabilitate fringing vegetation must be mindful of maintaining suitable amenity to avoid future conflicts with landowners and preventing ongoing encroachment of lawns and gardens into reserve areas.

2.6.2 Birds

Birds are an important part of the Toby Inlet ecosystem and are appreciated by members of the community and by visitors. No formal bird monitoring data is available for the study area, however surveys were conducted during spring in 1996 and results are reported in Clay (2005). This survey recorded 68 bird species including 26 waterbirds and 42 forest birds. Given the level of community interest in birds there is an opportunity to engage people in data sharing to better understand bird populations of Toby Inlet.

The surrounding vegetation and open water areas are important habitat for birds. Threats to bird populations include degradation of habitats, predation by domestic and feral animals, and disturbance from human activities.

2.6.3 Aquatic Fauna

Though impacted by modified hydrology, nutrient enrichment and sedimentation, Toby Inlet is considered to provide important fish habitat. Sheltered estuarine systems such as Toby Inlet are important for fish breeding, particularly for estuarine species which require both fresh- and salt-water for different phases of growth and reproduction. Estuaries also tend to be highly productive, supporting aquatic invertebrate communities that provide an important food resource for fish and waterbirds.

Aquatic invertebrates

Aquatic invertebrate sampling of Toby Inlet in 1997 found a combination of estuarine and freshwater species, with more diverse wetland-type communities at upstream sites. Though species diversity was high at some sites, the system was considered dominated by cosmopolitan species characteristic of a degraded system (Streamtec 1997).

Recent sampling downstream of Caves Road in November 2017, prior to opening of the sand bar, also found higher-diversity wetland communities in more upstream regions and lower-diversity estuarine communities downstream (Tweedley et al. 2018). This study found a relatively diverse aquatic invertebrate community, including species that are intolerant of pollution and low oxygen levels, indicating a fairly healthy ecosystem. Other notable fauna observed during the study by Tweedley et al. (2018), were: Southern Bobtail Squid (*Euprymna tasmanica*, Blue Swimmer Crab (*Portunus armatus*) and Western King Prawn (*Penaeus plebejusl*). A list of taxa from both these studies is provided in Appendix 7.

The effect of opening of the sand bar on the invertebrate population, and implications of this in terms of food resources for fish and birds, have not been assessed. The recent sampling provides a useful baseline for future assessments in Toby Inlet.

Fish

Fish in Toby Inlet have long provided a food resource for Aboriginal people, and fishing has been a valued recreational pursuit for many years. There is a general perception that the fish population has declined in Toby Inlet, though it is still perceived as providing important fish habitat.

A recent study of the fish population in Toby Inlet (Tweedley et al. 2018) provides the first formal description of the fish population. For this study, fish were sampled in November 2017 and March 2018, prior to and following the opening of the sand bar (11th December 2017). The type of fish found were typical of those found in other south west estuaries and include estuarine and marine species and some freshwater-estuarine fish. Several marine species known for using estuaries as nursery areas were present. Mosquitofish, which is aggressive to native fish and not able to be controlled, was also recorded.

Following opening of the sand bar in December 2017, fish density remained similar to before opening, but species diversity increased owing to an increase in the number of marine species which recruited into the estuary. However in general, the fish population was more influenced by timing of life cycles than by opening of the sand bar.

2.6.4 Other Fauna

The terrestrial vegetation provides habitat for many species of birds and other fauna, including two mammal species of conservation significance: the Critically Endangered[6] Western Ringtail Possum (Ngwayir, *Pseudocheirus occidentalis*); and the priority 3 listed[7] Quenda (Southern Brown Bandicoot). A site survey and summary of observations by local residents in November 1996 found these two mammals, Grey kangaroos present, two species of frogs, 13 species of reptiles and the possible

[6] Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017 (WA); (EPBC Act)
[7] Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017 (WA)

presence of Water Rat (Rakali, *Hydromys chrysogaster*) (Hart et al. 1997) (Appendix 6.). The Brush-tailed Phascogales (*Phascogale tapoatafa*) may also be present, and is listed as a conservation-dependent species[8].

Impacts on vegetated habitat, predation by domestic and feral animals and fire are the main threats to these native mammals. Remnant vegetation is at risk of degradation from physical disturbance, inappropriate fire regimes, weed invasion and physical disturbance.

2.7 Recreation and Education

Toby Inlet provides significant recreational and educational opportunities. Activities such as fishing, swimming and paddling on the Inlet have been important recreational pastimes since early European settlement during the mid to late 1800's. Bird watching and other passive enjoyment activities are also important. Toby Inlet is the focus of a number of tourism accommodation businesses on and around the inlet. The visual amenity and opportunity for recreational pursuits are critical to both visitors and local residents alike. Poor water quality and sedimentation problems restrict access for recreation within the water, and visual amenity and odour problems affect other recreational activities. This affects a broad cross section of the community, visitors and local businesses.

Despite these problems, a number of trails, beaches and open space adjoining the Toby Inlet continue to provide recreational opportunities and these are highly valued by the community. However, unmanaged access has led to disturbance of foreshore vegetation and erosion of banks in some locations. There is significant potential for improving recreational and educational opportunities in and around Toby Inlet, by addressing water quality and sediment problems, improving facilities and providing information resources.

Private use of reserves and private jetties

Considerable areas of foreshore reserves do not have public access and some areas adjacent to private property owners are managed for private purposes. The condition of foreshore vegetation and bank stability in these areas varies from remnant vegetation in good condition to extensive clearing and bank instability. Illegal clearing of native vegetation within public reserves to improve views is an ongoing problem. Private use of public reserves by residents conflicts with access by the broader public; but some residents are concerned that increased public access will create security issues.

These privately used foreshore reserves include a number of private jetties. They have been present in Toby Inlet for many years and in general have not been raised as a key management issue. However there is an issue relating to the structural integrity of these jetties and the materials they are built from. For example a jetty made from plastic drums has come apart and a plastic drum floated in the Inlet. In addition, building of more jetty structures may cause inappropriate disturbance to foreshore areas. The City currently has no policy regarding these structures.

[8] Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017 (WA)

2.8 Cultural Heritage

2.8.1 Aboriginal heritage

Toby inlet holds significant cultural value for Wadandi people. In pre-European times, local groups traditionally gathered to conduct ceremonies and take advantage of food resources. Following European settlement, the area continued to be used for camping, with evidence of several historical camps still present from times when Aboriginal people were not permitted to live in town (BGA 2018). There is a historical camping ground within the survey area, which has been lodged as an Aboriginal site under the *Aboriginal Heritage Act 1972* and is awaiting an outcome.

On-site discussions with local Aboriginal representatives were held during the preparation of this plan. The group described historical use of Toby Inlet and surrounds by Aboriginal People for camping and fishing and the substantial changes to the area since European settlement (BGA 2018). The group related the decline in water quality and fish abundance to the substantial changes in drainage and development of the surrounding lands. A key issue raised by the group was minimising additional access and infrastructure for recreation, while retaining access for Aboriginal people.

2.8.2 European History

The area around Toby Inlet was an important part of early European colonisation. Quindalup was the primary settlement established in 1866, supporting local timber industry, and is the site of the original school. There is also a history connected to whaling.

This extract about European history is from the Management Plan prepared by Clay (2005):

Toby Inlet was named after Captain Jacob Toby, of the coastal schooner 'Ellen'. The Ellen used to take on water at Meelup, and while in the area Captain Toby would moor close to the mouth of Toby Inlet and barter with the local residents, exchanging knives, tools, sugar and tea for fresh produce (Guinness, 1984; Smith, pers.comm2004). In the 1800's Jack Molloy commenced construction of a boat in the sheltered waters of Toby Inlet near the sand bar. The boat was well into construction when the mouth broke out, and washed away the boat supports. The boat was buried by sand and left at the site. This incident is referred to as 'Molloy's Folly" (Smith, pers. comm.).

The European history of Toby Inlet, is documented by several authors (Guiness, 1984; Kinsella, 1990: Horwitz & Wardell-Johnson, 1996). Anecdotal evidence supports the fact that Toby Inlet used to be considerably deeper than it is today. In the 1920's the channel was deep enough for small boats, and due to the accretion of sediments, this is obviously no longer possible. In 1967 the Inlet was dredged by a very unsophisticated piece of equipment, along the north bank, from a point just west of the Edgewater subdivision to a point some 400 metres east of this sub-division. From this point to the ocean a channel was cut to allow passage for small boats (Ken Davies pers.comm.2004).

In 1994 the Water Authority constructed a bund across the Inlet, at the western end of Campion Way to allow for the maintenance of an existing water main. It is said by the locals that after maintenance had been completed, the bund was not completely removed, thus restricting water flow (Ken Davies pers.comm.2004).

2.9 Governance

Governance was not identified as a priority issue of concern in the community views session, but was indicated as an area needing change. It was recognised as an important focus area during the development of management objectives, and is clearly an important overarching issue for implementation of the WMP.

The independent review of water asset management (Hart 2014) highlighted the need for Toby Inlet to have a designated manager, which was further supported in the State Government response. The review acknowledged the work of the Toby Inlet catchment Group in developing the existing management plan (Clay 2005). However, implementation of this plan has been limited by a lack of funding and support from relevant organisations, and the management roles have not been clear.

The existing management plan is not connected to any targets or monitoring, so progress and outcomes have not been measurable. The community have been dissatisfied with the progress of management for Toby Inlet. Although there has been no formal tracking of progress, there is a general perception in the community that the ecological health of Toby Inlet has continued to decline (Hart 2014).

The review also recommended that identifying research needs should be a component of future management. Annual reporting to the community on the health of Toby Inlet and the effectiveness of management was also recommended, with government support, which will require clear goals/targets and associated monitoring.

Management of Toby Inlet is minimalist at best. The community-based Toby Inlet Catchment Group have developed a Management Plan for Toby Inlet, and could do a serviceable job of managing the Inlet if they had more funding and greater backup from CoB and DoW (Independent Review - Hart 2014).

3 Management Objectives

Sixteen management objectives across the nine the focus areas are listed below. These objectives were strongly guided by community input. They provide important statements for future assessment of the implementation of this WMP.

3.1 Sedimentation

1. Reduce catchment sediments and contaminants from existing and new developments entering Toby Inlet.
2. Manage existing sediment to improve water quality, water flow and amenity of Toby Inlet.

3.2 Amenity

3. Improve visual amenity, public health and odours so that residents and visitors alike can enjoy Toby Inlet.

3.3 Water quality

4. Reduce and manage nutrients and other pollutants entering Toby Inlet to improve water quality and lessen the frequency and severity of algal blooms.
5. Minimise any additional nutrients entering Toby Inlet from new developments and agricultural intensification.

3.4 Water flow

6. Optimise all water flow in Toby Inlet to balance improvement of water quality, protection of ecological values and public amenity, while maintaining flood protection.

3.5 Toby Inlet ocean exchange

7. Actively manage the Toby Inlet mouth to maximise ecology, water quality and recreational values.

3.6 Ecology

8. Restore, maintain and protect the ecological values of Toby Inlet.
9. Reduce the impacts of threatening processes on the ecological values of Toby Inlet.

3.7 Recreation and Education

10. Improve and manage public access for recreational purposes that support the amenity and ecological values of Toby Inlet.
11. Facilitate appropriate water based recreational activities with consideration to the ecological values and water quality of Toby Inlet.
12. Raise community awareness of Toby Inlet’s recreational, cultural and ecological values.

3.8 Cultural Heritage

13. Understand, protect and preserve the heritage values of Toby Inlet.

3.9 Governance

14. Develop and maintain partnerships and a collaborative approach between stakeholders and the community when managing Toby Inlet.
15. Involve the community in the future management of Toby Inlet.
16. Adopt evidence based decision making in the long term management of Toby Inlet.

4 Review of Management Options

Development of management strategies for Toby Inlet involved consideration of a range of potential initiatives. Some of these are based on fundamental waterway management approaches, such as minimising nutrient and sediment loads, and enhancing the important function of fringing vegetation. Other initiatives involve further work to better understand potential outcomes and challenges. Many of the strategies and actions build on community suggestions for future management of Toby Inlet.

4.1 Sediment Removal

There is strong community support for active removal of sediments from Toby Inlet. Community input indicates that this is driven by perceptions that sediment removal will lead to outcomes in the following areas:

- Flushing of water through the system to improve water quality.
- Removal of unsightly sediment deposits.
- Addressing unpleasant odours associated with exposed sediments.
- Deepening of the Inlet to improve boating conditions.
- Improved conditions for fish.

Removal (dredging) of sediment could be progressed if it can be justified on ecological grounds, rather than for amenity outcomes only.

4.1.1 Challenges

Previous investigations (ENV Australia 2007) have shown a layer of sandy sediments approximately 0.5m deep in the area of obvious sediment deposits downstream of Caves Road. This area would be a likely focus of sediment removal should it be deemed an appropriate action. This area did not contain MBOs but did contain potential acid sulphate soils (PASS). Potential for acidity means sediment removed would require treatment for disposal.

The deeper area downstream was assessed as having a surface layer of MBO in the sediments and also contained PASS (ENV Australia 2007). The presence of MBOs is probably linked to a history of macroalgal blooms in the area. Disturbance of MBOs can cause deoxygenation, heavy metal release, nutrient release, sulphide toxicity and bad odours.

Removal and transport for disposal would involve significant costs, and may also cause physical disturbance to the environment. Further investigations would be needed to prioritise areas for sediment removal; determine volumes and characteristics of the sediment to inform disposal options; and assess potential environmental impacts. Volumes of sediment have been estimated for the large area of deposition downstream of Caves Road as:

- Deepening the channel to -0.4m AHD: 1684m^3
- Removal of large sandy deposit to 0.4m AHD: 714m^3

4.1.2 Potential outcomes of removal

The main objective associated with this approach is improved amenity: removal of sediment deposits would improve water vistas for some local residents; and deepening the Inlet would improve access for watercraft. Outcomes for water quality and ecology and potential impacts of removal are also possible but not well understood, and further investigation is needed to assess potential for both beneficial outcomes and negative impacts.

Removal of sediment in the upper and lower reaches of Toby Inlet was included in hydrological modelling done for the *Reconnecting Toby Inlet* project. This indicated some potential for improvement in water quality through increased water circulation in the estuary: reducing the bathymetry to -0.5mAHD (removing about 300mm of sediment) would create additional regular flushing of about 2%, or 100m (Frazer and Hall 2017).

Deeper conditions may also improve open water habitat for fish and birds, but this is not known. There are risks of negative impacts on the environment, which may in turn have negative effects on amenity. Risks associated with sediment removal in Toby Inlet include:

- disturbance of acid sulphate soils and monosulfidic black ooze;
- physical disturbance of bed and bank habitats; and
- damage to fringing vegetation.

Before a recommendation can be made with regards to sediment removal, management should focus on defining priority areas for sediment management and understanding the costs and benefits of removal.

4.1.3 Alternatives to removal

Other than removal, some potential management options to address sedimentation in Toby Inlet are:

- Minimising future sediment loads into the system.
- Mobilisation of sediment through agitation to resuspend sand into the water column, using a hydraulic sludge pump during high flows, to facilitate its movement into to the ocean.
- Acceptance of sediment deposits and rehabilitation (e.g. planting) of these areas to improve ecology.

4.2 Toby Inlet ocean exchange

Connectivity of Toby Inlet to the ocean has direct effects on water quality and water levels. Potential connections are via a culvert into Station Gully, which is intermittently open to the ocean; and via a direct separate channel to the west of Station Gully. The status of these connections depends on flows coming from the catchment and the nature of the sand bars, determined by coastal processes.

The Toby Inlet Ocean Entrance Study in 1999 (Rogers and Associates 1999) identified a common channel for Station Gully and Toby Inlet as the more desirable option to improve water quality and alleviate flooding, as the combined flows from the systems have greater potential to maintain the opening. In June 2000, a Memorandum of Understanding (MoU) was developed which specified management of Toby Inlet/Station Gully with a common ocean outlet to ensure:

1. *Protection of residential properties from flooding.*
2. *Maintenance of tidal flushing to maintain water quality in the Inlet.*
3. *Protection of rural properties from flooding.*

This MoU was signed by representatives of the (then) Shire of Busselton, Water Corporation, Toby Inlet Catchment Group, (then) Water and Rivers Commission and the Geographe Catchment Council.

The *Reconnecting Toby Inlet* hydrodynamic modelling study (Frazer and Hall 2018) determined that a separate ocean connection for Toby Inlet resulted in tidal flushing of 72% of the Inlet, compared with only 36% flushing via Station Gully. A key difference for this study was additional bathymetric survey in the area, which showed that the narrow connection between Station Gully and Toby Inlet allowed only very limited exchange between the two waterways. Thus much greater flushing of Toby Inlet is achieved via a separate ocean connection.

This work also determined a minimum sill height for the channel of -0.15 m AHD to avoid excessive draining of the Inlet on low tides. Very low water levels have caused problems with past sand bar openings owing to increased exposure of sediments, and isolation of shallow pools that provide unfavourable conditions for aquatic fauna. Recommendations from this study were:

- The Toby inlet mouth is kept open throughout the year, with a minimum sill elevation of -0.15 m AHD from October to June to avoid very low water levels during low tides.
- Keeping the culvert between Station Gully and Toby Inlet open permanently.
- Potentially, to investigate a second cut for Toby Inlet if increased flushing of the upper estuary is considered necessary.

A telemetered data logging system is in place to monitor water levels and sill height of the ocean connection.

4.2.1 Summer - water quality protection

During 2017-2018 the opening of the mouth of Toby Inlet has been maintained. A draft operational procedure is in place to keep the sandbar open, with a minimum sill elevation of -0.15 m AHD (Appendix 2. The sand bar was opened in November 2017. It stayed open until late March 2018 and was re-opened on 6th April 2018. The feedback from the community on this management initiative has generally been positive.

4.2.2 Winter - flood protection

The *Reconnecting Toby Inlet* project recommends the ocean outlet be kept open all year (Frazer and Hall 2018). However, periodic closing of sand bar through natural processes during winter creates unpredictability in works requirements to achieve this. A trigger level for flood protection purposes would be useful to initiate opening of the sand bar in winter. Detailed water level data (15-minute intervals) from the telemetered monitoring system provides some useful information for setting trigger levels for winter sandbar opening.

Intense storms in May and June 2018 resulted in a high level of sand deposition on the beach and very high water levels in Toby Inlet. Despite large rainfall events, there was insufficient flow to naturally cut through the sand bar. Water levels were in the vicinity of 1.5m (above sea level AHD) from 10th to 14th June, following a series of rainfall events from the 25th May (Figure 11). Photographs of the area during this time show minor flooding in adjacent lands at these water levels (Figure 12). The sand bar was opened on 13th June 2018, lowering water levels to about 0.8m within two days. This opening was effective, and the outlet remained open intermittently for about four weeks. Rising water levels initiated further opening of the sand bar on 24th July when water levels were around 1.1m. In this instance the sand bar closed within two days.

Maintaining the ocean outlet throughout winter may incur excessive costs if it closes frequently. An appropriate trigger level would direct works only when there is a risk of flooding, and coincide with sufficient flows to maintain the opening. Given the flooding observed when water levels were at 1.5m, and the lack of a consistent channel when opened at around 1.1m, an appropriate trigger level would be at a height between these levels.

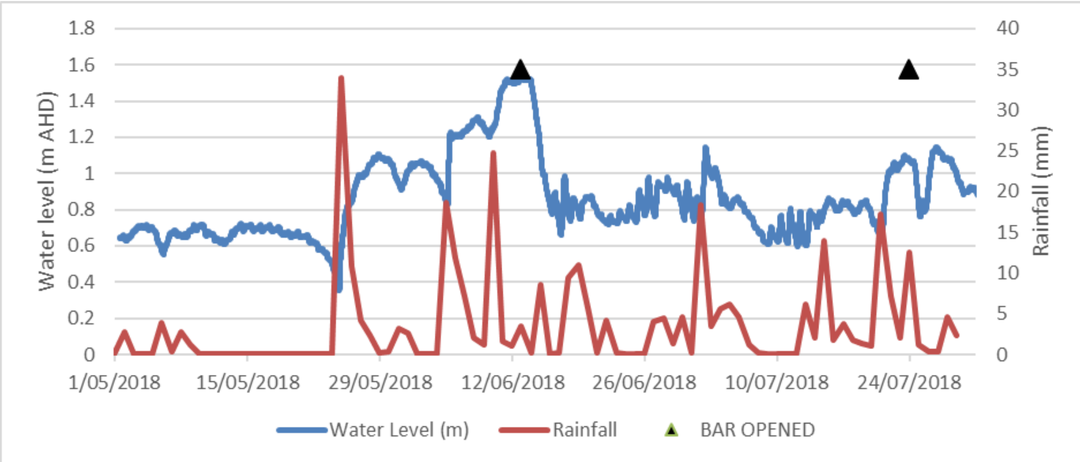


Figure 11. Water levels (blue line) at the Toby Inlet ocean outlet, daily rainfall (red line) and times when sand bar was opened (black markers) during May, June and July 2018. Rainfall data from BoM (2018).

Figure 12. Photos showing minor flooding in the vicinity of Toby Inlet from 11th - 13th June 2018.

4.3 Reconnecting catchment flows

Water flow within Toby Inlet has been significantly altered since European settlement. Notably, the Carbunup River and a number of other smaller waterways have been diverted and no longer connects to the Inlet or contribute to its flow. These changes have resulted in a significant decline in flows and influence the accumulation of nutrients and sediments in the system. The *Reconnecting Toby Inlet* hydrological modelling study investigated options to reinstate flow through Toby Inlet through reconnection of catchment tributaries (Frazer and Hall 2018).

Increasing water flow may improve water quality through dilution of nutrients and by reducing water residence time (flushing). Nutrient concentrations in Station Gully, with a predominately agricultural catchment, are higher than in Toby Inlet, so additional flow from this source may have a negative effect on water quality through increased nutrient loads (Frazer and Hall 2018). Flushing of the estuary has minimal effect on water quality during winter, but is needed during summer when water quality problems occur. However, owing to seasonal flows, there is little potential for catchment flows to provide summer flushing, do the reconnection of catchment sources would not provide this benefit (Frazer and Hall, 2018). There is insufficient water available from other sources, such as Dunsborough lakes dams, to provide summer and autumn flows.

Increasing catchment inflows is also perceived as an option for addressing sedimentation problems. Although the volume of flow through Toby Inlet would be increased by additional catchment water flows, the flat landscape means that flow velocities would remain low, and would not facilitate sediment scouring (Frazer and Hall 2018). It is also worth considering that if velocities were sufficient to mobilise sediment, there may also be a risk of increased sediments from the catchment to Toby Inlet (not assessed).

4.4 Recreation Planning

Community feedback on recreation in and around Toby Inlet was sought during the consultation process and via a specific online survey (City's *Your Say* platform). These forums have indicated very clearly that management should focus on encouraging passive recreation, and on improvements to existing access rather than increasing accessibility.

Aboriginal consultation revealed a strong desire to maintain a passive level of recreation in and around Toby Inlet. Representatives also suggested that additional infrastructure and signage in the area should be minimised.

An access management plan has been developed to identify existing recreational access and infrastructure in the study area and opportunities for improvements (SWE 2018). This plan identifies four categories for management:

i. Vegetated areas with no tracks: to be retained as high conservation value areas with no further access.
ii. Vegetated areas with existing tracks: to be improved and potentially linked to each other and parkland areas enhance access for recreation and management purposes (e.g. weed control and infill planting).
iii. Parkland cleared areas: existing high-use areas where improved infrastructure and formal paths would be appropriate and foreshore protection may be needed.
iv. Private property access only: not accessible for assessment and unlikely to be suitable for further public access.

Management options identified in the plan include improvements to existing tracks and the potential for additional tracks and/or a boardwalk; potential sites for canoe access, bird watching facilities, picnic facilities and outdoor classroom; and protection works for revegetation, weed control and erosion control. The concept plans for these options provide an ideal basis for further community consultation and project development.

4.5 Managing foreshore reserves

Foreshore reserves require improved management to protect remnant vegetation from weed invasion and physical disturbance from uncontrolled access. Revegetation is also needed in some degraded areas, particularly along banks where vegetation is important for stabilisation and ecological functions.

The Ecoedge (2017) vegetation survey report provides mapping of weeds that would form a basis for strategic control. This report also proposed five areas for revegetation based on size (≥ 1500m^2), accessibility for implementation, and low density of existing vegetation (Ecoedge 2017). These should be further considered in consultation with the community. Weed control and revegetation is needed to ensure protection of natural values in the study area. Some further planning may be needed to direct these efforts.

Recreation and access planning also provide recommendations for areas requiring weed control and revegetation in association with managing access and addressing foreshore erosion, and improving recreation opportunities (SW Environmental 2018). Pathways provide opportunities to formalise boundaries of reserves or interfaces between areas of parkland and natural vegetation.

Some foreshore reserves adjacent to private properties do not have public access to undertake an assessment of management issues or opportunities for improvement. The condition of foreshore vegetation, bank stability and integrity of private jetties in this area varies. A process of assessment of these areas is needed that identifies:

- inappropriate management of public land;
- jetty structures that require maintenance or removal;
- areas of recreational value for the broader community;
- required management actions to conserve ecological values; and
- potential fire risk.

This process could also be used to develop relationships with local landholders and foster community stewardship for ongoing management, such as through formation of localised *Friends of* groups that could partner with the Toby Inlet catchment Group. In addition, a policy relating to current and future jetty structures would be valuable to minimise potential impacts of the structures and ensure adjacent foreshore areas are protected.

4.6 Catchment management

The portion of the catchment closest to the Inlet has experienced rapid urban development and this is projected to continue into the future. Unsewered urban areas of Quindalup have been identified as a significant nutrient source, particularly through the critical summer months. Sewerage infill works in this area are imminent (update progress as needed). Once completed, the connection of properties to this infrastructure will be vital to ensure outcomes from this investment. There may need to be targeted awareness campaign to maximise connection.

The broader Toby Inlet catchment contains a range of land uses with significant portions dominated by native vegetation, beef grazing, lifestyle blocks and highly developed urban or commercial areas. Management of the broader catchment is beyond the scope of this plan. However, as the catchment has substantial influence on the health of waters within the study area, it is logical that its implementation would support initiatives that reduce catchment sources of nutrients and sediments. GeoCatch has a lead role in catchment management including improved land use management practices, waterway restoration and educational approaches. In addition, the Toby Inlet Catchment Group has long advocated catchment management and could partner with GeoCatch to extend initiatives in the Toby Inlet catchment.

There is also a role for land use development planning in catchment protection. Proposals for changes in land use and new developments can trigger the imposition of new environmental protection requirements. This applies directly to the objective: *reduce catchment sediments and contaminants from existing and new developments entering Toby Inlet.* The use of planning approaches is part of the governance framework for this plan.

4.7 Governance arrangements

The independent review of water asset management (Hart 2014) highlighted the need for Toby Inlet to have a designated lead manager. The City was recognised as the most appropriate manager for Toby Inlet, and this has been supported by the Western Australian Government in its response to the review. It is appropriate that the City adopts this role, given its management responsibility for a large proportion of adjacent foreshore reserves. Although the City is responsible for overall implementation of management actions, several key stakeholders also have important roles, outlined below. These roles and responsibilities are also summarised in Table 1, Section 6.

The City's management responsibility is generally limited to the study area and does not extend into the broader catchment. Ongoing management initiatives in the catchment, in particular to address issues of nutrient enrichment and sedimentation, are a fundamental component of waterways management. GeoCatch, with the support of DWER, is the lead manager for catchment management. The Water Corporation has management responsibility for its rural drainage network. This network extend into the Station Gully catchment, but is not part of the existing Toby Inlet catchment.

DWER has an ongoing role in providing support for the management of Toby Inlet through continued involvement in water science, modelling and monitoring. If the implementation of this WMP is to be funded through ongoing investment in a broader program for Geographe Bay catchment waterways, DWER is likely to continue to have an important project management and networking role.

The Toby Inlet Catchment (TIC) Group also has an active role in the management of Toby Inlet and its catchment, with a long history in management planning and on-ground works. Members of TIC Group are important advocates in the community for protection of Toby Inlet, increasing support for, and recognition of, improved management. The group continues to undertake restoration activities such as weed control, revegetation and feral animal control. This greatly assists with management of public reserves, and should continue to be supported by the City.

Establishment of "Friends of Reserves" groups for sections of Toby Inlet foreshore has been suggested during consultation as a way of fostering community stewardship to assist with and maintain restoration efforts. These groups could partner with TIC Group, increasing overall capacity. The City recognises the valuable contribution of volunteers to environmental management, and has a commitment to supporting volunteer groups such as TIC Group and Friends of Reserves groups.

The City also has an important role in its planning capacity. Through the *Revitalising Geographe Water*ways program, the City has been responsible for the *Optimising Planning Tools* project to review the potential role of planning in water resource protection.

4.8 Research needs

Research is needed to enable assessment and reporting on progress of management initiatives and to fill knowledge gaps. Research outcomes need to feed back into management planning through an adaptive process. The key research areas for Toby Inlet are summarised below.

Water quality: Ongoing water quality monitoring is an essential part of long-term assessment and reporting for waterway health. There appears to be an adequate sampling program for open waters of Toby Inlet. Investigative sampling within of tributaries and groundwater in the Toby Inlet catchment should be considered to ensure information requirements for prioritising and reviewing management initiatives are met.

Water flow: Assessment of the potential for existing flows to move sediment in association with resuspension of sediment through agitation may require further modelling or a trial.

Sediments: If removal of sediment is deemed appropriate in the future, further studies of physical and chemical characteristics will be needed to inform priority locations, the removal technique and disposal options.

Bird life: There has been little formal surveying of bird life of Toby Inlet, so the overall importance of the study area for providing bird habitat and the particular sites of importance are not well understood. There is an opportunity for community-based surveying to assist in prioritising management initiatives (e.g. habitat restoration) and in developing information resources for visitors.

Aquatic fauna: Fish and aquatic invertebrates are good indicators of waterway health. Recent research has provided baseline information for future monitoring and reporting. Community involvement in this research has highlighted the potential for educational opportunities that engage people in the management of Toby Inlet.

Aquatic flora: There have been no studies of macroalgae and other aquatic plants in Toby Inlet and associated wetlands. Aquatic flora has an important structuring role, with a strong seasonal influence on habitat and water quality and hence on aquatic fauna and food web interactions. The extent and composition of macroalgal growth (as blooms or at non-nuisance levels) have not been formally monitored and may provide a good indicator of water quality.

5 Management Strategies and Actions

The management strategies and actions included here have been developed to work towards meeting the management objectives and vision for Toby Inlet. Specific actions have been grouped into strategies for each of the management focus areas, although many have potential outcomes for several objectives. A framework for implementing the WMP is provided in Section 6, including the roles and responsibilities of key stakeholders and a process for ongoing action planning, reporting and review.

5.1 Toby Inlet ocean exchange

5.1.1 Strategy OE1: Optimal management of Toby Inlet ocean exchange

Effective management of the Toby Inlet ocean exchange has clear outcomes for water quality by through dilution of nutrient concentrations and preventing algal growth. Establishing a minimum sill height during summer will reduce areas prone to sediment exposure and associated problems with visual amenity and odours. Management of the sand bar is also important in mitigating the flood risk for adjacent properties.

Management actions:

OE1.1 Maintain Toby Inlet ocean outlet, the Station Gully culvert and the Station Gully outlet in accordance with Operational Procedures in Appendix 2.

OE1.2 Monitor the status of the outlet through a telemetered system to determine when opening of the sand bar is necessary.

OE1.3 Ensure the culvert between Station Gully and Toby Inlet will be left open to improve water quality in the upper reach of Toby Inlet, east of the ocean outlet.

5.2 Sedimentation

5.2.1 Strategy S1: Investigate sediment removal

There is strong community support for active removal of sediments from Toby Inlet, however the main objective associated with this approach is improved amenity. Outcomes for water quality and ecology and potential impacts of removal are not well understood, and further investigation is needed. An alternative approach to mobilising sediment may be mechanical agitation of sediments in depositional areas during high flows. There is community support to further investigate potential to mobilise deposited sediment.

Management actions:

S1.1 Defining priority areas for sediment management and determine sediment composition and volume for these areas, building on previous sediment investigations.

S1.2 Assess potential outcomes and impacts of sediment removal from priority areas and undertake a cost/benefit analysis of strategic sediment removal.

S1.3 Assess whether sediment agitation would facilitate mobilisation and flushing of sediment deposits on Toby Inlet.

5.2.2 Strategy S2: Prevent further sedimentation

Existing land uses in the catchment and ongoing development are likely to continue to contribute additional sediment to the drainage system, wetlands and Toby Inlet. Minimising sources of sediments and trapping mobile sediments before they reach receiving waters is important to prevent further deposition.

Management actions:

S2.1 Improve understanding of sediment sources and transport through water quality monitoring (refer to WQ1.6).

S2.2 Develop an education approach to reducing sediments inputs from the catchment.

S2.3 Identify and ensure management of potential erosion problems from new developments and changes in land use during the planning process, through implementing the *Better Urban Water Management* framework.

S2.4 Investigate key sediment sources in the catchment and potential for works to stabilise drains and increase sediment trapping within the drainage network.

5.2.3 Strategy S3: Rehabilitate exposed sediment deposits

Revegetation of exposed sediments may address amenity issues. It would also stabilise the sediments, provide additional habitat, and trap additional sediments and nutrients entering the Inlet.

S3.1 Identify areas of exposed sediments that could be planted to improve habitat and amenity and stabilise sediments.

S3.2 Undertake trial revegetation of samphire in exposed sediment.

5.3 Water quality

Increased nutrient loads from the catchment are a major cause of water quality decline. Actions to reduce point and non-point sources of nutrients are thus a fundamental component of managing water quality. Management of the sand bar to provide flushing during summer and autumn is a key strategy to improve water quality in Toby Inlet (Strategy OE1). However, ocean flushing does little to address water quality issues in the upper reach of Toby Inlet or in the upstream wetland environments.

5.3.1 Strategy WQ1: Reducing nutrient sources from the catchment

Nutrients are a key driver of algal blooms, so ongoing load reduction actions are a fundamental part of management. Infill sewerage works is important to addressing nutrient sources from adjacent residential areas. Reducing nutrient inputs at the catchment level is a long-term management initiative, fundamental to protecting water quality in receiving aquatic environments.

Management actions:

WQ1.1 Completion of scheduled infill sewerage works in residential areas adjacent to Toby Inlet.

WQ1.2 Review the sewerage works once completed, and address any lack of connection to sewerage infrastructure through education campaigns or incentives if deemed necessary.

WQ1.3 Ensure Geographe Bay catchment management initiatives extend to Toby Inlet catchment, including: implementation of best management practices; and community education to reduce inputs from gardening and livestock activities in urban and special rural areas.

WQ1.4 Increase potential for nutrient assimilation in the rural drainage network in conjunction with sediment trapping and through restoration.

WQ1.5 Identify opportunities for reducing nutrient, sediment and pollutant sources through upgrades to stormwater infrastructure.

WQ1.6 Continue current water quality monitoring within Toby Inlet, and determine required monitoring for associated wetlands and catchment tributaries, to ensure information requirements for prioritising and reviewing management initiatives are met.

WQ1.7 Support educational campaigns that aim to reduce nutrients in runoff through individual and community actions (e.g. Bay OK) and investigate options to improve nutrient management in public open space.

WQ1.8 Minimise future nutrient sources from new development and land use change at the planning stage through implementing the *Better Urban Water Management* framework.

WQ1.9 Support implementation of the Vasse Wonnerup wetlands Geographe Bay Water Quality Improvement Plan.

5.4 Ecology

5.4.1 Strategy E1: Effectively manage foreshore reserves

Foreshore reserves in the study area contain important areas of vegetation, provide habitat for native fauna and contribute to heathy aquatic ecology. These reserves present considerable opportunity for conservation, however active management is needed to address threats of weeds, pests, unmanaged access, clearing of native vegetation, and vegetation decline.

Management actions:

E1.1 Prepare and implement a prioritised works program for weed control, revegetation and feral animal control.

E1.2 Support community efforts in weed control, revegetation and feral animal control.

E1.3 Ensure revegetation in high amenity areas is appealing and maintains vistas to increase community support for these activities.

E1.4 Effectively management recreational access to protect and enhance the key values of reserve areas.

E1.5 Create awareness of reserve boundaries through bollards and signage where appropriate.

E1.6 Develop information resources for landholders to raise awareness of reserve boundaries, the importance of fringing vegetation, weed problems, and the restrictions on clearing native vegetation and building jetty structures.

E1.7 Assess foreshore reserve areas that have no public access and develop appropriate management actions to benefit the broader public.

E1.8 Develop a policy for jetties that ensures structural integrity and protection of adjacent foreshore areas and prevents establishment of new structures.

5.4.2 Strategy E2: Understanding fauna

There is limited formal knowledge of the fauna of Toby Inlet. Recent research on fish and aquatic invertebrates has provided an important baseline and has had excellent outcomes for community engagement. While there is some knowledge of the occurrence of other fauna in the study area such as birds and mammals, this is not based on formal surveys. Increased understanding of fauna can be achieved through scientific and community based approaches to improve information, and sharing this knowledge with the broader community.

Management actions:

E2.1 Support further research on aquatic and terrestrial fauna and bird populations to inform management initiatives and assess outcomes.

E2.2 Pursue a community science approach to collecting bird data.

E2.3 Develop information resources to increase community interest and understanding of fauna.

5.5 Amenity, Recreation and Education

Strategies for amenity, recreation and education have been combined owing to overlap between these focus areas. All relate to the interaction between people and Toby Inlet, and improving potential enjoyment.

5.5.1 Strategy ARE1: Improving facilities for community appreciation

There is a need to formalise access and improve recreational facilities around Toby Inlet, but with a clear focus on passive recreational pursuits, such as walking and running, bird watching, fishing and non-motorised water sports. The *Access Management Plan* for Toby Inlet provides an excellent basis for improving recreational opportunities and access around Toby Inlet (Appendix 9. Although this has been developed with consideration of outcomes of previous community consultation, further review and feedback from the community will be required prior to its implementation.

Management actions:

ARE1.1 Seek community input on the *Access Management Plan* for Toby Inlet (SW Environmental 2018), and subsequently develop and implement appropriate access-ways and recreational infrastructure.

ARE1.2 Determine requirements for additional parking in support of improved facilities.

ARE1.3 Enhance bird habitat in connection with existing and potential bird watching sites.

ARE1.4 Encourage bird watchers to join with a community science approach to collecting bird data.

ARE1.5 Support schools in using Toby Inlet as an outdoor learning environment, including provision of information resources and consideration of an outdoor classroom.

5.5.2 Strategy ARE2: Providing informative resources

Management strategies around education often include interpretive signage. However given the desire for passive recreation in the Inlet and minimal facilities, extensive signage is not appropriate around Toby Inlet. Some signage regarding the values and management of the Inlet, and access points would be appropriate. Information in other forms would also be valuable for those who are interested, including learning resources for school groups. This includes printed resources and online information.

Management actions:

ARE2.1 Develop appropriate signage in connection with improved access and facilities to inform the community about: ecological values of Toby Inlet; location and use of access and facilities; and management initiatives underway.

ARE2.2 Prepare and distribute fact sheets and educational material, printed and online, for key management focus areas, relevant to schools, community members and natural resource managers.

ARE2.3 Continue to update the Revitalising Geographe Waterways website with information on Toby Inlet and its management.

5.6 Culture and Heritage

Heritage values in the vicinity of the Toby Inlet study area include traditions and history of Aboriginal people and European settlement.

5.6.1 Strategy CH1: Recognising Aboriginal custodianship

Toby Inlet holds significant cultural value for the local Wadandi people, as important place for food resources and camping. The area has continued to be an important camping and fishing area since European settlement. An area of campgrounds has been lodged for assessment as a Registered Aboriginal Site under the *Aboriginal Heritage Act* (1972).

Aboriginal representatives indicated clearly that they did not support extensive cultural information on signs in the area. However, acknowledgement of the significance of the area to Aboriginal people may be appropriate on signs for other purposes, and in other information resources suggested in this plan. There is also potential to recognise Aboriginal peoples' connection to the area through other means, such as artwork or design of recreational facilities.

As traditional custodians, Aboriginal people are concerned about declining health of the environmental and should also be given opportunities to contribute to the future management of Toby's Inlet.

Management actions:

CH1.1 In partnership with local Aboriginal people, include reference to traditional custodianship of the waterways and land in development of information resources.

CH1.2 Manage future access in a way that avoids additional disturbance and considers protection of potential sites of Aboriginal significance – however activities of local Aboriginal people, such as fishing, camping, the gathering of bush foods and family recreational and educational activities, should not be restricted by implementation of this plan.

CH1.3 Seek to improve partnerships with the Nyungar community to increase their involvement in the management, protection and restoration of Toby Inlet and the study area.

CH1.4 Consult further with Aboriginal representatives in regard to specific works which result from this plan.

CH1.5 Support programs that engage the Aboriginal community in implementation of works associated with this plan.

5.6.2 Strategy CH2: Conserve historical values

There is a great deal of history associated with the whaling industry and European settlement in the study area. It is important that future generations have access to historical information and that historical sites are maintained.

Management actions:

CH2.1 Identify and ensure appropriate maintenance of sites historical importance.

CH2.2 Develop interpretive material to increase understanding of local history, and to promote, appreciate and access historical sites.

5.7 Governance

Management of Toby Inlet requires leadership which is most appropriately provided by the City. There is strong interest in the management of Toby Inlet from a broad range of stakeholders with varying interests and responsibilities. A collaborative approach to management is needed, that facilitates ongoing input from stakeholders and provides support to active members of the community, in particular the Toby Inlet Catchment Group. Partnerships with researchers are also valuable to improve our understanding of the system, inform management decisions and monitor success or otherwise of management actions.

5.7.1 Strategy G1: Defined and collaborative management

The City has coordinated the development of this WMP, and has overall responsibility for implementation. However other stakeholders have important roles in undertaking and supporting many management actions. Collaboration of stakeholders will therefore be essential to successful future management of the Toby Inlet study area. Major stakeholders and their roles in the future management of Toby Inlet and the study area are summarised in Table 1.

Management actions:

G1.1 City to consider securing management order over waterways and adjacent public lands in study area, to facilitate implementation.

G1.2 Establish a Management Advisory Committee comprised of representatives from the City, Toby Inlet Catchment Group, Department of Water and Environmental Regulation, Department of Biodiversity Conservation and Attractions, Water Corporation, GeoCatch, South West Catchments Council, Aboriginal representatives, and community members.

G1.3 Support the Toby Inlet Catchment Group as active participants in planning, on-ground works, and as a key link to the community.

G1.4 Facilitate the development of locally-active Friends of Toby Inlet groups to advocate and coordinate on-ground work in reserves and on private property.

G1.5 Define and resolve issues around vesting of Unallocated Crown Land.

5.7.2 Strategy G2: Evaluate and adapt management actions

Implementation will require an ongoing process of monitoring and evaluation of outcome, and future management will need to be informed by this proves and by new information gained through research. Long term water quality data is a fundamental tool for defining management issues and assessing outcomes of management. While an established routing monitoring program is in place for Toby Inlet itself, available data for catchment tributaries and groundwater is inconsistent. Biological monitoring approaches are valuable to assess current and future ecological health, and to provide interesting information for the community. Recent sampling of aquatic fauna has helped establish a baseline for future assessment of decline or improvement. Despite the nuisance growth of macroalgae in Toby Inlet, there has been no assessment of species or estimates of biomass.

Management actions:

G2.1 Continue monitoring of water quality in Toby Inlet.

G2.2 Review monitoring requirements for catchment tributaries and groundwater.

G2.3 Support future sampling of aquatic fauna.

G2.4 Undertake assessment of macroalgal growth.

G2.5 Ensure timely reporting of monitoring and research outcomes to the management advisory group.

G2.6 Review future management actions in light of monitoring and research outcomes.

6 Implementation

6.1 Roles and responsibilities

The lead role of the City in the future management of Toby Inlet will be recognised through endorsement and adoption of this WMP. This will task the City with responsibility for coordinating implementation, however key stakeholders will have ongoing roles in many aspects of the WMP. These roles and responsibilities are defined in Table 1.

As captured in action G1.2 a Management Advisory Group is recommended to oversee implementation of this WMP, comprised of representatives from the City, Department of Water and Environmental Regulation, Department of Biodiversity Conservation and Attractions, Water Corporation of WA, GeoCatch, Wadandi representatives and broader community representatives.

6.2 Implementation process

An adaptive process of action planning, works, evaluation and reporting is recommended for the WMP, summarised by Figure 13. The strategies and actions presented provide a basis for planning actions for a specified period of time, dependent on available budgets and identified priorities. This would be a key role of the Management Advisory Group. Outcomes of these actions are measured through adequate monitoring, with results assessed in terms of progress towards the management objectives and vision. Reporting of outcomes to the community is essential to maintain community support and this forum would provide an opportunity to gain input to the next action planning cycle.

Table 1. Key stakeholders for future management of Toby Inlet and main roles and responsibilities.

Stakeholder	Roles and Responsibilities
City	Overall implementation of the WMP. Management of reserves. Maintenance of Toby Inlet ocean exchange. Operation of Station Gully culvert. Support to community groups.
Toby Inlet Catchment Group	Undertaking weed control, revegetation and feral animal control activities. Advocating protection and enhancement of Toby Inlet. Representing community interests in future management of Toby Inlet and reserves. Leadership for citizen science opportunities.
South West Boojarah Working Party	Advocating protection and enhancement of Toby Inlet. Providing input ion management decisions to ensure maintenance of cultural values.

	Engagement of Aboriginal people in management decisions and actions.
Department of Water and Environmental Regulation	Monitoring of water quality. Technical contributions to management decisions.
GeoCatch	Support to private landholders to improve land and waterway management in the catchment. Educational programs to minimise nutrient and sediment loads. Education, habitat restoration, and community group support for protection of Western Ringtail Possums.
Water Corporation	Maintenance of Station Gully ocean exchange. Maintenance (ownership) of Station Gully culvert. Managing flooding risk.
Department of Biodiversity, Conservation and Attractions	Coordinate native wildlife management programs and implement recovery plans for native flora and fauna of conservation significance. Provide guidance and direction to community group in relation to the protection and conservation of Western Ringtail Possums. Providing information about native flora and fauna.
South West Catchments Council	Support for funding opportunities.
Friends of reserves groups	Future role in local-level advocacy and management actions.

Figure 13. Implementation process for the Toby Inlet Waterway Management Plan.

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8 Appendices

Appendix 1. Land tenure listing

Current vesting details for public lands in the study area.

TYPE	PIN	RESERVE	CURRENT PURPOSE/LEGAL USE	CURRENT VESTING
Reserve	1039621	23572	RECREATION	City
Reserve	532402	31944	PUBLIC RECREATION	City
Reserve	532412	31944	PUBLIC RECREATION	City
Reserve	11342942	31591	PUBLIC RECREATION	City
Reserve	11767346	46	LANDSCAPE PROTECTION AND	City
Reserve	1341995	26122	PUBLIC RECREATION	City
Reserve	1051637	26122	PUBLIC RECREATION	City
Reserve	532482	26122	PUBLIC RECREATION	City
Reserve	1208973	26122	PUBLIC RECREATION	City
Reserve	1107483	36262	PUBLIC RECREATION	City
Reserve	532377	36262	PUBLIC RECREATION	City
Reserve	532386	36262	PUBLIC RECREATION	City
Reserve	532394	36262	PUBLIC RECREATION	City
Reserve	1153703	45169	PUBLIC RECREATION &	City
Reserve	1112023	46086	PUBLIC RECREATION, DRAINAGE	City
Reserve	1214511	46086	PUBLIC RECREATION, DRAINAGE	City
Reserve	532322	26524	PUBLIC RECREATION	City
Reserve	532329	26524	PUBLIC RECREATION	City
Reserve	532342	26524	PUBLIC RECREATION	City
Reserve	532350	26524	PUBLIC RECREATION	City
Reserve	532494	36429	RECREATION	City
Reserve	1186196	45436	PUBLIC RECREATION	City
Reserve	1215108	45436	PUBLIC RECREATION	City
Reserve	523991	29844	PUBLIC RECREATION	City
Reserve	523992	29844	PUBLIC RECREATION	City
Reserve	523989	37416	WATER SUPPLY	Water Corporation
Reserve	524084	40677	DRAINAGE	Water Corporation
Reserve	1287021	26225	RECREATION & ROAD	DEPARTMENT OF LANDS (SLSD)
Reserve	1034792	32282	DRAIN	DEPARTMENT OF WATER
UCL	11676813			
UCL	1237261			
UCL	11154519			
UCL	11154521			
UCL	11627253			
UCL	11608890			
UCL	11154520			

Appendix 2. Operational Procedures for maintenance of Toby Inlet sand bar

OPERATIONAL PRACTICE AND PROCEDURE

<u>OPENING AND MAINTENANCE OF THE TOBY INLET SAND BAR AND CULVERT</u>

PURPOSE

This document details the procedures that apply to the opening and maintenance of the Toby Inlet sand bar and the culvert between Toby Inlet and Station Gully. The main purposes of opening the sand bar are to improve water quality in the inlet by increasing water flushing and reduce the likelihood of algal blooms and to mitigate flooding risks to neighbouring properties.

OE1.4 Ensure the ocean outlet is kept open through the period from 1 November to 31 April to improve water quality, with a minimum sill height of -0.15m AHD to prevent excessively low water levels.

OE1.5 Open the sand bar during the period 1 May to 31 October if water levels exceed an interim trigger value of 1.3m AHD. The outcomes of this approach will be monitored and management guidelines adapted accordingly.

SPECIFICATIONS

<u>Ocean entrance</u>

Summer – water quality improvement

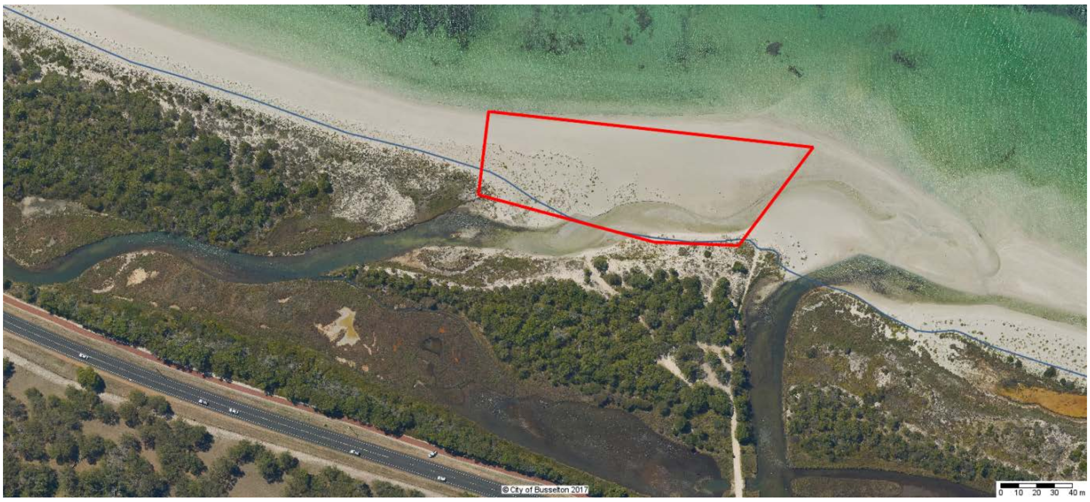
1. The Toby Inlet mouth is maintained open from 1 November to the 30 April at a minimum sill elevation of -0.15m AHD.
2. Opening to be facing approximately 45 degrees eastward, to the width of inlet.
3. Opening to be located in area highlighted in aerial photo below, subject to seasonal varibility of inlet's position.
4. Opening works to coincide with rising tide and greatest tidal variations (as practicable).
5. Sand removed to be deposited to the east of opening and flattened out to not impede access by pedestrians and horses.
6. Machinery to access site via Quindalup boat ramp.
7. Sand bar to be open within two weeks of notification received of it being closed.

Winter – flooding mitigation

1. The Toby Inlet mouth is to be opened when water levels reach 1.3m AHD, causing a potential flooding risk to neighbouring properties and infrastructure.
2. Opening to be located in area highlighted in aerial photo below, subject to seasonal varibility of inlet's position.
3. Opening works to coincide with lowering tide.
4. Sand removed to be deposited to the east of opening and flattened out to not impede access by pedestrians and horses.
5. Machinery to access site via Quindalup boat ramp.

Culvert

1. Culvert between Station Gully drain and Toby Inlet to remain open all year around.



RESPONSIBILITIES

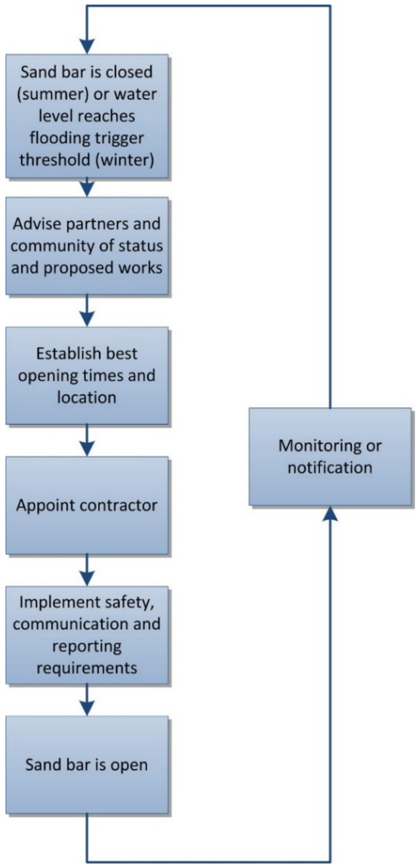
The City is responsible for:

- Monitoring status of the Toby Inlet ocean entrance, with a minimum of a check per fortnight during the period of October to May.
- Organising, supervising and funding the manual opening of the Toby Inlet ocean entrance by machinery as required from October to June.
- Notifying other stakeholders (including the Water Corporation and Department of Water and Environmental Regulations) and the public of upcoming maintenance works.
- Ensuring public safety during operations, including at works site and upstream of Toby Inlet.
- Keep records of sand bar opening times.
- Maintaining the culvert between Toby Inlet and Station Gully in a good state of repair and open all year around.

The Water Corporation and the Department of Water and Environmental Regulations are responsible for:

- Notifying the City if it becomes aware that the Toby Inlet entrance has closed.
- Provide any information that may assist the City in managing the opening of the Toby Inlet ocean entrance.
- Opening Station Gully ocean outlet for flood protection purposes as necessary.

PROCESS TO BE FOLLOWED IF SAND BAR CLOSES (FLOWCHART)



Appendix 3. Plant species found within the Toby Inlet study area

List of vascular flora identified in the study area during survey by Ecoedge (2017)

FAMILY	SPECIES	COMMON NAME	NATURALISED
Aizoaceae	*Carpobrotus edulis*	Hottentot Fig	*
Anacardiaceae	*Schinus terebinthifolius*		*
Apiaceae	*Apium prostratum*	Sea Celery	
Apiaceae	*Centella asiatica*	Centella	
Apiaceae	*Daucus glochidiatus*	Australian Carrot	
Apocynaceae	*Vinca major*	Blue Periwinkle	*
Araceae	*Zantedeschia aethiopica*	Arum Lily	*
Araliaceae	*Hedera helix*		*
Araliaceae	*Trachymene pilosa*	Native Parsnip	
Asparagaceae	*Acanthocarpus preissii*		
Asparagaceae	*Asparagus asparagoides*	Bridal Creeper	*
Asparagaceae	*Lachenalia bulbifera*		*
Asphodelaceae	*Trachyandra divaricata*		*
Asteraceae	*Carduus pycnocephalus*	Slender Thistle	*
Asteraceae	*Cotula coronopifolia*	Waterbuttons	*
Asteraceae	*Gazania linearis*		*
Asteraceae	*Hypochaeris glabra*	Smooth Cats-ear	*
Asteraceae	*Olearia axillaris*	Coastal Daisybush	
Asteraceae	*Osteospermum jucundum*		*
Asteraceae	*Osteospermum ecklonis*		*
Asteraceae	*Senecio jacobaea*	Ragwort	*
Asteraceae	*Sonchus asper*	Rough Sowthistle	*
Asteraceae	*Symphyotrichum squamatum*	Bushy Starwort	*
Boraginaceae	*Echium plantagineum*	Paterson's Curse	*
Casuarinaceae	*Allocasuarina fraseriana*	Sheoak	
Chenopodiaceae	*Atriplex hypoleuca*		
Chenopodiaceae	*Atriplex prostrata*		
Chenopodiaceae	*Rhagodia baccata*	Berry Saltbush	
Chenopodiaceae	*Salicornia quinqueflora*	Beaded Samphire	
Chenopodiaceae	*Suaeda australis*	Seablite	
Convolvulaceae	*Dichondra repens*	Kidney Weed	
Cupressaceae	*Callitris preissii*	Rottnest Island Pine	
Cyperaceae	*Baumea juncea*	Bare Twigrush	
Cyperaceae	*Carex divisa*	Divided Sedge	*
Cyperaceae	*Ficinia nodosa*	Knotted Club Rush	
Cyperaceae	*Gahnia trifida*	Coast Saw-sedge	
Cyperaceae	*Lepidosperma gladiatum*	Coast Sword-sedge	
Dennstaedtiaceae	*Pteridium esculentum*	Bracken	
Dilleniaceae	*Hibbertia cuneiformis*	Cutleaf Hibbertia	
Ericaceae	*Leucopogon parviflorus*	Coast Beard-heath	

FAMILY	SPECIES	COMMON NAME	NATURALISED
Euphorbiaceae	*Euphorbia paralias*	Sea Spurge	*
Euphorbiaceae	*Euphorbia terracina*	Geraldton Carnation Weed	*
Fabaceae	*Acacia cochlearis*	Rigid Wattle	
Fabaceae	*Acacia cyclops*	Coastal Wattle	
Fabaceae	*Acacia littorea*		
Fabaceae	*Acacia saligna*	Orange Wattle	
Fabaceae	*Chamaecytisus palmensis*	Tagasaste	*
Fabaceae	*Dipogon lignosus*	Dolichos Pea	*
Fabaceae	*Hardenbergia comptoniana*	Native Wisteria	
Fabaceae	*Lotus subbiflorus*		*
Fabaceae	*Melilotus indicus*		*
Fabaceae	*Podalyria sericea*		*
Fabaceae	*Templetonia retusa*	Cockies Tongues	
Fabaceae	*Trifolium campestre*	Hop Clover	*
Geraniaceae	*Geranium molle*	Dove's Foot Cranesbill	*
Geraniaceae	*Geranium solanderi*	Native Geranium	
Geraniaceae	*Pelargonium capitatum*	Rose Pelargonium	*
Goodeniaceae	*Dampiera trigona*	Angled-stem Dampiera	
Goodeniaceae	*Scaevola crassifolia*	Thick-leaved Fan-flower	
Hemerocallidaceae	*Dianella revoluta*	Blueberry Lily	
Iridaceae	*Watsonia meriana*	Bulbil Watsonia	*
Juncaceae	*Juncus kraussii*	Sea Rush	
Lauraceae	*Cassytha racemosa*	Dodder Laurel	
Liliaceae	*Lilium* sp.		*
Loganiaceae	*Logania vaginalis*	White Spray	
Moraceae	*Ficus carica*	Common Fig	*
Myrtaceae	*Agonis flexuosa*	Peppermint	
Myrtaceae	*Eucalyptus rudis*	Flooded Gum	
Myrtaceae	*Melaleuca cuticularis*	Saltwater Paperbark	
Myrtaceae	*Melaleuca osullivanii*		
Myrtaceae	*Melaleuca rhaphiophylla*	Swamp Paperbark	
Myrtaceae	*Melaleuca* sp.		*
Myrtaceae	*Melaleuca viminea*	Mohan	
Orchidaceae	*Cyrtostylis robusta*		
Orobanchaceae	*Parentucellia viscosa*	Sticky Bartsia	*
Oxalidaceae	*Oxalis corniculata*	Yellow Wood Sorrel	*
Oxalidaceae	*Oxalis pes-caprae*	Soursob	*
Papaveraceae	*Fumaria muralis*	Wall Fumitory	*
Phyllanthaceae	*Phyllanthus calycinus*	False Boronia	
Plantaginaceae	*Plantago lanceolata*		*
Poaceae	*Ammophila arenaria*	Marram Grass	*
Poaceae	*Austrostipa compressa*		
Poaceae	*Austrostipa flavescens*		
Poaceae	*Avena fatua*	Wild Oat	*

FAMILY	SPECIES	COMMON NAME	NATURALISED
Poaceae	*Briza maxima*	Blowfly Grass	*
Poaceae	*Bromus diandrus*	Great Brome	*
Poaceae	*Lagurus ovatus*	Hare's Tail Grass	*
Poaceae	*Lolium perenne*	Perennial Ryegrass	*
Poaceae	*Piptatherum miliaceum*	Rice Millet	*
Poaceae	*Poa porphyroclados*		
Poaceae	*Sporobolus virginicus*	Marine Couch	
Poaceae	*Stenotaphrum secundatum*	Buffalo Grass	*
Polygalaceae	*Comesperma virgatum*	Milkwort	
Polygonaceae	*Muehlenbeckia adpressa*	Climbing Lignum	
Polygonaceae	*Rumex brownii*	Swamp Dock	*
Ranunculaceae	*Ranunculus muricatus*	Sharp Buttercup	*
Rhamnaceae	*Spyridium globulosum*	Basket Bush	
Rosaceae	*Rosa chinensis* x *multiflora*		*
Santalaceae	*Exocarpos sparteus*	Broom Ballart	
Santalaceae	*Santalum acuminatum*	Quandong	
Solanaceae	*Solanum linnaeanum*	Apple of Sodom	*
Stylidiaceae	*Stylidium adnatum*	Common Beaked Triggerplant	
Thymelaeaceae	*Pimelea argentea*	Silvery Leaved Pimelea	
Typhaceae	*Typha orientalis*	Typha	

Appendix 4. Revegetation species the Toby Inlet study area

Suggested revegetation species for main soil types in the Toby Inlet study area (Ecoedge 2017)

Saline Soils:
Atriplex prostrata
Ficinia nodosa (Knotted Club Rush)
Juncus kraussii (Sea Rush)
Melaleuca cuticularis (Saltwater Paperbark)
Salicornia quinqueflora (Beaded Samphire)
Suaeda australis (Sea Blite)

Loams:
Acacia saligna (Orange Wattle)
Agonis flexuosa (Peppermint)
Eucalyptus rudis (Flooded Gum)
Exocarpos sparteus (Broom Ballart)
Hakea varia
Hibbertia cuneiformis (Cutleaf Hibbertia)
Jacksonia furcellata
Kunzea micrantha
Melaleuca viminea (Mohan)
Spyridium globulosum (Basket Bush)
Viminaria juncea (Swish Bush)

Quindalup Dunes:
Agonis flexuosa (Peppermint)
Spyridium globulosum (Basket Bush)
Acacia littorea
Acacia cochlearis
Hibbertia cuneiformis (Cutleaf Hibbertia)
Leucopogon parviflorus
*Hardenbergia comptoniana (*Native Wisteria)
Lepidosperma gladiatum (Sword Sedge)

Appendix 5. Birds of Toby Inlet and associated wetlands

Bird species reported to occur in the study area, from a survey by Clay and Clay (1996, cited in Comer and Clay 1999).

COMMON NAME	SPECIES NAME
Water Birds	
Hairy-headed Grebe	Poliocephalusi poliocephalus
Australasian Grebe Australian Pelican	*Tachybaptus novaehollandiae* *Pelecanus conspicillatus*
Darter	*Anhinga melanogaster*
Little Black Cormorant	*Phalacrocorax sulcirostris*
Little Pied Cormorant	*Phalacrocorax melanoleucos*
White Faced Heron	*Ardea novaehollandiae*
Great Egret	*Egretta alba*
Sacred Ibis	*Threskiornis aethiopica*
Straw-necked Ibis	*Threskiornis spinicollis*
Yellow Billed Spoonbill	*Platalea flavipes*
Black Swan	*Cygnus atratus*
Australian Shelduck	*Tadorna tadornoides*
Pacific Black Duck	*Anas superciliosa*
Grey Teal	*Anas gibberifrons*
Australian Wood duck	*Chenonetta jubata*
Musk Duck	*Biziura lobata*
Pink-eared Duck	*Malacorhynchus membranaceus*
Hardhead	*Aythya australis*
Osprey	*Pandion haliaetus*
Eurasian Coot	*Fulica atra*
Purple Swamphen	*Porphyrio porphyrio*
Hooded Plover	*Charadrius rubricollis*
Black-fronted Plover	*Charadrius melanops*
Greenshank	*Tringa nebularia*
Silver Gull	*Larus novaehollandiae*
Caspian Tern	*Hydropgne caspia*
Crested Tern	*Sterna bergii*
Fairy Tern	*Sterna nereis*
Bush Birds	*Scientific Name*
Black-shouldered Kite	Elanus notatus
Whistling Kite	*Haliastur sphenurus*
Brown Goshawk	*Accipiter fasciatus*
Australian Kestrel	*Falco cenchroides*
Laughing Turtle-dove*	*Streptopelia senegalensis*
Common Bronze wing	*Phaps chalcopterai*
Red-tailed Black Cockatoo	*Calyptorhynchus magnificus*

White-tailed Black Cockatoo	*Calyptorhynchus baudinii/latirostris?*
Red-capped Parrot	*Purpureicephalus spurius*
Western Rosella	*Platycercus icterotis*
Australian Ringneck	*Barnardius zonarius*
Tawny Frogmouth	*Podargus strigoides*
Laughing Kookaburra	*Dacelo novaeguineae*
Sacred Kingfisher	*Halyconi sancta*
Rainbow Bee-eater	*Merops ornatus*
Welcome Swallow	*Hirundo neoxena*
Tree Martin	*Hirundo nigricans*
Richard’s Pipit	*Anthus novaeseelandiae*
Black-faced Cuckoo-Shrike	*Coracina novaehollandiae*
Scarlet Robin	*Petroica Multicolor*
Rufous Whistler	*Pachycephala rufiventris*
Grey Shrike-thrush	*Colluricincla harmonica*
Grey Fantail	*Rhipidura fuliginosa*
Willie Wagtail	*Rhipidura leucophrys*
Splendid Fairy-Wren	*Malurus splendens*
White-browed Scrub-Wren	*Sericornis frontalis*
Western Gerygone	*Gerygone fusca*
Western Thornbill	*Acanthiza inornata*
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*
Varied Sitella	*Daphoenositta chrysoptera*
Rufous Treecreeper	*Climacteris rufa*
Red Wattle Bird	*Anthochaera carunculata*
Brown Honeyeater	*Lichmera indistincta*
New Holland Honeyeater	*Phylidonyris novaehollandiae*
Western Spinebill	*Acnathorynchus superciliosus*
Silvereye	*Zosterops lateralis*
Australian Magpie-Lark	*Grallina cyanoleuca*
Dusky Woodswallow	*Artamus cyanopterus*
Grey Butcherbird	*Cracticus torquatus*
Australian Magpie	*Gymnorhina tibicen*
Australian Raven	*Corvus coronoides*

Appendix 6. Other Fauna likely to occur in study area

Fauna identified as present or likely to be present in the study area in the survey by Hart et al. (1997)

Frogs		
	Litoria adalaidensis* Litoria moorei* Crinia georgiana Heleioporus eyrie Limnodynastes dorsalis Pseudophryne glauerti Ranidella insignifera	
Reptiles		
Turtle	Chelodina oblonga*	Long-necked turtle
Gecko	Phyllodactylus marmoratus*	
Legless lizards	Aprasia repens Pygopus lepidopodus	
Dragon lizards	Pogona m. minor*	Western bearded dragon
Skinks	Bassiana trilineata* Cryptoblepharus plagiocephalus Egernia kingie* Egernia napoleonis* Glaphyromorphus australis Hemiergis peronei Lerista distinguenda* Menetia greyii* Morethia lineoocellata* Tiliqua r. rugose*	
Monitors	Varanus gouldii Varanus rosenbergi	
Snakes	Ramphotyphlops australis Drysdalia coronate Echiopsis curta Notechis scutatus occidentalis*	Tiger snake

	Pseudonaja affinis affinia* Rhinocephalus gouldii Rhinocephalus nigriceps	Dugite
Mammals		
	Pseudocheirus occidentalis* Isoodon obesulus* Macropus fuliginosus* Hydromys chrysogaster	Western ringtail possum Southern brown bandicoot Western grey kangaroo Rakali, Water rat
Introduced species		
	Mus musculus* Rattus rattus Vulpes vulpes* Felis catus Oryctolagus cuniculus*	

*Evidence of presence found

Appendix 7. Aquatic invertebrates of Toby Inlet and associated wetlands

Aquatic invertebrates found in Toby Inlet during the two surveys by Streamtec (1997) and Tweedley et al. (2018).

Phylum / Order		Family / Species		Streamtec (1997)	Tweedley et al. (2018)
Nematoda			Nematoda sp.	✓	
Mollusca					
	Gastropoda	Ancylidae	Ferrissia petterdi	✓	
			(?) Fluviopupa sp.	✓	
		Planorbiidae	Physastra sp.	✓	
		Tateidae	Potamopyrgus sp.		✓
	Veneroida	Galeommatidae	Arthritica semen		✓
	Littorinimorpha	Pomatiopsidae	Coxiella striatula		✓
Annelida	Oligochaeta		Oligochaeta spp.	✓	
	Cnidaria			✓	
	Hydrozoa	Hydridae	Hydra sp.	✓	
	Arachnida			✓	
	Acarina		Hydracarina sp.	✓	
	Phyllodocida	Nereididae	Simplisetia aequisetis		✓
	Spionida	Spionidae	Pseudopolydora kempi		✓
	Polychaeta	Capitellidae	Capitella captitata		✓
	Polychaeta	Orbiniidae	Scoloplos normalis		✓
	Canalipalpata	Serpulidae	Ficopomatus enigmaticus		✓
Crustacea					
	Cladocera		Cladocera sp.	✓	
		Daphiidae	Daphinia sp.	✓	
	Ostracoda	Ilyocypridae	Ilyodromas sp.	✓	
			Ostracoda sp.	✓	
	Copepoda	Cyclopoida	Cyclopidae sp.	✓	
		Harpacticoida	Harpacticodae sp.	✓	

	Amphipoda	Gammaridae	Perthia sp.	✓	✓
			Amphipod sp.	✓	
		Aoridae	Grandidierella propodentata		✓
		Melitidae	Barnardomelita matilda		✓
	Decapoda	Palaemonidae	Palaemonetes australis	✓	
		Parastacidae	Cherax quinquecarinatus	✓	
	Isopoda	Armadillidae	Oniscidea sp.		✓
	Malacostraca	Chiltoniidae	Austrochiltonia subtenuis		✓
Crustacea	Mysida	Mysidae	Mysida sp. 1		✓
Insecta					
	Ephemeroptera	Leptophlebiidae	Bilbumena	✓	
		Baetidae	Baetis soror	✓	
		Caenidae	Tasmanocoenis tillyardi (Lestage)	✓	
	Odonata Zygoptera	Coenagriidae	Ischnura aurona	✓	
	Odonata Zygoptera	Coenagriidae	Odonata sp. 1		✓
	Odonata Zygoptera	Coenagriidae	Odonata spp.		✓
	Odonata	Aeshnidae	Austrolestes annulosus		✓
	Anisoptera	Corduliidae	Hemicordulia tau Selys	✓	
	Diptera	Simuliidae	Austrosimulium sp.	✓	
			Simulium ornatipes (Skuse)	✓	
		Ceratopogonidae	Ceratopogonidae sp. F	✓	
		Chironomidae		✓	
			Chironomidae sp. 1		✓
			Chironominae sp. 2		✓
			Chironominae spp.		✓
			Chironominae occidentalis		✓

			Chironominae alternans		✓
			Procladius sp.		✓
		Tipulidae	Tipulidae sp. A	✓	
			Tipulidae sp. B	✓	
			Tipulidae sp. X	✓	
			Unidentified spp.	✓	
		Empidadae	Empididae sp. B	✓	
			Unidentified spp.	✓	
		Culicidae	Culicidae sp. B	✓	✓
			Unidentified sp.	✓	
		Muscidae spp.	Unidentified sp.	✓	
		Stratiomyidae spp.	Unidentified sp.	✓	
		Syrphidae sp.		✓	
		Ephydridae	Ephydridae sp. X	✓	
	Lepidoptera		Lepidoptera sp. X	✓	
			Unidentified sp.	✓	
	Trichoptera	Ecnomidae	Ecnomus pansus/turgidus complex	✓	
			Oecetis sp.	✓	
			Notalina fulva	✓	
Insecta			Triplectides australis	✓	
			Oxyethira retracta	✓	
			Hellethira sp. C	✓	
		Leptoceridae	Notalina spira		✓
	Odonata	Aeshinidae	Aeshinidae sp.		✓
	Hemiptera	Notonectidae	Paranisops sp.	✓	
	Coleoptera		Carabidae sp.	✓	
		Dytiscidae	? Rhantus sp.	✓	
			Necterosoma sp. B	✓	
			Liodesus sp.	✓	
			? Megaporus sp.	✓	
			Platynectes decempunctatus	✓	

			Homeodyetes scutelaris	✓	
			Dytiscid sp. X	✓	
		Hydrophilidae	Hydrophilidae sp. A	✓	
			Hydrophilidae sp. X	✓	
			Hydrophilidae spp.	✓	
			Berosus approximans	✓	
			Berosus sp.	✓	
			Haliplidae sp.	✓	
		Lestidae	Austrolestes annulosus		✓

Appendix 8. Fish survey results 2017-2018

Fish species captured in nearshore and offshore waters of Toby Inlet before (November 2017) and after (March 2018) opening of the sand bar (Tweedley et al. 2018).

Species name	Common name	Estuarine use group*	November 2017	May 2018
Nearshore waters				
Leptatherina wallacei	Western Hardyhead	EF	✓	✓
Atherinosoma elongata	Elongate Hardyhead	E	✓	✓
Pseudogobius olorum	Bluespot Goby	EF	✓	✓
Gambusia holbrooki	Eastern Gambusia	FEO	2.36 ✓	✓
Gambusia holbrooki	Eastern Gambusia	EF	3.24 ✓	✓
Favonigobius lateralis	Southern Longfin Goby	EM	3.10 ✓	✓
Leptatherina presbyteroides	Silver Fish	EM		✓
Amniataba caudavittata	Yellowtail Grunter	E	✓	✓
Pelates octolineatus	Western Striped Grunter	MEO		✓
Mugil cephalus	Sea Mullet	MEO	✓	✓
Rhabdosargus sarba	Tarwhine	MEO	✓	✓
Galaxias occidentalis	Western Galaxias	FEO	✓	
Craterocephalus mugiloides	Spotted Hardyhead			✓
Sillago burrus	Western Trumpeter			✓
Pseudorhombus jenynsii	Smalltooth Flounder			✓
Atherinomorus vaigiensis	Common Hardyhead			✓
Acanthopagrus butcheri	Black Bream		✓	
Offshore waters		**EUFG**		
Mugil cephalus	Sea Mullet	MEO	✓	✓
Amniataba caudavittata	Yellowtail Grunter	E	✓	✓
Acanthopagrus butcheri	Black Bream	E	✓	✓
Aldrichetta forsteri	Yelloweye Mullet	MEO	✓	✓
Pelates octolineatus	Western Striped Grunter	MEO		✓
Rhabdosargus sarba	Tarwhine	MEO		✓
Arripis georgianus	Australian Herring	MEO		✓
Sillago schomburgkii	Yellowfin Whiting	MEO		✓
Pomatomus saltatrix	Tailor	MEO		✓
Gerres subfasciatus	Common Silverbiddy	MEO		✓
Sphyraena novaehollandiae	Snook	MS		✓
Pseudorhombus jenynsii	Smalltooth Flounder	MEO		✓
Nearshore waters				
Leptatherina wallacei		EF	✓	✓
Atherinosoma elongata		E	✓	✓
Pseudogobius olorum		EF	✓	✓
Gambusia holbrooki		FEO	✓	✓
Afurcagobius suppositus		EF	✓	✓
Favonigobius lateralis		EM	✓	✓
Leptatherina presbyteroides		EM		✓
Amniataba caudavittata		E	✓	✓
Pelates octolineatus		MEO		✓
Mugil cephalus		MEO	✓	✓

Rhabdosargus sarba		MEO	✓	✓
Galaxias occidentalis		FEO	✓	
Craterocephalus mugiloides				✓
Sillago burrus				✓
Pseudorhombus jenynsii				✓
Atherinomorus vaigiensis				✓
Acanthopagrus butcheri			✓	
Offshore waters		**EUFG**		
Mugil cephalus		MEO	✓	✓
Amniataba caudavittata		E	✓	✓
Acanthopagrus butcheri		E	✓	✓
Aldrichetta forsteri		MEO	✓	✓
Pelates octolineatus		MEO		✓
Rhabdosargus sarba		MEO		✓
Arripis georgianus		MEO		✓
Sillago schomburgkii		MEO		✓
Pomatomus saltatrix		MEO		✓
Gerres subfasciatus		MEO		✓
Sphyraena novaehollandiae		MS		✓
Pseudorhombus jenynsii		MEO		✓

* Estuarine usage functional groups: E, solely estuarine; MEO, marine estuarine-opportunist; MS, marine straggler; FEO, freshwater estuarine-opportunist; EF, estuarine & freshwater; E, solely estuarine; EM, estuarine & marine; MEO, marine estuarine-opportunist)

Appendix 9. Access Management Plan for Toby Inlet

Access Management Plan

Toby Inlet, Quindalup

JUNE 2018

SW environmental

Document Set ID: 4118022
Version: 3, Version Date: 01/07/2019

Photo: Toby Inlet

Version control

Project number:	SW175			
Project file path:	SW175 Toby Inlet access planning			
Client:	City of Busselton			
Revision	Date	Prepared by (name)	Reviewed by (name)	Approved by (name)
V1.1	19/06/18	Shane Priddle SW Environmental	Robyn Paice (City of Busselton)	Shane Priddle SW Environmental
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The City of Busselton ('the City') is preparing a Water Management Plan for Toby Inlet and required a conceptual plan for improving access and recreation facilities around Toby Inlet. The vision for the management plan is "*A healthy waterway and fringing vegetation that is actively managed, protected, valued and enjoyed by the community*". One of the key management strategies is to improve access and facilities for community enjoyment that incorporate appropriate rehabilitation measures such as weed control, revegetation and erosion control.

This Access Management Plan has been prepared in consideration of the above and to meet the required scope of work. The study area includes the areas of Toby Inlet from the south western corner of the Palmers Estate downstream to the foot bridge crossing on Caves Road just east of the residential area of Quindalup. There was a preference to focus on the northern side of Toby Inlet.

This Access Management Plan for Toby Inlet categorised the Toby Inlet reserve into four access management precincts:

- **Vegetated areas (no tracks):** Areas of intact remnant native vegetation where there are no access tracks or only small foot tracks through vegetation. They often extend from the private property areas all the way to the foreshore vegetation or high water mark. Native vegetation has a high biodiversity conservation value and tracks should be generally avoided in these areas. Without clearing, these areas do not require any further attention.
- **Vegetated areas (existing tracks):** Areas consisting of intact remnant native vegetation with existing tracks. Tracks often link up sections of other precincts, such as street parking to foreshore parklands, or have been constructed as fire breaks. With the exception of the Geographe Bay foreshore path and footbridge east of Geographe Bay Road, most of these tracks are in need of maintenance or could be improved with either a 1.2m red hot mix seal in high traffic areas or at flood risk (e.g. foreshore areas) or compacted limestone along the firebreaks.
- **Parkland cleared (existing constructed tracks or maintained grassy areas):** Extensive sections of foreshore that have been cleared and are subject to ongoing maintenance (e.g. mowing). They are typically located in high use areas and would be ideal public parks. The construction of formal pathways following the contour of the inlet edge would encourage public use of these areas, are in close enough proximity to parking to be ideal locations for recreational infrastructure such as tables, barbeques, an outdoor class room or other passive recreation features. Additional parking may be required at these locations and should be considered in line with any infrastructure improvements. These existing high use areas are also typically the areas that are most degraded along the inlet banks. The loss of riparian vegetation has had numerous negative effects on the overall health of the inlet.
- **Private property access only:** Extended areas of foreshore reserve that are only able to be accessed by the adjacent private landowners. As these areas were not able to be accessed they were not surveyed in detail, nor is a pathway likely to be suitable.

Each precinct has unique opportunities to improve access and associated infrastructure (recreation facilities) around Toby Inlet. Site specific recommendations have been made in Appendix A including existing access, and recommended weed control, revegetation and erosion control. Additional opportunities including canoe access points, a boardwalk and clearing for new tracks was also discussed and could further enhance the existing Toby Inlet reserve.

A continuous pathway along the inlet could be achieved between Mc Dermott Street and Campion Way (approximately two kilometres) with the recommendations made in this report. Apart from the far western section around Palmers, Wilson Avenue and some isolated locations (e.g. Bloor Street) the other areas are inaccessible due to private property and/or vegetation.

1 Introduction

1.1 Background

The City of Busselton ('the City') is preparing a Water Management Plan for Toby Inlet and required a conceptual plan for improving access and recreation facilities around Toby Inlet.

The vision for the management plan is "*A healthy waterway and fringing vegetation that is actively managed, protected, valued and enjoyed by the community*".

One of the key management strategies is to improve access and facilities for community enjoyment that incorporate appropriate rehabilitation measures such as weed control, revegetation and erosion control.

Public consultation has shown very clearly that management should focus on encouraging passive recreation, and on improvements to existing access rather than increasing accessibility. There is also a perception that access pathways should act as barriers for protection of foreshore vegetation. The draft management actions for the management plan in relation to this are to develop and assess options for low-key access and recreation facilities in the area, such as:

- Install BBQ and seating at McBride Park or Wilson Avenue.
- Formalise carpark and access ways to horse beach, and improve signage.
- Provide some bird information and seating in appropriate, quiet areas.
- Investigate need for and location of bird hide.
- Enhance habitat for birds in connection with bird watching sites.
- Provide appropriate canoe-launching access at Mc Quade Park and address existing erosion.
- Improve existing walkways, and use these as reserve boundaries to protect fringing vegetation.
- Manage firebreak as bike access way.
- Determine requirements of additional parking in support of improved facilities.

This Conceptual Access Plan or 'Access Management Plan' has been prepared in consideration of the above and to meet the scope of work outlined below.

1.2 Scope of works

The study area includes the areas of Toby Inlet from the south western corner of the Palmers Estate downstream to the foot bridge crossing on Caves Road just east of the residential area of Quindalup. There was a preference to focus on the northern side of Toby Inlet. The study area is shown in Figure 1-1.

The scope of the consultation is to:

1. Review of 2017 vegetation survey as it relates to weed mapping and vegetation condition within the project area.
2. On-site meeting with City officer to discuss project.
3. Site survey to ground-truth existing pathways and access.
4. Recommendations for improvements to:
    - access pathways,

- canoe-launching area/s (provide ideas and examples for this),
- bird watching places,
- resting and observing areas.

5. Identify any requirements for weed control, erosion control and revegetation associated with these improvements. Note these will be generally high level, as in recommending areas that require these actions, rather than identifying site specific, prescriptive actions on how to undertake the actions.
6. Digitising of existing access, pathways, facilities, and recommendations.
7. Preparation of maps that clearly show existing features and recommendations.
8. A brief report that:
    - describes existing access/facilities,
    - outlines the recommendations and rationale,
    - links recommendations to maps.

Mapping layers will be provided as PDF in the report and as ESRI shapefiles.

Figure 1-1 Toby Inlet study area

2 Methods

This Access Management Plan was prepared based on desktop review and ground truthing.

2.1.1 Desktop review

Recent high resolution aerial photography (provided by the City of Busselton, 2018) was reviewed over the study area and potential tracks and lineal areas of vegetation disturbance digitised for follow up ground truthing. As many areas across the study area back onto private property with limited public access, this was useful to determine general land use and existing access opportunities.

A flora and vegetation report (Ecoedge 2017)[1] was also commissioned by the City for the broader study area. The flora and vegetation report results (vegetation types, condition and weeds and recommended revegetation locations) were reviewed, summarised in Section 3.2, and considered in the preparation of this Access Management Plan.

2.1.2 Ground truthing

The mapped areas were ground truthed by walking over the site on foot and investigating some inaccessible areas by drone (DJI Mavic Pro). A site meeting was carried out with Robyn Paice (Senior Environment Officer, the City) on 4th May and follow up fieldwork was carried out over two days by SW Environmental on 11th and 12th June 2018.

2.1.3 Limitations

Some areas were unable to be accessed due to a combination of the high water level at the time of the survey, heavy vegetation or tenure issues (private land uses or property restricting access). The high water level was due to the inlet not being open and an accumulation of water following seasonal rains. Some seasonally accessible low laying tracks may have been missed in this report. Whilst high water levels restricted access, it also provided insight as to where any access tracks and other recreational infrastructure may not be suitable or would be under water if constructed.

Heavy vegetation was not considered to be a constraint in terms of access. The management actions outlined a clear preference *to improvements to existing access rather than increasing accessibility* and *protection of foreshore vegetation*. These areas were therefore not considered further for access.

Private property backs onto the Toby Inlet along extended sections, with fencing, clearing and retained remnant native vegetation extending right to the Inlet itself (often within the reserve). For the most part, other than direct access from an adjacent house, there are no existing pathways along these sections nor would future proposed paths likely to have the support of the adjacent landowner.

The underwater, vegetated and restricted access locations throughout the study area are generally not considered appropriate for pathways in line with the management plan actions and scope of work.

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[1] Ecoedge (2017) Report of a Flora and Vegetation survey at Toby Inlet. Unpublished report to the City of Busselton.

3 Results

3.1 Existing environment and tenure

The 47 ha study area is located along the Toby Inlet, a 118 ha low energy coastal lagoon that meanders from the eastern edge of the Dunsborough Township east to the mouth at Geographe Bay. It is formed from the flooding and drainage of low laying sumplands south of Caves Road. The study area comprises a combination of Crown Land and reserves vested in or managed by the City.

The residential locality of Quindalup is located between Toby Inlet and the Geographe Bay foreshore. It is long and narrow in extent, well less than 100m wide at some locations, with many of the residential properties backing directly onto the reserves associated with the inlet. Historic pressures from with local development and secondary uses relating to the recreational opportunities offered by the inlet (access, water sports, fishing, picnics, water craft launching etc) have created additional pressures on the inlet, such as impacts to foreshore riparian vegetation and bank stability. A general background on Toby Inlet and land uses will be addressed in more detail in the Water Management Plan.

3.2 Vegetation (including weeds)

Ecoedge (2017) carried out a flora and vegetation report which is useful in identifying

- areas of intact vegetation or areas of conservation significance that should be avoided in terms of access,
- areas that are already cleared or degraded,
- areas of weeds that will require management.

A summary of the flora and vegetation report (Ecoedge 2017) is provided below. One hundred and four vascular plant taxa were recorded for the survey area, almost 50% were naturalised, planted, or non-locally native species. The high proportion of non-native species reflects the long disturbance history of much of the vegetation, the degree of urbanisation, and the narrow width of much of the inlet foreshore reserves.

Of the non-native species, 14 were considered potential or actual environmentally significant weeds. Two groups of weeds ("mixed agricultural weeds" and "mixed garden escapees") were recorded; those that have probably been present in the native vegetation for 100 years or more (e.g. Bridal Creeper, Blue periwinkle, Arum Lily, Onion Weed and Hare's Tail Grass) and are more or less naturalised, and those that are more recent garden escapees such as *Dimorphotheca ecklonis* (Cape Daisy) and *D. juncundum* (African Daisy) an *Lilium* spp. which are seen invading the surrounding bushland from gardens established on Crown land adjacent to the inlet. Weeds are shown in Appendix A where they should be considered in context of access management.

No State or federal listed threatened flora, Priority flora or other flora of conservation significance were found. Several Environmentally Sensitive Areas (ESAs) have been designated within the survey area associated with the Toby Inlet, which is classified as a Conservation Category wetland.

Nine native vegetation units were recognised, six of them part of the Vasse Complex (Wetland and Estuarine Fringe Vegetation units) and three of them in the Quindalup Complex (Beach and Dune Vegetation units). Four other non-native or planted vegetation units were also mapped (**Ammophila arenaria – Spinifex hirsutus* grassland, Plantation (Amenity plantings), Heavily Disturbed Area (includes lawn areas with scattered *A. flexuosa* or *Melaleuca* spp.), and Water (Toby Inlet)).

About 35.5 ha of Quindalup Complex vegetation was mapped in the survey area, most of it in Very Good or Excellent condition. Two of these vegetation units fit the diagnostic criteria of the Federally-listed Threatened ecological community "Subtropical and Temperate Coastal Saltmarsh", which is also listed as a Priority 3 ecological community at the State level. In particular, *Salicornia quinqueflora* low shrubland and *Juncus kraussii-Ficinia nodosa* closed sedgeland fit within the Coastal Saltmarsh TEC criteria. There was 5.7 ha of Coastal Saltmarsh TEC (comprised of the above two vegetation units) in the survey area, most of it in Good or Very Good condition.

Just over 40% of the remnant vegetation within the survey area was classified as "Very Good" or "Excellent" condition. These areas were mainly in the eastern part of the survey area on Crown reserves (A class reserve No. 46 and Sussex lots 4748 and 4857). Almost all of the remnant native vegetation on privately owned land south of Caves Road was classed as "Degraded".

A regional ecological linkage runs through the survey area for much of its length (Molloy et al 2009)[2]. As a result of the location of this linkage, survey area vegetation has been assigned proximity rating values of 1a, 1b and 1c, which are the three highest ratings.

Ecoedge (2017) identified areas that would benefit from revegetation, associated with where the Toby Inlet crosses Caves Road. These are shown in Appendix A. They are broad scale (only areas over 1500 m^2 are mapped) and best adopted separately to this Access Management Plan. Finer scale recommendations are addressed further in this document (Sections 3.3, 3.4 and Appendix A).

In addition to the conservation values highlighted by Ecoedge (2017) several threatened fauna may also utilise the site for habitat and as an important connection along the inlet foreshore, including the Critically Endangered Western Ringtail Possum (WRP).

3.3 Existing access, infrastructure and opportunities

Throughout the Toby Inlet reserve, existing access types are generally reflective of current foreshore usage patterns and demand. Built up areas typically have more frequent visitors, a higher need for formalised access and require management intervention the most. Long term trends of population increase are likely to result in higher foreshore usage and access requirements. This has been considered in relation to opportunities in this Plan.

3.3.1 Existing access and opportunities

There are numerous existing pathways from formal vehicular tracks and firebreaks, concrete paths, cleared and maintained parkland areas to informal access through native vegetation. Considering access types the study area can generally be broken up into several management precincts:

- Vegetated areas (no tracks),
- Vegetated areas (existing tracks),
- Parkland cleared (existing constructed tracks or maintained grassy areas),
- Private property access only.

These are mapped in Figure 3-1 (detailed in Appendix A) and are described below. Additional location specific recommendations, such as track closures and revegetation opportunities are also made in the Appendix.

[2] Molloy, S., Wood, J., Hall, S., Wallrodt, S. and Whisson, G. (2009) *South West Regional Ecological Linkages Technical Report*, Western Australian Local Government Association and Department of Environment and Conservation, Perth.

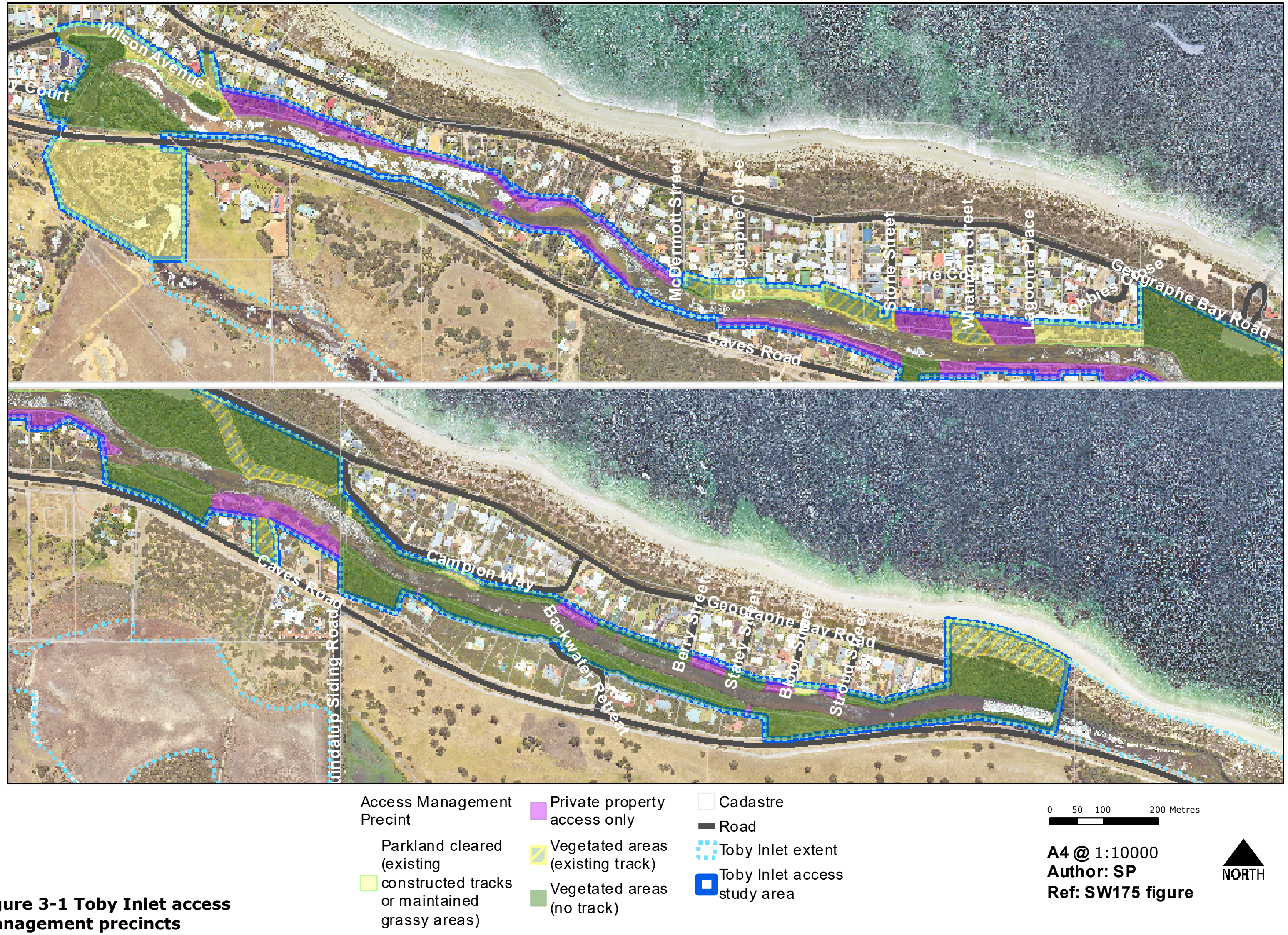

Figure 3-1 Toby Inlet access management precincts

Vegetated areas (no tracks)

These areas consist of intact remnant native vegetation where there are no access tracks or only small illegal foot tracks through vegetation. They often extend from the private property areas all the way to the foreshore vegetation or high water mark. Native vegetation has a high biodiversity conservation value and tracks should be generally avoided in these areas. For the most part these areas do not require any further attention other than small illegal foot tracks.

Vegetated areas (existing tracks)

These areas consist of intact remnant native vegetation with existing tracks. Tracks often link up sections of other precincts, such as street parking to foreshore parklands, or have been constructed as fire breaks. Typical examples include

- the 1.2m sealed access to the foreshore from Geographe Close and Stone Street (Maps 5 and 6),
- the 3m wide emergency access to the foreshore from Lagoona Place (Map 6),
- the degraded 1m sealed access to the foreshore from Robbies Close (Map 7),
- the fire trail linking the foreshore to Geographe Bay Road east of Robbies Close (Map 7),
- the unsealed 3m wide firebreak from the Dunsborough Boat Club overflow carpark to Campion Way (Map 7 and 8),
- the existing Geographe Bay foreshore walk and footbridge east of Geographe Bay Road (Map 12).

With the exception of the Geographe Bay foreshore walk and footbridge east of Geographe Bay Road, most of these tracks are in need of maintenance or could be improved with either a 1.2m (or City standard) red hot mix seal in the high traffic areas or those at risk of flooding (e.g. foreshore areas), or compacted limestone along the firebreaks. Formalising tracks would encourage use and contain potential impacts that might otherwise occur (e.g. minimise trampling along the edges). Some existing areas need to be repaired (e.g. existing concrete path south of Geographe Close, shown in Figure 3-2). Location specific management recommendations are provided in Appendix A.

Figure 3-2 Existing path south of Geographe Close needing repair.

Figure 3-3 Existing path near Stone Street requiring maintenance.

Figure 3-4 Emergency access off Lagoona Place that could be improved with new hot mix.

Figure 3-5 Firebreak from the Boat Club overflow carpark to Campion Way that could be formalised with compacted limestone.

Parkland cleared (existing constructed tracks or maintained grassy areas)

These include extensive sections of foreshore that have been cleared and are subject to ongoing maintenance (e.g. mowing). They are typically located in high use areas and would be ideal public parks. Examples include

- the parkland at Wilson Avenue (currently no pathway),
- Campion Way (Mc Quade Park) (currently no pathway),
- the area west of Palmers Estate (low use) (grass pathways / firebreaks),
- the resort areas off Lagoon Place and south of Robbies Close (existing 1.2m pathway), and
- the grassy area at Bloor Street (currently no pathway).

The construction of formal pathways following the contour of the inlet edge would encourage public use of these areas, are in close enough proximity to parking to be ideal locations for recreational infrastructure such as tables, barbeques, an outdoor class room or other passive recreation features. Pathways can also provide boundaries for protection of foreshore vegetation. Additional parking may be required at these locations and should be considered in line with any infrastructure improvements.

These existing high use areas are also typically the areas that are most degraded along the inlet banks. The loss of riparian vegetation has had numerous negative effects on the overall health of the inlet, including but not limited to

- Loss of bio filter mechanism (plants) for sediments and pollutants entering the inlet from upslope,
- Increased erosion (the areas with no vegetation stabilising the bank are those with the most erosion issues),
- Loss of habitat connectivity (particularly important for fauna such as WRP).

The areas between the existing / proposed tracks should be revegetated, with occasional trees but low sedges such as coastal sword-sedge (*Lepidosperma gladiatum*) or local provenance wetland species. It may be important to maintain a balance between the existing visual amenity of the inlet as an asset, given that some areas have already been cleared.

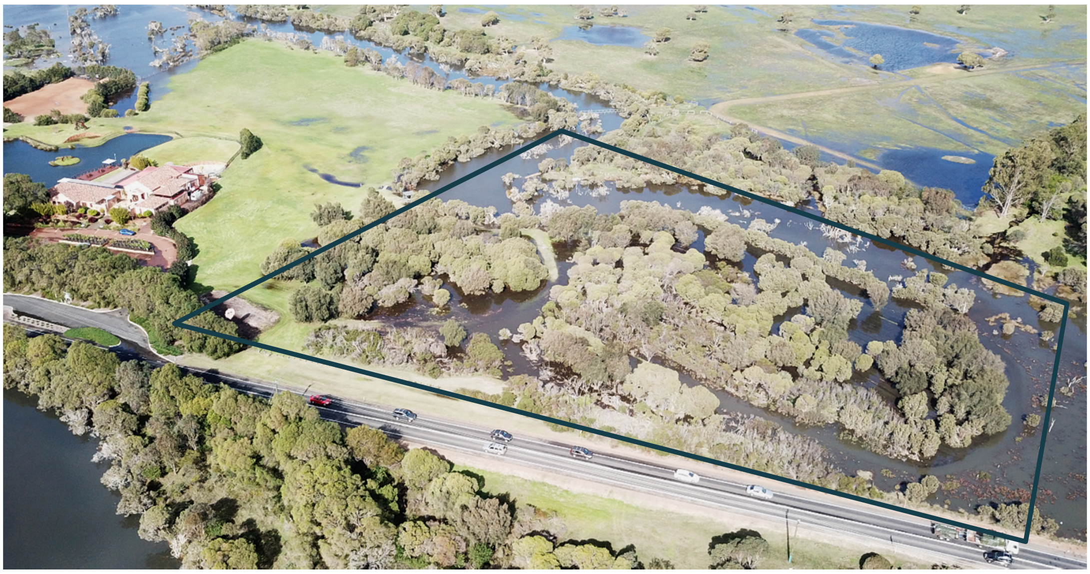

Figure 3-6 Caves Road, Palmers Estate to the left and the section of Toby Inlet outlined within the study area in the mid ground. Note although flooded in this picture there are extensive mowed grassy walkways that could be formalised with crushed limestone.

Figure 3-7 Maintained parkland at Wilson Avenue where a defined pathway would define the reserve boundary and protect fringing vegetation.

Figure 3-8 Example of erosion at Mc Quade Park (Campion Way) due to loss of stabilising foreshore vegetation.

Figure 3-9 Example of erosion at Mc Quade Park (Campion Way) due to loss of stabilising foreshore vegetation.

Figure 3-10 Cleared area off Bloor Street.

Figure 3-11 Cleared area off Bloor Street showing clearing from adjacent landowner and fencing to the water edge.

Private property access only

There are extended areas of foreshore reserve that are only able to be accessed by the private landowners that back onto it. This is either due to

- Inappropriate management by adjacent landowners (e.g. Figure 4-10 above) where through fencing or personal use of the reserve, public access is difficult or discouraged,
- Restricted access due to terrain, narrow foreshore reserve, or sections of intact vegetation or other obstacles (such as high water level).

As these areas were not able to be accessed they were not surveyed in detail, nor is a pathway likely to be suitable.

These areas will be a challenge to the City in terms of ensuring appropriate foreshore management and will likely be addressed in the broader Water Management Plan. There are several sections that could be used by the public where a landowner(s) could be contacted, but in isolation and without connectivity to other pathways, they are limited in what they can offer in this Plan.

Figure 3-12 Example of restricted access and private property adjacent to the reserve.

3.3.1 Additional existing infrastructure and opportunities

Existing

Additional existing recreational infrastructure noted during fieldwork included passive infrastructure elements that may improve the recreational experience associated with the access, or that may encourage access by enriching the foreshore environment.

Existing additional infrastructure is very limited along the foreshore, to the point of being neglected. This is probably due to low use historically coupled with low demand for new infrastructure. Existing infrastructure observed in relation to the foreshore access, included (refer to Appendix A for waypoint locations):

- Bird hide (WP 1)[3] (Map 1)
- Foot bridge (WP 2)[3] (Map 1)
- Bench seat (WP 3) (Map 3)
- Seat (WP 4) (Map 6)
- Water taps (WP 5, 6, 7) (Map 9)
- Derelict table (WP 8) (Map 9)
- Bench seat (WP 9) (Map 9)

These are shown in the photos below. There are a number of pontoons and other informal structure private property structures that may require inspection and assessment by the City as to whether they should be removed due to a public liability risk (risk delegation signage might be more appropriate than removal).

[3] Note these are outside or on the edge of the study area or within other insecure tenure.

Figure 3-13 Bird hide (WP 1)

Figure 3-14 Foot bridge (WP 2)

Figure 3-15 Bench seat (WP 3)

Figure 3-16 Seat (WP 4)

Figure 3-17 Bench seat (WP 9)

Figure 3-18 Derelict table (WP 8)

Opportunities

There are opportunities for the development of new low key infrastructure to enhance the foreshore and encourage public access. Examples include (see Appendix A):

- Wilson Avenue: Barbeque or picnic table within the parkland at Wilson Avenue.

- WP 10: Bird hide (easy access, good cover and existing bird attracting snags within the inlet. Drawback would be possible low water level during summer months).
- WP 11: Bench seat or bird hide (easy access, good cover and though a lack of existing snags within the inlet and possible low water level during summer months).
- Resort area between Geographe Close and Stone Street Bench: add bench seat.
- End of Stone Street (WP 12): Add compacted ramp for canoe access or fishing, otherwise close off and revegetate.
- Parkland area off Lagoona Place (WP 13): Add seat / table in the park areas, and consider fishing platform (stabilised bank) along a small section of degraded bank.
- Track off Campion Way (WP 14): Add compacted ramp for canoe access or fishing, otherwise close off and revegetate.
- Mc Quade Park (Campion Way): Barbeque or picnic table within the parkland. Consider fishing platform (stabilised bank) along a small section of degraded bank. Formalise a canoe launching area in the eastern edge of the park (where there is existing scouring of the bank). Remove bollards and add parking bays at the eastern end of the park.

Foreshore access from public roads are typically hard to find and should be clearly sign posted. Access points along the cul de sacs would benefit most from this:

- Mc Dermott Street
- Geographe Close
- Stone Street
- Whatman Street
- Lagoona Place
- Bloor Street

3.4 Other opportunities

Other opportunities for further consideration include canoe access points, a boardwalk around areas of limited access, and clearing for the construction of new tracks.

3.4.1 Canoe access points

Formal canoe (or equivalent such as stand up paddleboard) access points are required at different locations along the Inlet. Canoes appear to be being launched at several locations including Mc Quade Park (within the eroded area at the eastern edge of the park), Stone Street and off Campion Way.

Given the demand for use at these locations it is recommended that all of these locations are formalised. A formal entry point should consider the following:

- Close access to parking,
- Located downstream enough so that water levels are adequate for most of the year,
- Ensure the natural bank is stabilised,
- Ensure construction materials will withstand periodic inundation,
- Include appropriate signage,
- Alternative use as a fishing platform.


Figure 3-19 Examples of stepped retaining walls that could be enlarged for canoe access, or as a fishing platforms in degraded areas.

Figure 3-20 Example of graded access to the water mark. Note that retaining walls would still be required at the bank cutting. Source: https://www.lcfpd.org/launches/

3.4.2 Boardwalk

The construction of timber boardwalks, whilst generally out of the scope of this consultation, should be considered in areas where there is

- Dense vegetation or private property along the foreshore limiting foreshore access,
- High scenic quality,
- Tracks would contribute to connecting other access areas and improve the overall value of the foreshore,
- Could be also used as a fishing platform.

These are low key features, relatively cheap to build, with low construction impacts if constructed during summer low water level months (with little or no clearing required). They have been adopted with high success by other local governments in high value sensitive coastal lake locations such as Bottom Lake, Merimbula (Bega Valley Shire Council) (see Figure 3-21) and Narooma Foreshore (Eurobodalla Shire Council). A starting point for the installation of a boardwalk might be the 100m and 70m private property sections between Stone Street and Lagoona Place, which would then enable a continuous pathway of about two kilometres long.

Figure 3-21 Boardwalk examples around Bottom Lake, Merimbula

3.4.3 Clearing

The clearing of native vegetation for the purposes of walking tracks is generally exempt from requiring a clearing permit under the walking tracks exemption (*Regulation 5, Item 13* of the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*). This exemption however does not apply in Environmentally Sensitive Areas (ESAs) such as the mapped Conservation Category wetland section of Toby Inlet. Clearing that is not exempt requires a clearing permit in accordance with the *Environmental Protection Act 1986*.

Whilst there is a general preference to avoid native vegetation in line with the Toby Inlet draft management actions, low impact clearing could be carried out at specific locations

- To maintain continuity and connectivity of the existing track network, thereby improving the overall value and usage of the asset,
- Control impacts to native vegetation, e.g. provide a formal, controlled access to the foreshore where existing access has been informally achieved. In some cases if there has been informal access then there may be a demand to access the foreshore at that location.

An example would be the construction of a pathway along Campion Way road reserve linking Mc Quade Park to the east to the existing pathway off Campion Way to the Boat Ramp parking lot. Low impact clearing of sword sedge would be required.

Figure 3-22 Clearing required for a pathway along the southern Campion Way roadside (see red line).

4 Conclusions

Toby Inlet reserve was categorised into four access management precincts:

- Vegetated areas (no tracks)
- Vegetated areas (existing tracks)
- Parkland cleared (existing constructed tracks or maintained grassy areas)
- Private property access only

Each type has unique opportunities to improve access and associated infrastructure (recreation facilities) around Toby Inlet. For at least some locations the recommendations associated with these opportunities could be implemented relatively easily to meet the Water Management Plan vision of "*A healthy waterway and fringing vegetation that is actively managed, protected, valued and enjoyed by the community*".

A continuous pathway along the inlet could be achieved between Mc Dermott Street and Campion Way (approximately two kilometres). Apart from the far western section around Palmers, Wilson Avenue and some isolated locations (e.g. Bloor Street) the other areas are inaccessible due to provide property and/or vegetation. Site specific recommendations have been made in the Appendix including existing access, recommended weed control, revegetation and erosion control. Additional opportunities including canoe access points, a boardwalk and clearing for new tracks was also discussed and could further enhance the existing Toby Inlet reserve.

Appendix A Access Management Maps (2018)

GOVERNMENT OF WESTERN AUSTRALIA
Department of **Water and Environmental Regulation**
Department of **Primary Industries and Regional Development**

Lower Vasse River water treatment trials 2016–18: synthesis report

Can phosphorus-binding clay reduce algal blooms in the Lower Vasse River?

Revitalising Geographe Waterways

VASSE taskFORCE

Water Science
technical series

Report WST83
May 2019

Lower Vasse River water treatment trials 2016-18: synthesis report

Can phosphorus-binding clay reduce algal blooms in the Lower Vasse River?

Department of Water and Environmental Regulation

May 2019

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Cover photograph: Peter Collins

Disclaimer

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Summary

In the summers of 2016–17 and 2017–18, the Department of Water and Environmental Regulation (DWER) trialled a new phosphorus-binding clay product (HT-clay) in the Lower Vasse River to explore new management options for controlling algal blooms. The project was part of the Revitalising Geographe Waterways strategy and supported by the Regional Estuaries Initiative (REI). This report summarises the trials and makes management recommendations. The trials follow on from a large-scale trial conducted by DWER in the early 2000s which indicated that Phoslock® (now a widely established phosphorus-binding clay) was an excellent management option to reduce algal growth and improve water quality in the Lower Vasse River, where toxic algal blooms occur annually. More technical detail and results from the trials will be published in separate technical reports.

Objectives of the study

The trials were designed to answer the following questions:

1. Is HT-clay a viable alternative to the commercially available Phoslock® and can it be used in the future to reduce algal blooms in the Lower Vasse River?
2. How much HT-clay needs to be added to efficiently control phosphorus concentrations and algal growth?
3. How much phosphorus is released from the sediments without clay treatment? Does the HT-clay layer on top of the sediments efficiently reduce phosphorus release?
4. Does the HT-clay treatment affect invertebrate organisms living in the Lower Vasse River?

Key findings

- HT-clay treatment showed promising results in the Lower Vasse River water treatment trials and was able to efficiently control phosphorus concentrations and algal blooms when applied at a similar dosing rate to Phoslock®.
- Concentrations of phosphate (soluble and bioavailable form of phosphorus) and total phosphorus were reduced substantially within two to three hours of HT-clay application in both trials.
- Phosphate and total phosphorus concentrations remained below the recommended water-management target thresholds of 0.04 and 0.1 mg P/L respectively: this was over the entire monitoring period for both trials when clay doses ≥ 0.75g/L were applied.
- The HT-clay was able to immediately remove an algal bloom within hours of application by binding algae into larger aggregates, causing them to sink to the bottom of the river. This is an advantage compared with the Phoslock® clay, which has to be applied before the onset of an algal bloom.
- The clay treatment reduced algae growth and improved water quality for the entire length of both trials when compared with non-treated control areas. This

was evident using both visual assessment and evaluation of algal growth indicators such as algal cell count (2016–17 trial only) or chlorophyll concentrations.

- A temporary increase of floating algal mats was observed in areas treated with clay. This was likely due to the improved water quality conditions which enabled light penetration to the ground of the river, creating more favourable conditions for benthic algae.
- The HT-clay treatment did not have any negative effects on small invertebrate organisms living in the Lower Vasse River. However, further testing of a more diverse range of organisms will be conducted before large scale HT-clay applications.
- The HT-clay layer on the bottom of the river was able to reduce phosphorus release from the sediments to the overlying water, despite partial burial at some sites. The average estimated phosphate amounts released from the sediments in the surrounding river ranged from 6.16 to 3.74 mg phosphorus/m^2/day in early summer (December) and early autumn (May), whereas only an average of 1.1 mg phosphorus/m^2/day was released from treated mesocosms.
- HT-clay may become a viable alternative to Phoslock® for the treatment of algal growth in the Lower Vasse River depending on the success of further development work (such as improvements in the clay production process), laboratory testing for producing a detailed environmental risk assessment, and testing for clay performance under varying environmental conditions.
- Improved water quality through the use of phosphorus-binding clay is likely to provide conditions for the establishment of a healthier and more diverse ecosystem.

Recommendations

- Use phosphorus-binding clay annually in the Lower Vasse River as a treatment to significantly reduce algal growth and sediment build-up.
- Continue to investigate opportunities to progress HT-clay from an experimental product to one suitable for large-scale application during the next two years through the REI project, by:
    - optimising the clay production method to enable affordable large-scale production and transport
    - developing a detailed environmental risk assessment of HT-clay application, including toxicity studies with invertebrate organisms as well as looking at the behaviour of clay under changing environmental conditions, such as low/high pH or higher salinities.
    - further researching clay dosing rates and clay performance under different conditions, such as high organic matter contents or higher salinities

   - further investigating ways to reduce floating algal mats associated with clay treatment

- Undertake regular treatment of the Lower Vasse River with commercially available Phoslock® clay to immediately improve water quality in the Lower Vasse River. In the future, this treatment might be replaced by or combined with HT-clay application.
   - To efficiently control algal blooms, 40 tonnes of Phoslock® should be applied annually to treat the stretch of the river between the weir boards at the old butter factory and the causeway bridge (20 tonnes in November before algal bloom onset and top-up applications as required). It is anticipated that the total amount of clay applied annually will be able to be reduced significantly after a few years of regular application.
   - Phoslock® is distributed and applied by an Australian company (Phoslock® Water Solutions) at a price of $3000 per tonne (approximately $120 000 for the annual application of 40 tonnes).
- Treat the stretch of the river between the weir boards at the old butter factory and the causeway bridge as a priority. The most severe algal growth is typically seen in this area and algal blooms appear to develop at the downstream end of the Lower Vasse River before spreading further upstream.
- Combine applications of phosphorus-binding clay with other long-term nutrient management strategies such as nutrient reduction from catchment sources (agricultural as well as urban). It may also be combined with *in situ* remediation such as sediment removal or the establishment of beneficial aquatic plants to improve water quality in the Lower Vasse River in the longer-term.

1 Purpose and background

1.1 Toxic algal blooms and sediment build-up in the Lower Vasse River

The Lower Vasse River, which meanders through the Busselton town centre, has regular toxic blue-green algal blooms during summer: this is a result of limited water flow, elevated water temperatures and most importantly, high concentrations of nutrients such as phosphorus. Nutrients that fuel the excessive algal growth not only enter the system from agricultural and urban catchment sources, but are also released from a thick layer of black, muddy sediments on the bed of the river.

The water regime of the Lower Vasse River has been highly altered, effectively turning it into a stagnant pond throughout the summer months. Most of the upstream river flow bypasses the lower stretch of the Vasse River and is diverted directly into the ocean through the Vasse Diversion Drain. In addition, the weir structure near the old butter factory restricts water exchange with the estuary at its downstream end.

Apart from producing nuisance odours and reducing the amenity of the river, the algal blooms also contribute to the rapid accumulation of the nutrient and organic matter-rich sediments when they decay and sink to the bottom of the river. This creates a system of internal nutrient cycling, where nutrients are released from the sediments back to the overlying water under low oxygen conditions. In this situation, algal blooms can develop independently from external nutrient sources.

The Department of Water and Environmental Regulation (DWER) conducted water treatment trials in the Lower Vasse River with a new phosphorus-binding clay product in the summers of 2016–17 and 2017–18. The aim of the trials was to explore management options for improving water quality and reducing sediment build-up. The trials were funded by the Revitalising Geographe Waterways (RGW) program and were also supported by the Regional Estuaries Initiative (REI).

1.2 What is phosphorus-binding clay?

Phosphorus-binding clay is an innovative product for the treatment of surface waters. It works by locking up the nutrient phosphorus, making it unavailable to fuel algal growth. By reducing the amount of algae, the clay also lowers the accumulation rate of organic sediments. The clay is sprayed onto the water surface as a slurry and removes dissolved phosphorus from the water as it settles. Afterwards it forms a protective layer on top of the sediments that captures phosphorus released from them (Figure 1).

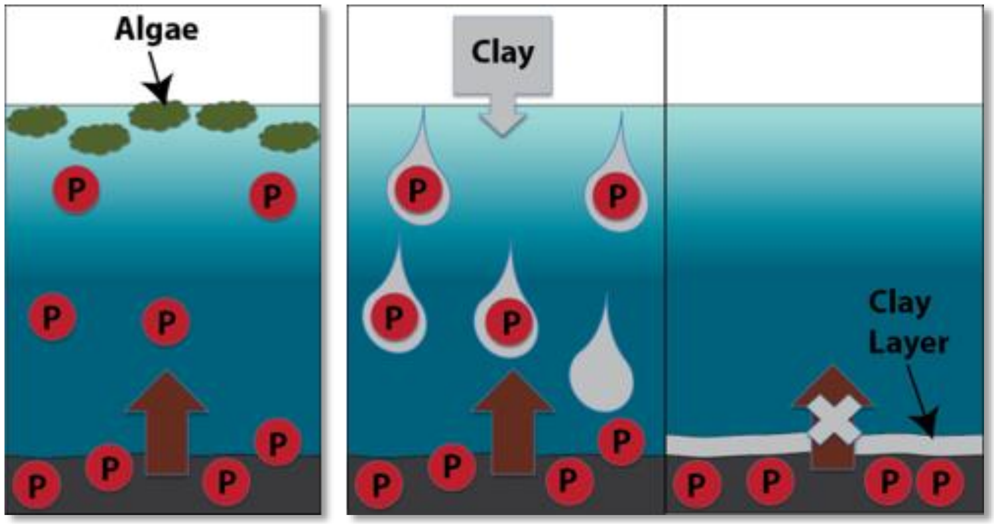

Figure 1: Phosphorus-binding clay products such as Phoslock® or the new HT-clay lock up phosphorus, making it unavailable to algae. Phosphorus is removed as the clay settles through the water and it also forms a protective layer on the sediments – reducing phosphorus release.

At present Phoslock® is the only commercially available phosphorus-binding clay product. It was developed in the 1990s by a DWER predecessor agency, the Water and Rivers Commission, in collaboration with CSIRO and is now being used around the world. The Lower Vasse River was an important site for field trials during Phoslock® development and for its initial testing. The largest and most successful Phoslock® trial in the Lower Vasse River was conducted by the Water and Rivers Commission in the summer of 2001–02.

Phoslock® does, however, have several limitations: it cannot be applied in marine or brackish environments, it is not produced locally, it contains the rare earth element lanthanum, and it has shown limited efficiency in reducing algal growth once a bloom has already established. A new phosphorus binding clay product, presently referred to as HT-clay, was therefore trialled in this study to address some of these limitations. HT-clay consists of a natural bentonite clay that is modified with a coating of the phosphorus-binding mineral hydrotalcite (HT). HT-clay can be produced from easily accessible and non-harmful materials in a straightforward manufacturing process. It is anticipated that it can be produced locally, potentially even onsite. Although initial laboratory testing of HT-clay has shown promising results, it is still an experimental product. The water treatment trials in the Lower Vasse River were the first larger field trials with this product.

Although algae also depend on other essential nutrients such as nitrogen, limiting phosphorus is often the most efficient strategy to manage algal growth and to control blooms of toxic blue-green algae (cyanobacteria) in particular. Most blue-green algal species are capable of converting and utilising atmospheric nitrogen if required, whereas harmless algal species such as green algae or diatoms depend on dissolved nitrogen species in the water such as nitrate or ammonia. Therefore, blue-green algae have an advantage over other species in a system where the supply of these forms of nitrogen is limited.

1.1 Successful Phoslock® trial in the Lower Vasse River

The Lower Vasse River has been the subject of many water treatment trials conducted by various organisations and agencies. These have ranged from floating islands to enzyme treatments and affected the water quality to varying degrees. The successful Phoslock® trial of summer 2001–02 involved 40 tonnes of Phoslock® being applied to a 650 m stretch of the river – from the weir boards behind the old butter factory to just past the current location of the new council buildings (see Figure 2). Twenty tonnes of clay were applied in October 2001, before the onset of algal blooms, and 10 tonnes each were applied in December and January. Phosphorus concentrations remained low throughout the whole summer and algal blooms were reduced significantly in comparison with a non-treated control area (Robb et al. 2003).

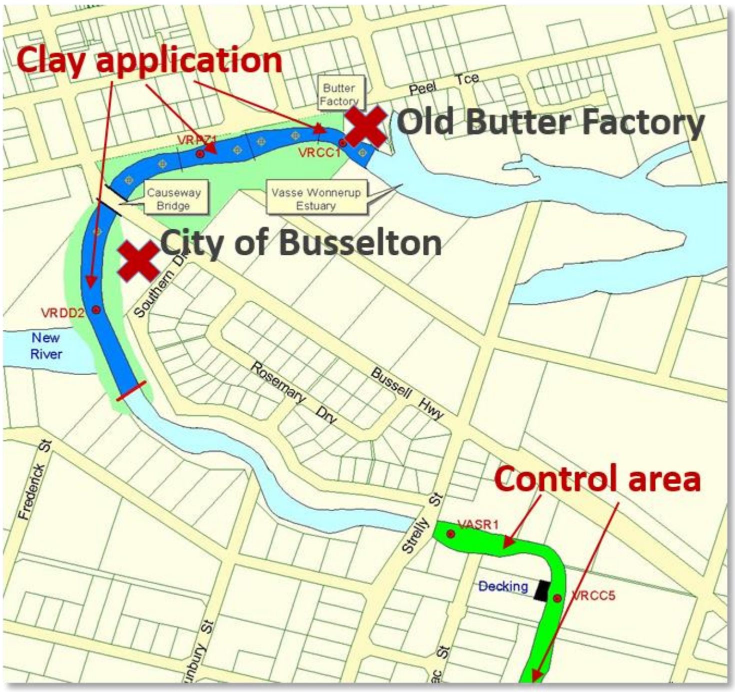

Figure 2: Area of the Lower Vasse River that was successfully treated with Phoslock® in summer 2001–02.

1.2 Aims of the HT-clay trials

These latest Lower Vasse River water treatment trials were the first longer-term field trials with the new HT-clay. They were designed to answer the following questions:

1. Is the HT-clay a viable alternative to Phoslock® and can it be used to reduce algal blooms in the Lower Vasse River?
2. How much clay needs to be added to efficiently control phosphorus concentrations and algal growth?
3. How much phosphorus is released from the sediments without clay treatment? Does the HT-clay layer on top of the sediments efficiently reduce phosphorus release?
4. Does the HT-clay treatment negatively affect invertebrate organisms living in the Lower Vasse River?

2 Methods

DWER tested the new HT-clay product in the Lower Vasse River for two consecutive summers (2016–17 and 2017–18). In both years the trials were set up in front of the new council buildings in an area of the river that typically suffers from severe blue-green algal blooms in summer and was easily accessible by boat (Figure 3).

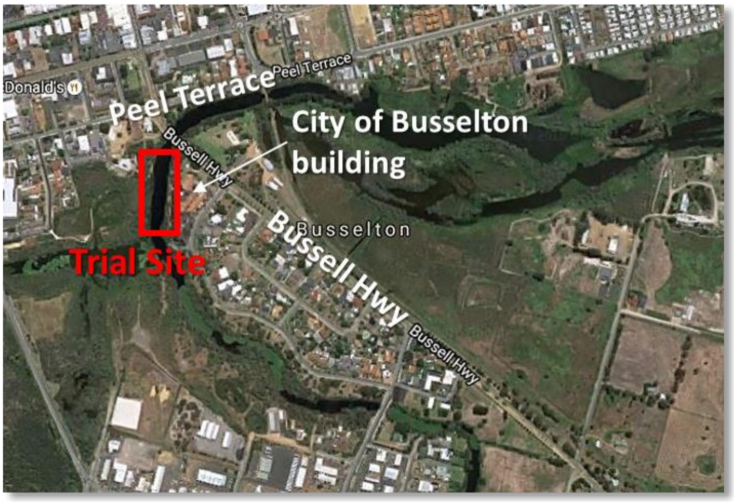

Figure 3: Location of the HT-clay trial site in front of the council buildings.

2.1 Mesocosm trial summer 2016–17

In summer 2016–17, 15 bottomless plastic tanks (75 cm x 75 cm x 2.3 m) were embedded in the ground of the Lower Vasse River, creating isolated trial areas of water and underlying sediments (mesocosms). In these mesocosms various HT-clay treatments and amounts were tested to determine the most efficient dosing rate (see Figure 4).

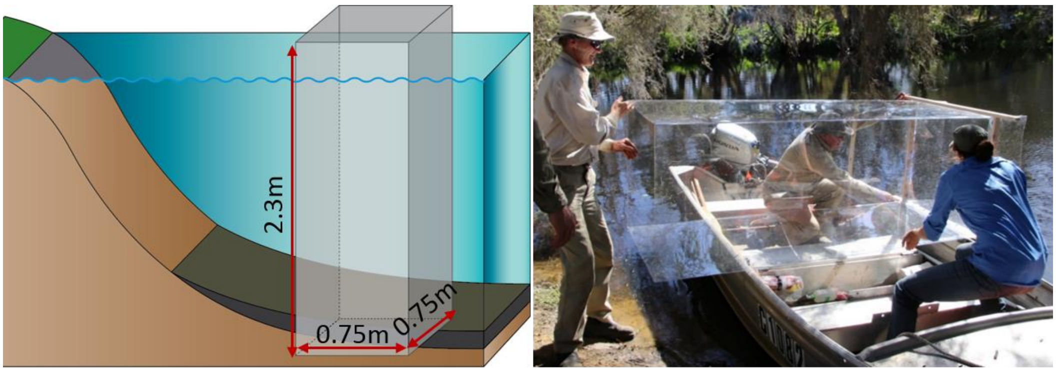

Figure 4: The mesocosm tanks used in this trial were open to the bottom, providing isolated trial areas of river sediments and overlying water.

In early December before the onset of algal blooms, nine randomly selected mesocosm tanks were treated with three different clay doses referred to as ‘low’, ’medium’ and ‘high’ clay doses in this report (see clay amounts in Table 1). To ensure high quality results and account for natural variability, each clay dose was tested in three different mesocosms to create replicates. Three randomly selected mesocosms were left untreated and served as controls. This approach was taken because the tank structure itself restricts water movement, creating slightly different conditions to the surrounding river, which may also influence algal growth. Hence it is important to compare the water quality conditions in the treated mesocosms with the conditions in the control mesocosms (rather than to the surrounding river) when evaluating the efficiency of the clay treatments.

To test whether HT-clay could still treat algae once a bloom had already established, one of the mesocosm tanks was treated with clay later in summer when an algal bloom was present.

Table 1: Clay amounts added to the mesocosms (given as g dry-weight clay/L).

	Clay amount [g clay /L]
Low clay dose	0.36
Medium clay dose	0.75
High clay dose	1.08
Clay dose added to spare mesocosm in March	1

2.2 Up-scaled trial summer 2017–18

After the successful mesocosm trial, the experiments were further up-scaled in the following summer to larger treatment areas of approximately 455 m^2 each. These were separated by PVC-curtains reaching from the bottom of the river to the water surface (Figure 5). The curtains were held at the water surface with floats and were sealed against the river bed by the weight of a chain and bricks. In addition, sand bags were used to seal small gaps near the banks.

Figure 5: Floating curtains installed in the Lower Vasse River for the 2017–18 HT-clay trial.

Two of the areas (area 1 and area 2) were treated with a total clay amount of nearly 1.5 tonnes. The dose was split and applied at different times throughout the summer (December for area 1 and February for area 2 – see Table 2). A third area was left untreated as a control to mimic the slightly altered conditions between the curtains to provide a baseline for the evaluation of the treatment efficiency.

The clay was evenly sprayed onto the water surface from a moving barge equipped with a 1000 L holding tank, a petrol pump and a spray boom (Figure 6). The tank on the barge was filled directly from the tanker truck that transported the clay to the trial site. To ensure the clay slurry was well-mixed, it was agitated inside the tanker truck by re-circulation with a petrol pump.

To test whether the curtains provided a sufficient seal, a bromide salt was added to the trial areas and used as a tracer to monitor any water exchange with the surrounding river.

Figure 6: Clay application from a moving barge equipped with a petrol pump and spray boom.

The trial was cut short due to two unexpected summer rain/storm events in mid-December and mid-January, which led to water movement in the otherwise stagnant river and caused the curtains to leak significantly. The bromide tracer indicated that during and after the storm events, a near-complete water exchange between the trial areas and the surrounding river occurred within 24 to 48 hours. This made it impossible to evaluate the effect on water quality of the first clay application in December. Sediment sampling with a handheld corer in January indicated that most of this clay was flushed out during the second storm event in mid-January.

When weather and flow conditions had normalised, the trial went ahead as planned, with a large clay application in February and a smaller top-up application in March (Table 2). To evaluate the treatment efficiency, water quality was monitored from the clay application in February until the end of the trial on 27 March.

Table 2: Amount and timing of clay application during the up-scaled second HT-clay trial. Clay doses were calculated assuming an average water depth of 1.6 m.

Application date	Clay dose	
	Area 1	**Area 2**
11 Dec 2017	*360kg (0.46 g/L)	–
8 Feb 2018	114kg (0.15 g/L)	606kg (0.83 g/L)
15 Mar 2018	180kg (0.24 g/L)	180kg (0.24 g/L)
Total	654kg (0.88g/L)	786kg (1.07g/L)

*Most of this was likely washed out in the storm on 16 Jan.

2.3 How did we monitor the success of the trials?

Water quality analysis

To evaluate the efficiency of the different clay treatments, the water quality at all trial sites and in the surrounding river was monitored immediately before and after clay application and then weekly throughout the trials. Water quality in the 2016–17 mesocosm trial was monitored for the entire summer from early December until the end of April, whereas the up-scaled trial in 2017–18 was cut short due to unexpected rain events and was monitored from early February until the end of March only.

Water quality variables of particular interest were phosphorus concentrations and algal growth indicators, such as phytoplankton cell counts or the concentration of algal pigments (chlorophyll). However, other water quality indicators that may have interfered with or been influenced by the HT-clay were also monitored (see

Table 3 for a complete list). In addition, weekly photographs were taken at each site to document the visual amenity of the water.

Figure 7: Water quality monitoring at a mesocosm tank.

Table 3: Water quality variables that were monitored as part of the trials.

Variable	Why was this measured?
TP, FRP, TN, NH_3, NO_x, Si	Test clay P-removal efficiency and monitor nutrients relevant for algal growth
Chlorophyll	Quantify algal growth
Phytoplankton species and cell count	Quantify algal growth and determine proportion of potentially harmful species in treated mesocosms versus non-treated controls
Turbidity	Is increased by algal growth and may possibly be altered by clay re-suspension
DO	Is heavily influenced by algal growth and may indicate water column stratification
Temperature	May indicate water column stratification and influences algal growth
pH	May interfere with clay efficiency and could also possibly be influenced by the addition of the alkaline clay slurry in the short term
Alkalinity	Carbonate concentration influences clay efficiency because it is also adsorbed by the clay and competes with phosphorus
DOC	Influences clay efficiency because it is adsorbed by the clay and competes with phosphorus
TSS	Test if it increases by clay application and monitor algal growth

TP: total phosphorus; FRP: filterable reactive phosphorus; TN: total nitrogen; NH3: ammonia; NOx: oxidised inorganic nitrogen species; Si: silica; DO: dissolved oxygen; DOC: dissolved organic carbon; TSS: total suspended solids

Sediment and pore water analysis

Sediments and the water contained within them (pore water) were sampled as part of the first mesocosm trial to:

- gain a better understanding of sediment volumes, accumulation rates and quality
- test if the clay could reduce phosphorus release from the sediments.

Sediment cores were collected with a hand coring device (Figure 8) before the trial was set up in early December and when it ended at the start of May. We sampled the mesocosms that were treated with the high clay dose, the untreated control mesocosms and the surrounding river. Two cores were collected from each location: one core for the analysis of total nutrient and organic matter contents and the other core for pore water analysis.

The sediment cores were accurately sectioned into fine depth intervals with a core slicing apparatus. Pore water was extracted from the sediments with a centrifuge. All steps of pore water sampling (including core slicing) were conducted under a nitrogen atmosphere to exclude air and avoid oxidation and precipitation reactions that would alter nutrient concentrations.

Figure 8: Sediment sampling with a hand coring device.

Macroinvertebrate count and identification

Small invertebrate organisms living within and near the sediments were collected and identified inside and around the trial areas as part of the second clay trial to ensure the clay treatment had no negative effect on these organisms.

Although the clay itself is non-toxic, some concern had arisen about detrimental effects due to increased turbidity and suspended solid content immediately after clay application and upon sediment disturbance. The organisms most affected would be small invertebrates living within and near the sediments. Thus we decided to see which organisms were present in the Lower Vasse River and to test whether the clay treatment had affected their abundance or diversity.

Figure 9: Sampling of invertebrate organisms with a fine sweep net.

Invertebrate organisms were counted and identified in samples that were collected at the end of the trial (late March) from each trial area, as well up and downstream of the floating curtains. Two samples were collected from each location: one sample was collected with a fine sweep net from the area near the banks over a length of 13 m; the other sample consisted of organic sediments and was collected from the middle of the river using an Ekman grab (sediment volume 7 L). In this report the different types of samples will be referred to as ‘channel’ and ‘sediment’ samples respectively.

3 Results

3.1 Did the clay treatment reduce phosphorus concentrations?

Immediate effects after clay application

Concentrations of phosphate (soluble and bioavailable form of phosphorus) and total phosphorus were reduced substantially within two to three hours of clay application in both trials (see figures 10 and 11). The phosphorus uptake took place instantaneously as the clay was settling through the water. In the mesocosm trial, phosphate concentrations were reduced by up to 98% at the highest clay dose. In the up-scaled trial, phosphate was almost completely removed in area 2 (phosphate concentration was below the method detection limit of 0.005 mg P/L) and reduced by 92% in area 1.

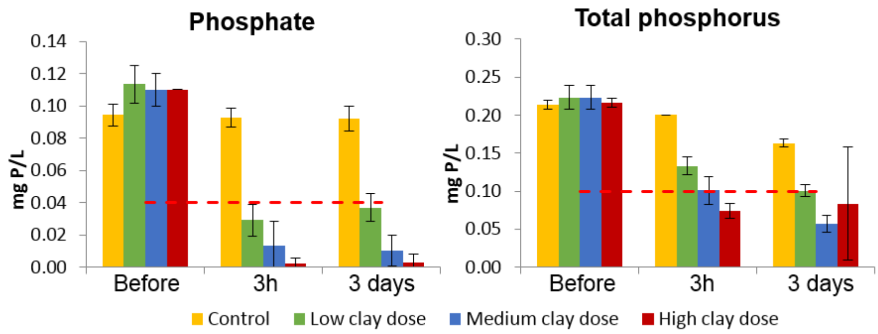

Figure 10: Concentrations of phosphate (soluble and bioavailable form of phosphorus) and total phosphorus before and after HT-clay treatment – mesocosm trial 2016–17. Red lines mark target thresholds, error bars represent standard deviation of three replicate mesocosm tanks.

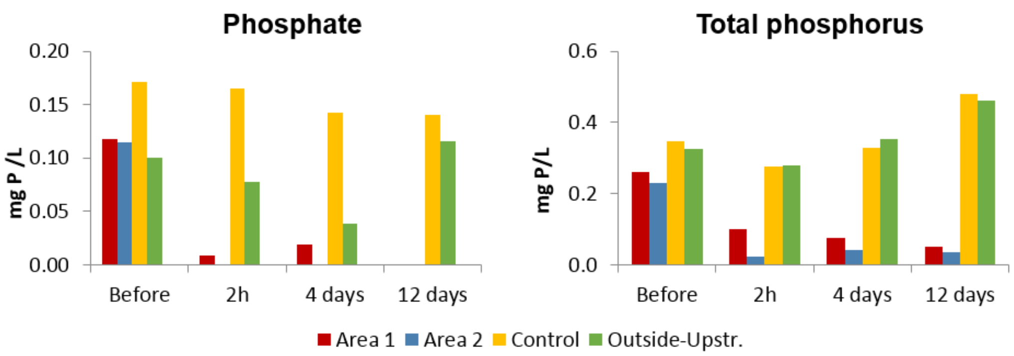

Figure 11: Phosphorus concentrations before and after HT-clay treatment in February 2018 – up-scaled trial 2017–18. (Note: the site downstream of the curtains was analysed from a later date onwards and is therefore not included in this graph.)

To evaluate the efficiency of the clay treatment, phosphate concentrations are more relevant than the concentration of the total phosphorus. Phosphate is the water soluble form of phosphorus which is immediately available to algae (the HT-clay is specifically designed to remove this form of phosphorus). Phosphate is typically analysed as filterable reactive phosphorus (FRP). In contrast, a large fraction of the total phosphorus is bound and contained within the algae. The clay treatment lowers the total phosphorus concentration in the water largely by removing algae and particulates, but it has not been designed for this purpose specifically.

All tested clay doses in both trials were able to drop phosphate concentrations below the recommended ANZECC & ARMCANZ guideline threshold of 0.04 mg P/L for lowland rivers (ANZECC & ARMCANZ 2000). Total phosphorus concentrations were reduced to below the management recommendations target threshold of 0.1 mg P/L to support a shift from phytoplankton to more beneficial macrophytes in Lower Vasse River, which was published by Novak and Chambers (2014).

Longer-term phosphorus reduction

Mesocosm trial 2016–17

The HT-clay treatment reduced total phosphorus and phosphate concentrations to values below the recommended target thresholds of 0.1 and 0.04 mg/L respectively (Novak & Chambers 2014; ANZECC & ARMCANZ 2000) for the entire monitoring period of five months when it was applied in sufficiently high doses (≥0.75 g/L). However, the total phosphorus threshold was slightly exceeded towards the end of summer at the lowest clay dose of 0.36 g/L (see Figure 12).

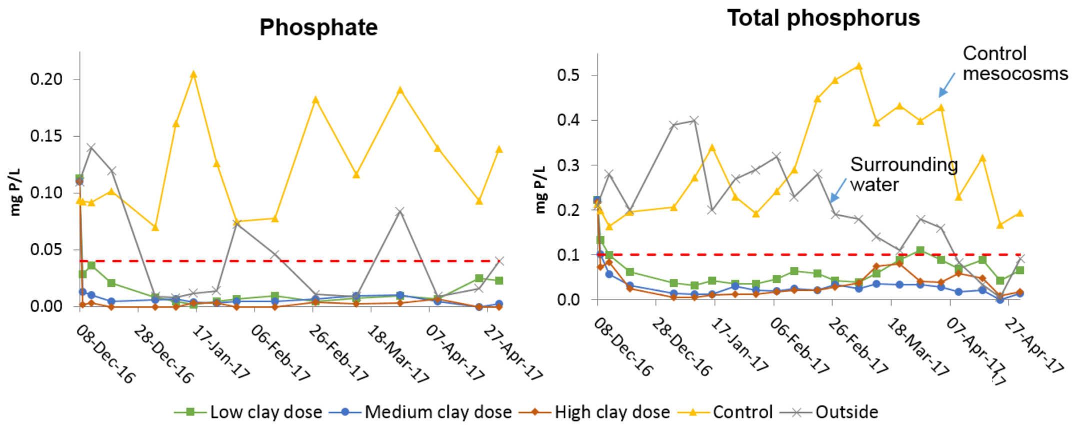

Figure 12: Phosphorus concentrations during the 2016–17 mesocosm trial over the entire monitoring period of five months.

Phosphate concentrations in the treated mesocosms were substantially lower compared with the conditions in the control mesocosms, indicating a high efficiency of the treatment. Phosphate concentrations in the surrounding river fluctuated with algal growth cycles, frequently exceeding the target threshold.

In the last month of the trial water quality conditions in the surrounding river started to improve, whereas algal blooms remained severe in the control mesocosms and also started to develop in some of the treated mesocosms (particularly for the lowest clay dose). This effect was also noticeable in the total phosphorus concentrations which decreased in the surrounding river (Figure 12).

Up-scaled trial 2017-18

Similar to the observations from the previous mesocosm trial, phosphate and total phosphorus concentrations remained low in the treated areas until the end of the trial, proving the efficiency of the clay on a larger scale and under slightly less restricted conditions (Figure 13). However, in the up-scaled trial a top-up clay dose was applied after 34 days, whereas in the mesocosm trial the whole clay amount was applied in a single dosing event in early summer. Top-up clay applications were planned in this trial to treat additional phosphorus input from external sources such as groundwater input or surface runoff, which would not have impacted water quality in the mesocosm trial. Large-scale clay treatment of the Lower Vasse River (with HT-clay as well as Phoslock®) will likely require one to two top-up applications throughout summer to account for this.

Phosphate and total phosphorus concentrations in the treated areas were much lower compared with the untreated control area and in the river upstream of the curtains (Figure 13). However, phosphate concentrations in the river downstream of the curtains were also low, albeit for different reasons.

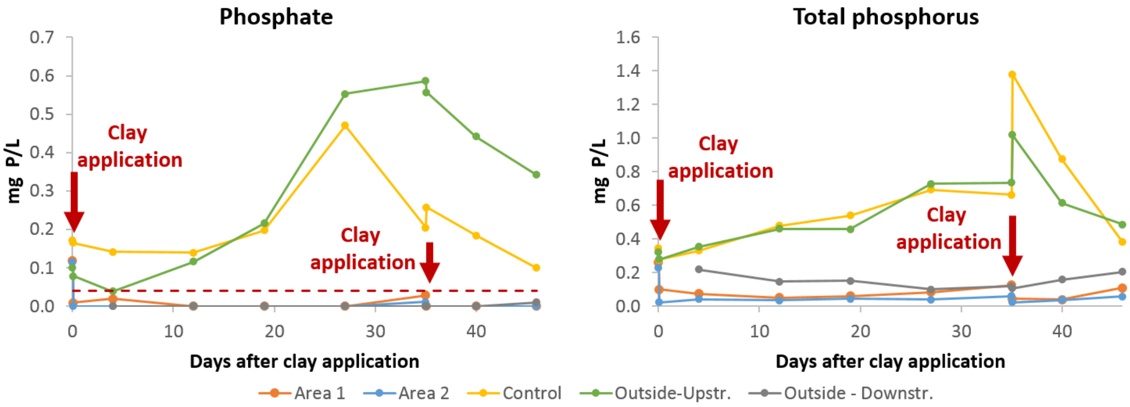

Figure 13: Phosphorus concentrations during the 2017–18 HT-clay trial. Phosphate concentrations were reduced to below the target thresholds (red line) as a result of clay application and remained low until the end of the trial.

We observed that the curtains acted as a barrier to the development of algal blooms. Typically the algal blooms started developing on the downstream side of the curtain setup in the area between the weir boards at the old butter factory and the causeway bridge (Figure 14). The blooms eventually spread to the upstream end of the curtains in late December/early January; however, after the storm event in mid-January – which temporarily cleared most of the algae – the subsequent blooms were largely restricted to the stretch of the river downstream of the curtains, particularly towards the end of the trial. Algal blooms may also temporarily deplete dissolved phosphate in the water until the bloom breaks down and releases the bound phosphorus. This is presumably the reason for the low phosphate concentrations that we measured downstream of the curtains where more severe algal blooms were present. Low phosphate concentrations during algal blooms have previously been observed in the Lower Vasse River during our long-term monitoring program and also to some extend in the mesocosm trial (see section above). Although total phosphorus concentrations at the downstream location were lower compared with the upstream location and in the control areas, they were generally higher than in the treated areas (Figure 13).

In summary, the clay treatment was successful in controlling phosphate concentrations at a larger scale; however, we recommend that the clay application be split into several dosing events throughout summer to account for potential additional phosphate input from runoff or groundwater after the initial clay application.

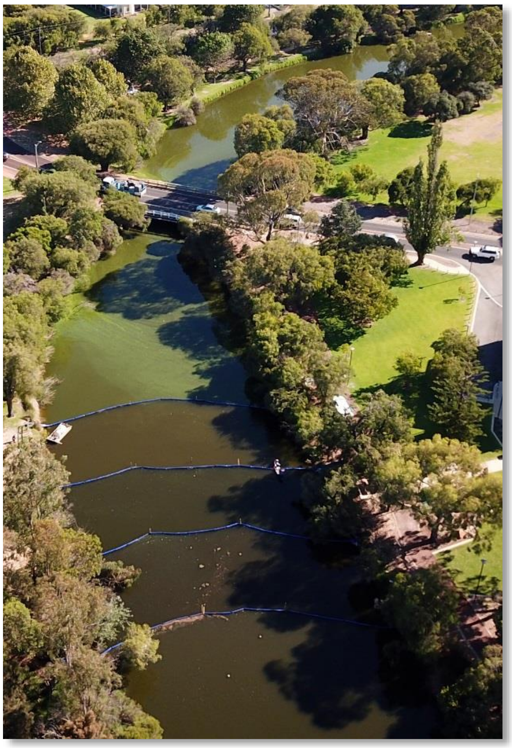

Figure 14: Aerial view before clay application in February 2018. Algal blooms in the Lower Vasse River typically start to develop at the downstream end between the weir boards and the causeway bridge before spreading further upstream.

3.2 Did the clay treatment reduce algal growth?

Immediate removal of algal blooms – flocculation

The HT-clay was able to remove an algal bloom within hours of application. This was shown in the 2016–17 mesocosm trial, the 2017–18 up-scaled trial and in laboratory experiments. The algae bind to the clay and sink to the ground of the river, a process called algal flocculation. The capability of the HT-clay to flocculate algae is a very useful side effect and gives it an advantage over Phoslock® clay, which solely controls algal growth by trapping phosphorus. Phoslock® has to be applied before the onset of an algal bloom (unless combined with a flocculating agent), whereas the new HT-clay still works when algae are already present. This enables more flexibility with timing and type of applications.

After clay application in the up-scaled trial, the water in the treated areas was extremely clear so that structures on the bottom of the river such as wooden debris became visible (see aerial photograph in Figure 15). Nevertheless, the treated areas appeared green, due to the algae that came to rest on the ground of the river together with the clay layer. The difference between the treated areas compared with the non-treated control area – which had thick algal scum on the water surface – was remarkable. These observations were also supported by the concentrations of algal pigments in the water before and after clay application (Figure 16). Similar results were achieved in the mesocosm trial when one of the mesocosms was treated later in summer (figures 18 and 19).

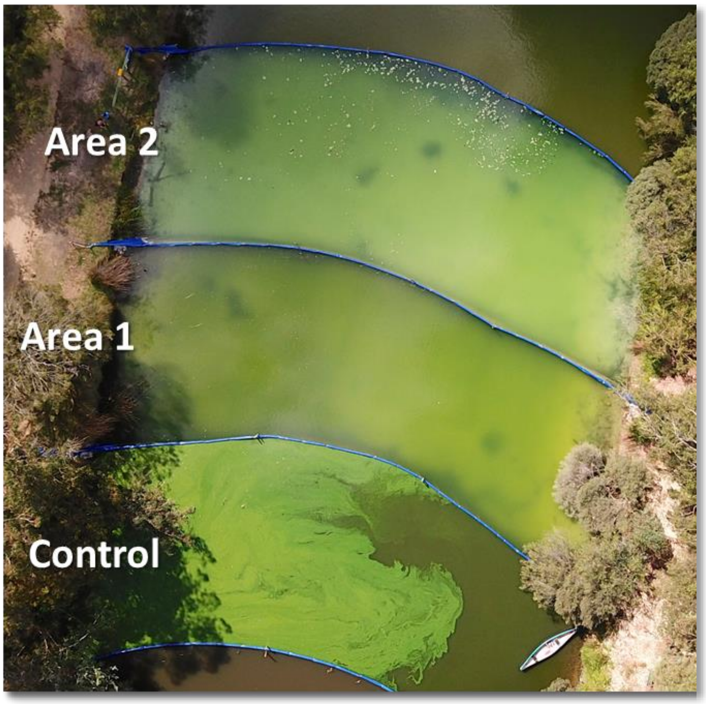

Figure 15: Aerial photo taken immediately after clay application in March 2018. In the treated areas the water is extremely clear, with structures such as wooden debris visible in the middle of the river. The green colour in these areas comes from algae which are now at the ground of the river together with the clay layer. In contrast, there is thick algal scum on the surface of the non-treated control area which is being moved across the trial area by the wind.

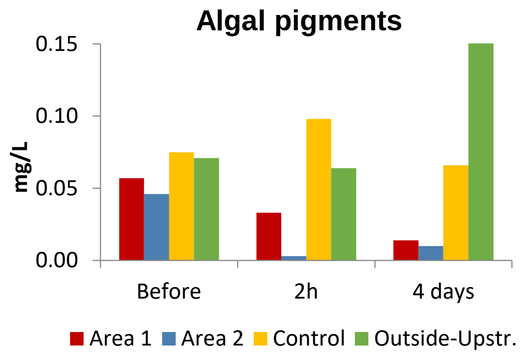

Figure 16: Concentration of algal pigments (chlorophyll and pheophytin) confirm that the clay largely removed an algal bloom within hours of application (up-scaled trial 2017–18, clay application in February).

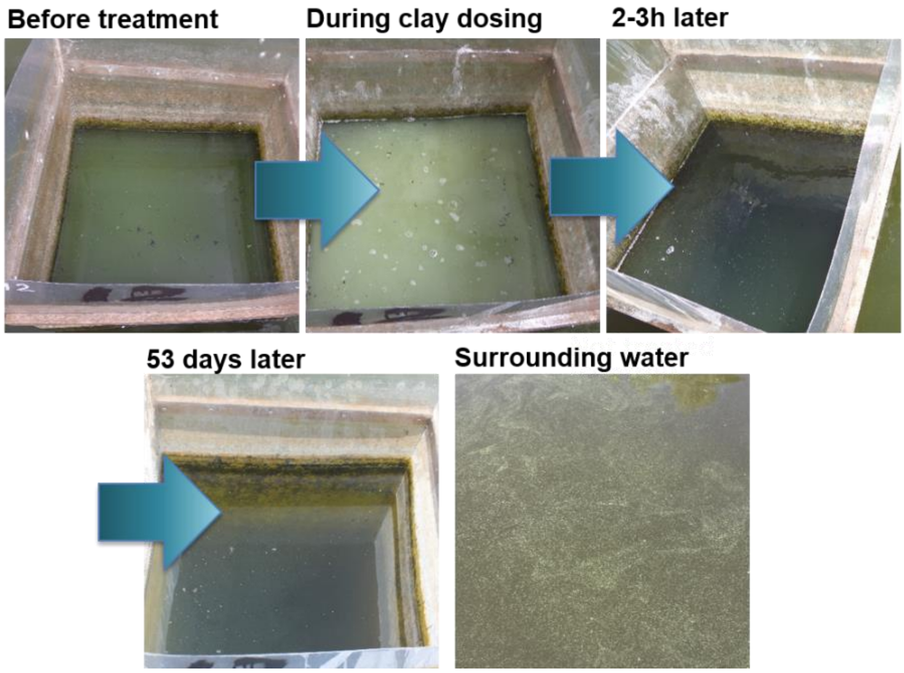

Figure 17: The HT-clay application was able to treat an algal bloom when it was applied to a mesocosm tank later in summer. The difference in visual amenity was immediately noticeable once the clay had settled. The water quality remained improved until the end of the trial 53 days later.

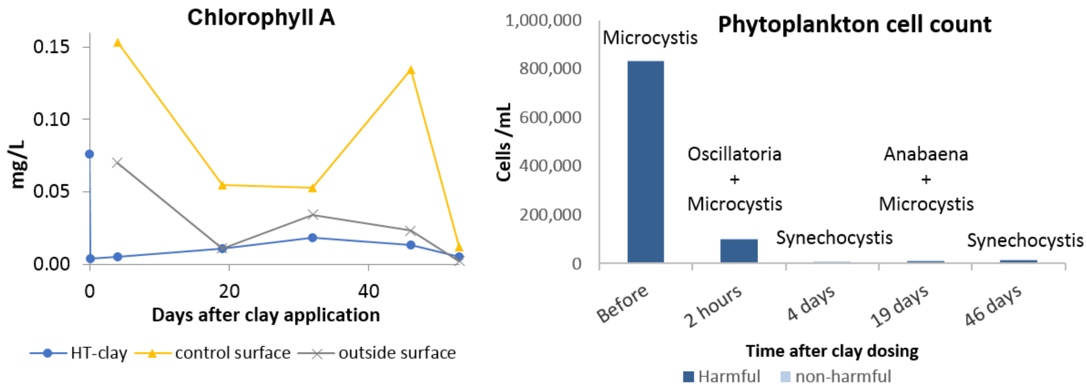

Figure 18: Concentration of chlorophyll A (algal pigment; left) and algal cell count with dominant species (right) in the mesocosm that was treated with clay later in summer when an algal bloom was already present. The algal bloom was largely removed and water quality conditions remained improved until the end of the trial.

Longer-term reduction of algal growth

The clay treatment reduced algal growth and improved water quality during the trial periods in both summers, when compared with the non-treated control area/control mesocosms. This was evident from visual assessment (e.g. Figure 19) and through evaluation of algal growth indicators such as algal cell count or chlorophyll concentration (e.g. figures 21 and 22).

Figure 19: Treated mesocosm versus surrounding water and non-treated control about three months after clay dosing (21 March 2017). The water in many mesocosms treated with the medium and high clay doses was still clear, often with visibility of the river ground. Phytoplankton growth was more severe in control mesocosms compared with the surrounding water towards the end of the trial.

Algal growth remained low in most mesocosms treated with the medium and high clay doses during the entire five-month monitoring period. However, towards the end of the trial when water quality conditions in the surrounding river were starting to improve, severe algal blooms developed in the control mesocosms and also in some of the treated mesocosms, particularly in those that had received the low clay dose (Figure 20). One of the mesocosms that received the high clay dose was presumably contaminated (e.g. by birds) and developed a very significant algal bloom in the second half of the trial. However, there were no algal blooms in the remaining two replicates that received the high clay dose. More detail on the concentration of phytoplankton cells and dominant species is included in Appendix C.

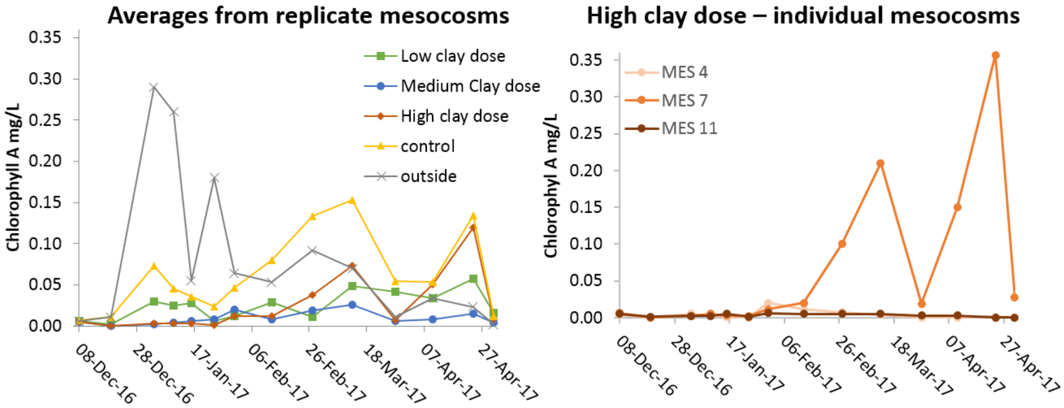

Figure 20: Chlorophyll concentrations during the 2016–17 mesocosm trial. The most significant algal bloom in the surrounding river occurred in late December and January. After that conditions started to improve in the river but algal growth further increased in the control mesocosms. The right figure shows the extremely high chlorophyll concentrations in one of the mesocosms that received the highest clay dose and was presumably contaminated.

Due to the unexpected weather events in summer 2017–18, the algal blooms in the Lower Vasse River followed an unusual pattern that year. Severe algal blooms had established in the river in late December/early January, yet the conditions improved significantly after the mid-January rainfall event. When the clay was applied in early February some algal blooms were present, especially downstream of the trial areas, but these were less severe than before the rain event.

Towards the end of the trial a severe algal bloom had established in the control area, but not in the river outside of the curtains (see concentrations of algal pigments in Figure 21). This shows that the curtains altered the conditions and provided more favourable conditions for algal growth. It is therefore important to compare the algal growth indicators from the treated area with the control area rather than to the surrounding river. Figure 21 indicates that the clay treatment significantly reduced algal growth for the entire trial period compared with the control area.

However, it should be noted that the clay treatment temporarily increased the abundance of floating algal mats associated with clay in both trials. This is presumably due to the improved water quality conditions which enable light penetration to the bottom of the river and support the growth of benthic algae.

Floating mats of benthic algae also developed in the surrounding river, particularly on sunny days, but they were not as abundant as they were in the treated areas.

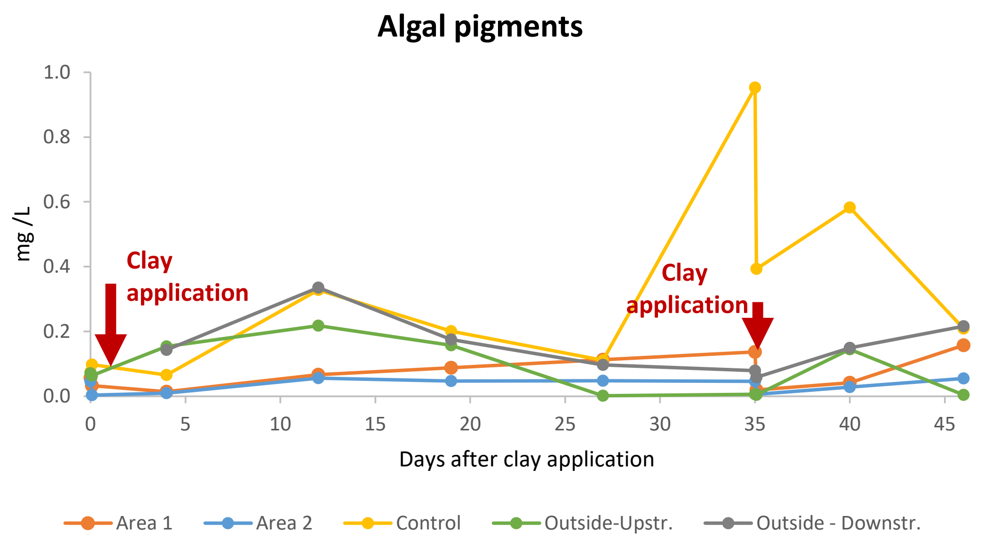

Figure 21: Concentration of algal pigments (chlorophyll and pheophytin) during the up-scaled 2017–18 HT-clay trial in treated and non-treated areas. The most severe algal bloom was present within the non-treated control area. It is important to compare the water quality variables from the treated areas with the control area (rather than to the surrounding river).

3.3 Did the clay treatment affect invertebrate organisms?

Although the clay itself is non-toxic, the presence of the clay layer and a short-term increase in turbidity immediately after application may have adverse effects on small invertebrate organisms living in water and sediments. To assess the impact of the clay on these organisms, the abundance and diversity of invertebrates were studied as part of the second up-scaled trial.

The results indicated no negative influence of the clay application on number and diversity of invertebrates present (Figure 22). However, the general invertebrate diversity in the river (also in non-treated sections) was low and limited to very resilient organisms, as was expected for a degraded environment such as the Lower Vasse River. Organisms found in sediments and water near the banks largely consisted of water boatmen, glass shrimp and larvae of non-biting midges (chironomids). Even fewer organisms were found in the sediments in the middle of the river, being limited to small red worms (oligochaetes) and very low numbers of chironomids. Both species are well-adapted to low oxygen conditions.

Although the present study did not indicate the clay treatment had any negative impacts on the organisms present in the Lower Vasse River, specifically designed laboratory toxicity tests with a higher diversity of invertebrate organisms will need to be conducted before large scale HT-clay applications.

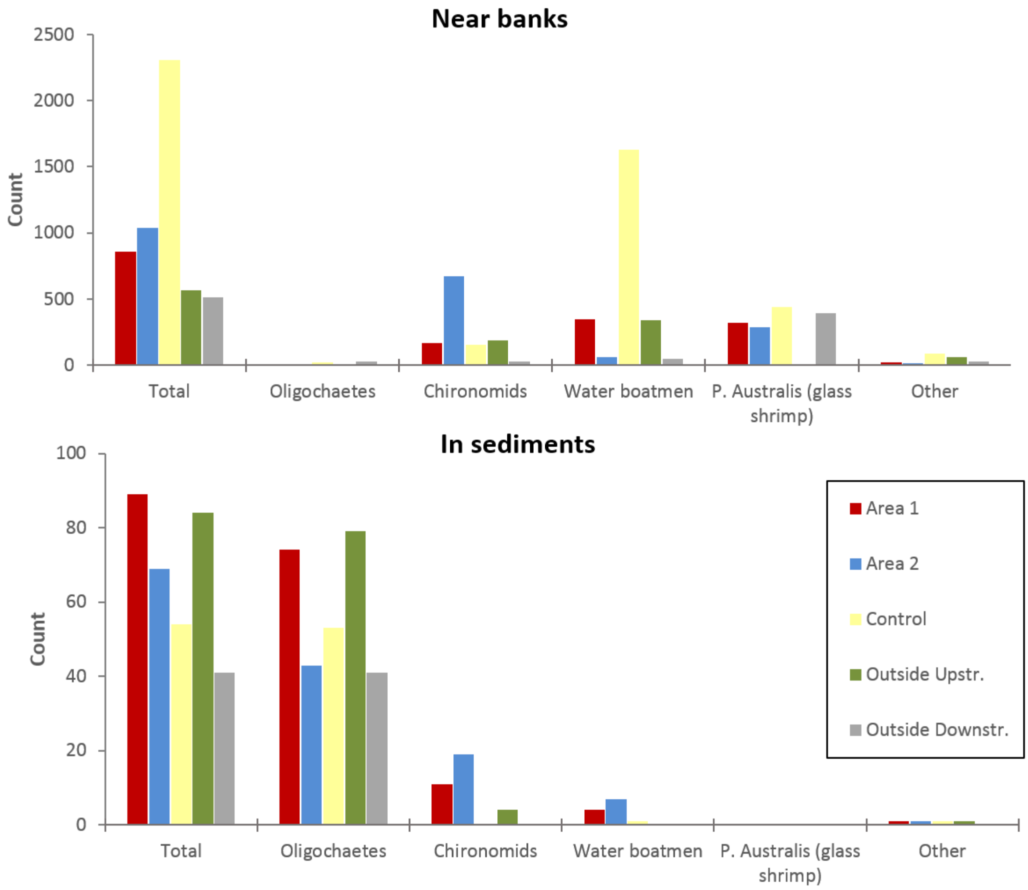

Figure 22: Macroinvertebrate organisms within and around the trial areas in the Lower Vasse River (up-scaled trial summer 2017–18). None of the organisms were negatively influenced by the clay treatment. Water boatmen were extremely abundant in the control area because of the severe algal bloom present in that area, which served as their food source.

3.4 Results from sediment studies

Did the clay layer reduce phosphorus release from sediments?

Pore water studies (conducted as part of the mesocosm trial) indicated that the clay layer capped the sediments and reduced phosphorus release (Figure 23; Appendix B). The estimated amount of phosphorus released from the sediments within the treated mesocosms during the entire trial period was 89 ±15 mg, which was lower compared with the phosphorus amount released from the same-sized sediment area in the surrounding river (301 ±151 mg) or from the control mesocosms (172 ±86 mg). In contrast, there were no statistically significant differences when comparing the release of ammonia and reactive silica between the treated and untreated mesocosms.

Nutrient release from the sediments to the overlying water can be estimated from nutrient concentrations in the pore water contained within sediments using finely sliced core intervals near the sediment/water interface. This is based on the assumption that in a stagnant system with fine-grained muddy sediments such as the Lower Vasse River during summer, nutrients are predominantly released from sediments to the overlying water by diffusion. Nevertheless, some nutrient release by sediment disturbance likely occurred at least in some of the mesocosms, which has not been considered in the calculations. Visual inspection and chemical analyses of the sediment cores indicated some sediment movement and burial of the clay layer (by up to 5 cm in one of the mesocosms). Despite this movement of the clay layer, phosphorus release from the sediments was still reduced in the treated mesocosms.

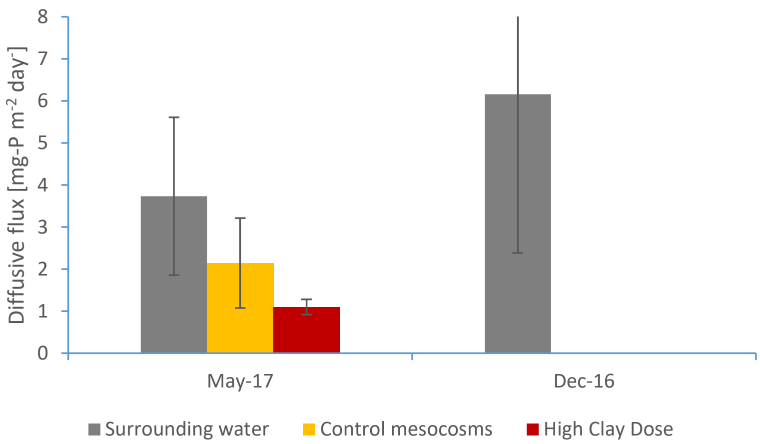

Figure 23: Daily diffusive phosphate release from sediments immediately before and after the HT-clay trial. The results show that the clay layer capped the sediments and reduced P-release. P-release from sediments in the control mesocosms was lower (despite much higher phosphate concentrations in the pore water) presumably due to higher phosphate concentration in the overlying water, which slows diffusive release. Error bars represent standard deviations from three replicate cores. Whereas the replicate cores from the treated mesocosms showed consistent results, there was some variation between the replicates in the control mesocosm and the surrounding area.

How fast do sediments in the Lower Vasse River accumulate?

Nutrient and organic matter-rich sediments often build up rapidly in aquatic systems of poor environmental health such as the Lower Vasse River.

The sediments covering the river bottom at the trial area consisted of an approximately 50 cm thick layer of fine-grained black mud overlying a riverbed of coarse sand. Most of the black sediment must have accumulated rapidly within 17 years because the sediments at this location were largely removed in March 2001 in an attempt to improve water quality.

To more accurately estimate the sediment accumulation rate we analysed lanthanum concentrations in sediment cores. Lanthanum is a major element in Phoslock® clay which was applied to the area in 2001–02. Based on a lanthanum spike in the sediment depth profiles, an accumulation rate of about 13– 17 mm per year was estimated. This is very high compared with typical rates for both lakes and estuaries.

4 Is the new HT-clay a viable alternative to Phoslock®?

Phoslock® and HT-clay each have advantages and disadvantages; thus the specific environment or particular situation for intended application will determine which clay may be more suitable. Both clays have shown promising results in the treatment of algal blooms in the Lower Vasse River. Table 4 lists the most important points in a direct comparison between both clays. However, it should be noted that while Phoslock® is a commercial product that is readily available, the HT-clay is still an experimental product that requires further testing and product development work (see following section).

Table 4: Comparison HT-clay versus Phoslock®

Phoslock®	New HT-clay
Tested dosing rate in the Lower Vasse River ➔1.2 g clay/L	Required dosing rate in the Lower Vasse River ➔ca. 1 g clay/L
Commercial product, readily available	Experimental product, requires further research and optimisation
Does not work in brackish or marine environments	Application may be possible but requires further research
Has to be applied before an algal bloom starts	Removes algal bloom when it has already established
Includes rare earth element lanthanum; is produced in China	Straightforward production process; potentially more economic starting materials; can likely be produced locally

4.1 What's next? – further HT-clay development

Although the HT-clay has shown promising results in first field trials, it is still an experimental product and requires further research and development work before large-scale application may become possible in the Lower Vasse River and at other locations. Current activities in the REI component of the project include:

1. Optimisation of the clay production method to enable affordable large-scale production and transport
2. Development of a detailed environmental risk assessment of HT-clay application, including toxicity studies with invertebrate organisms as well as looking at the behaviour of clay under changing environmental conditions, such as low/high pH or higher salinities.
3. Further research of clay dosing rates and clay performance under different conditions, such as high organic matter contents or higher salinities.

These experiments will be conducted in the next one to two years. If successful, it is anticipated that large-scale HT-clay treatment may become available in the next three to five years.

5 Conclusions - what treatment do we recommend for the Lower Vasse River?

Regular application of phosphorus-binding clay in the Lower Vasse River will reduce algal growth, sediment build-up and phosphorus release from sediments. Over time this will provide conditions for the establishment of a healthier and more diverse ecosystem (e.g. enable growth of macrophytes or aquatic plants).

- We recommend regular Phoslock® treatment for the Lower Vasse River as an immediately available and affordable measure to improve water quality and reduce sediment build-up.
- If the current testing and development of HT-clay is successful, HT-clay may replace or be combined with Phoslock® treatment of the Lower Vasse River in the future. We aim to improve the clay manufacturing process for HT-clay and intend to conduct laboratory testing to develop a detailed environmental risk assessment.
- Annual treatment would involve an estimated 40 tonnes of Phoslock® being split into three to four separate applications during summer (20 tonnes in November before the onset of algal blooms and smaller top-up applications throughout summer when required). It is anticipated that the total annual clay amount could be reduced significantly after a few years of regular application.
- Algal blooms in the Lower Vasse River develop at the downstream end in the area between the weir boards at the old butter factory and the causeway bridge before they spread further upstream. We therefore recommend treatment of this area.
- Phoslock® is a commercially available product that is distributed and applied by the Australian company Phoslock® Water Solutions at a price of $3000 per tonne. A 40 tonne application would therefore cost about $120 000 annually.

Appendices

Appendix A — How did we ensure the trial setup was working?

Bromide tracer

To obtain accurate results for this trial it was important that mixing of the water between the mesocosm tanks or trial areas separated by curtains and the surrounding river was kept at a minimum. To test this, a bromide salt was added to the trial areas and used as a tracer to monitor water exchange. Bromide is an established tracer used in many environmental applications. It is non-harmful with a low natural abundance: its concentrations typically do not change due to natural processes such as adsorption to particles or uptake by organisms.

Bromide loss from the mesocosm tanks was minimal during a monitoring period of almost two months, indicating only minor water exchange with the surrounding river (Figure 24). There was some water exchange with the surrounding areas during the 2017–18 up-scaled trial, particularly towards the end of the trial (Figure 25).

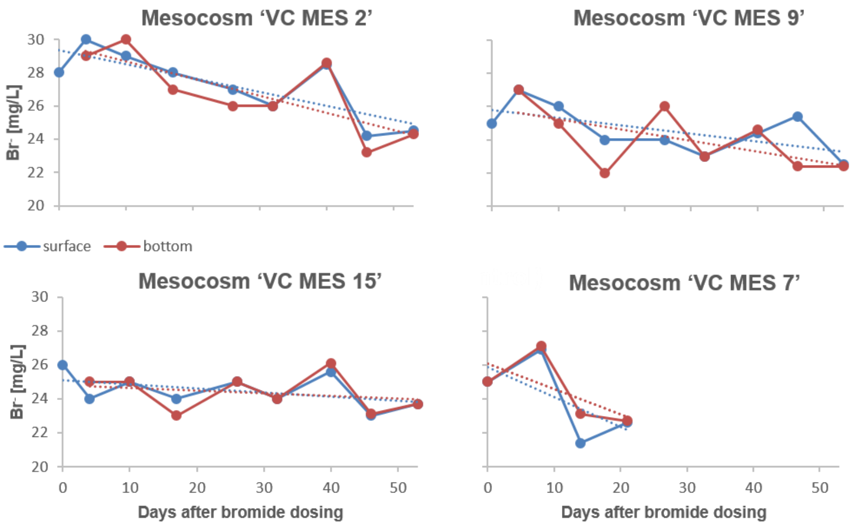

Figure 24: Concentrations of a bromide tracer added to selected mesocosms indicate no or only little water exchange with the surrounding river. Blue and red graphs represent concentration in surface and bottom water samples respectively.

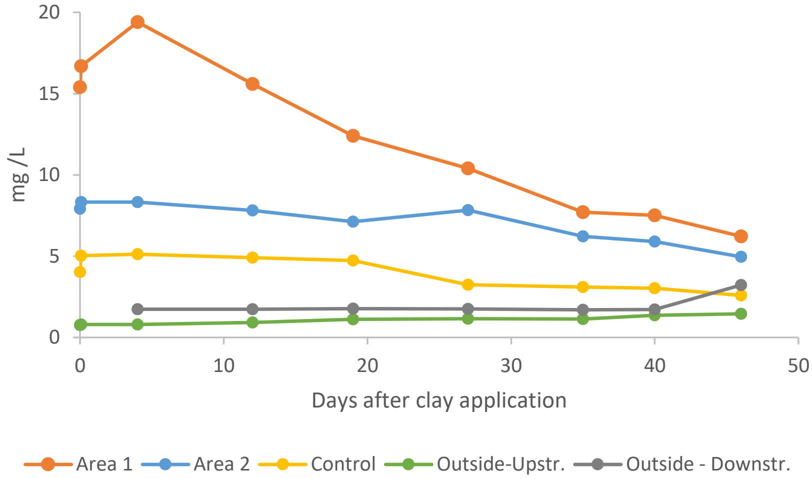

Figure 25: Bromide concentrations during the 2017–18 up-scaled HT-clay trial. Sodium bromide was applied to trial areas 1 and 2 before clay application. The loss of bromide from area 1 during the trial indicates some water exchange with the surrounding areas. Bromide concentrations in the non-treated control area were elevated compared with the surrounding river due to some water exchange with the treated areas, presumably this largely happened before clay application when there was still some water movement after the storm event.

Appendix B — Diffusive nutrient fluxes from the sediments to the overlying water

For this study the diffusive nutrient release was estimated from concentration gradients in pore water within the top three centimetres of the sediment cores that were collected in May 2017 and December 2016. Daily nutrient fluxes per square metre, as well as total nutrient release per mesocosm area over the whole trial duration are summarised in Table 5. All nutrient fluxes were generally very high, which can be expected from a system like the Lower Vasse River.

Table 5: Average diffusive nutrient fluxes (± standard deviation) determined immediately before and after the HT-clay trial in December 2016 and May 2017 respectively.

Sampling date	Nutrient	Clay treatment	Flux (F) [mg $m^{-2}day^{-1}$]	Estimated amount released during trial per mesocosm area
May 2017 (after trial)	Filterable reactive phosphorus (FRP)	Surrounding river (no clay)	3.74 ±*1.88*	301 ±*151* mg-P
		Control mesocosms (no clay)	2.14 ±*1.07*	172 ±*86* mg-P
		High clay dose	1.10 ±*0.18*	89 ±*15* mg-P
	Ammonia (NH_3)	Surrounding river (no clay)	45.4 ±*5.2*	3653 ±*417* mg-N
		Control mesocosms (no clay)	38.5 ±*19.7*	3098 ±*1586* mg-N
		High clay dose	36.0 ±*7.2*	2896 ±*582* mg-N
	Reactive silica	Surrounding river (no clay)	25.1 ±*2.7*	2018 ±*220* mg-Si
		Control mesocosms (no clay)	12.5 ±*9.5*	1006 ±*765* mg-Si
		High clay dose	19.3 ±*5.7*	1551 ±*459* mg-Si
December 2016 (before trial)	Filterable reactive phosphorus (FRP)	Surrounding river (no clay)	*6.16 ±*3.77*	*495 ±*303* mg-P
	Ammonia (NH_3)		30.5 ±*23.2*	2452 ±*1862* mg-N
	Reactive silica		11.4 ±*2.4*	918 ±*190* mg-Si

*Only determined from concentrations in top 2 cm sediment layers (all other fluxes calculated from top 3 cm)

Appendix C — Phytoplankton species analysis during the 2016–17 mesocosm trial

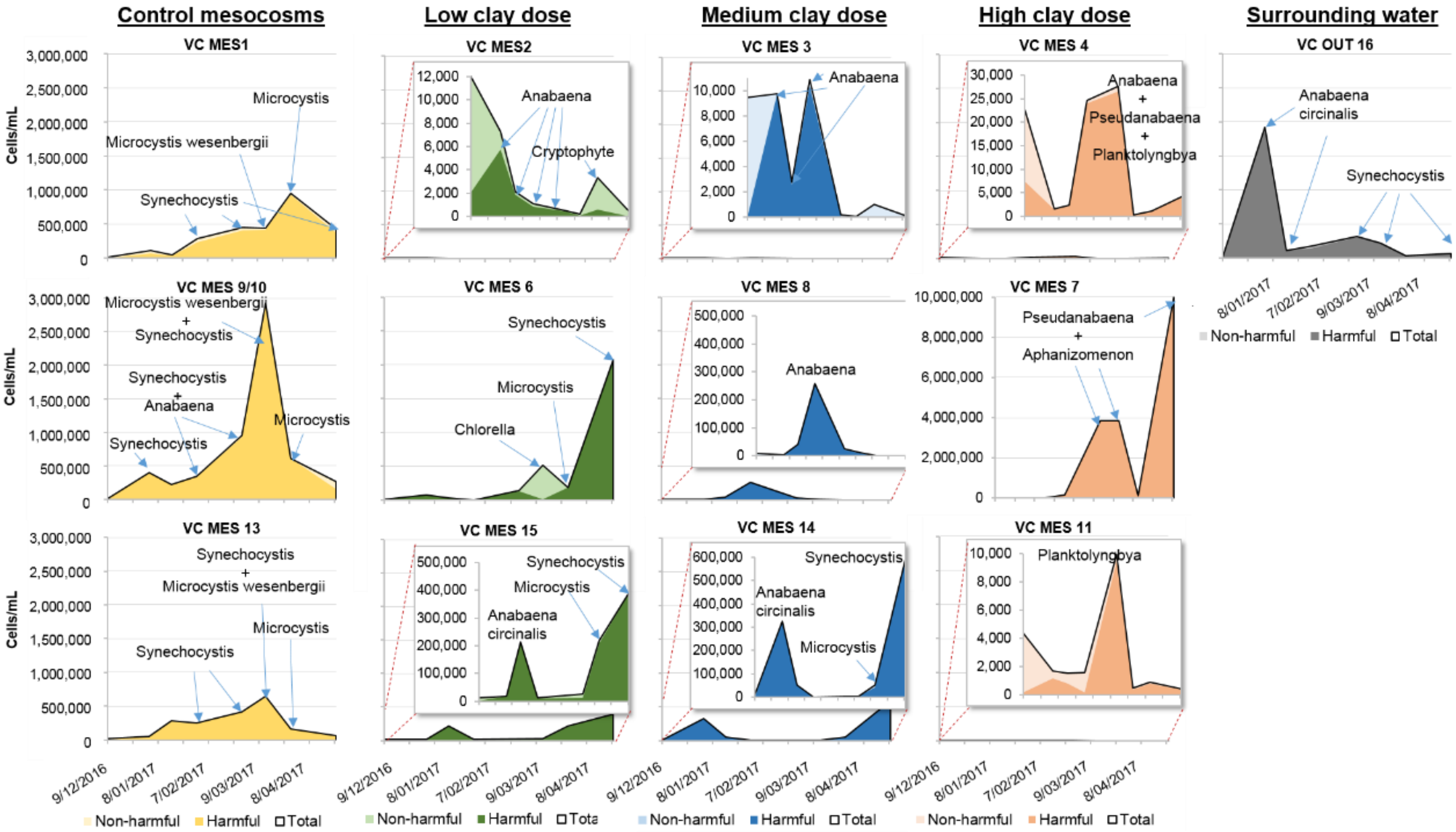

Figure 26: Phytoplankton cell counts and dominant species in the mesocosms and surrounding river throughout the 2016–17 trial.

Shortened forms

DO	Dissolved oxygen
DOC	Dissolved organic carbon
DWER	Department of Water and Environmental Regulation
FRP	Filterable reactive phosphorus
HT	Hydrotalcite
P	Phosphorus
REI	Regional Estuaries Initiative
RGW	Revitalising Geographe Waterways
TN	Total nitrogen
TOC	Total organic carbon
TP	Total phosphorus
TSS	Total suspended solids

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Department of Primary Industries and Regional Development

GOVERNMENT OF WESTERN AUSTRALIA

Lower Vasse River Waterway Management Plan

May 2019

City of Busselton
Geographe Bay

Revitalising Geographe Waterways

VASSE taskFORCE

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Acknowledgement of Wadandi people and country

The Vasse River has great spiritual, environmental, customary and social significance to the Wadandi Nyungar people. From its headwaters at Chapman Hill through to the Vasse-Wonnerup Wetlands, the Bilya (river) carries their songline. The Wadandi people are the traditional custodians of the Lower Vasse River, and this connection will be recognised in its future management.

All systems and beliefs have water as life, blood. We can't survive without fresh water: it's blood, life.

(Isaac Webb, 2018, cited in BGA 2018)

Executive Summary

Background

The Lower Vasse River is a reach of the Vasse River approximately 5.5km in length from the Vasse Diversion Drain to the weir structure at the Old Butter Factory. It flows through the centre of Busselton, about 250km south of Perth. This reach is greatly modified, with an estimated 90% of catchment flows diverted to Geographe Bay, and impoundment by the weir structure at its downstream end. The river is highly eutrophic, with severe algal blooms occurring each year during the warmer months.

Isolation in terms of flow; the conditions of extremely poor water quality experienced; and the high-profile location have led to the need for specific management of this area. This is the focus of this Water Management Plan. It was initiated though the Revitalising Geographe Waterways program, in response to community concerns about water quality issues in key water assets in the Geographe Bay Catchment. The Water Management Plan has been developed using a collaborative approach that has allowed for extensive consultation to work towards future management of the Lower Vasse River that aligns with community priorities, is well-understood and accepted, and has significant commitment to implementation by stakeholders.

Purpose and scope

The City of Busselton (the City) has developed this Waterway Management Plan (WMP) to guide future management strategies and actions that will work towards the vision for the Lower Vasse River:

> *The Lower Vasse River is an icon of Busselton, valued and enjoyed by the community, as a healthy waterway linking people and nature.*

The Plan includes a description of the characteristics and management issues for the Lower Vasse River, and provides objectives for the future. Through a review of available management options and consideration of stakeholder input, a comprehensive series of management strategies, each with specific actions, has been developed to guide works that will contribute to the objectives and overall vision for The Lower Vasse River.

Management focus areas

Management issues for the Lower Vasse River have been grouped into the following seven focus areas, with 16 associated management objectives, summarised here in order of importance as rated during community consultation. The table below provides management strategies and actions for each focus area.

1. Water Quality

Nutrients are a key driver of algal blooms, so ongoing load reduction actions are a fundamental part of management. However, it often takes a long time to achieve load reductions, and they may be counteracted by new developments and changes to land use. Algal blooms can also be addressed through interventions that limit nutrient availability or directly target algal blooms. They may also be managed by creating less favourable physical conditions for phytoplankton; or restoring ecosystem functions such as nutrient cycling and food web processes.

Objectives:

- Reduce nutrient contributions to the Lower Vasse River from all existing sources to improve water quality and reduce the frequency and severity of toxic algal blooms.
- Minimise any additional nutrients flowing into the Lower Vasse River from new developments and agricultural intensification.
- Utilise science and innovative technologies to improve water quality in the Lower Vasse River.

2. Ecology

Although degraded, the Lower Vasse River still provides habitat for native freshwater fish, frogs, turtles and invertebrates, and open water areas for waterbirds. The riparian vegetation contributes to aquatic habitats and also supports a range of terrestrial fauna and birds. The permanent fresh waters of Lower Vasse River provide a unique habitat in a landscape of seasonal wetlands and estuaries. There is significant scope to enhance ecological values through managing invasive species and restoring habitat.

Objectives:

- Protect and enhance native aquatic and terrestrial habitats in the Lower Vasse River and the foreshore reserve.
- Reduce the impact of threatening processes on the natural values of the Lower Vasse River and the foreshore reserve.
- Balance mitigation of fire risks with the protection of natural values of the Lower Vasse River foreshore reserve.

3. Water Flow

There have been substantial changes to the hydrology of the Lower Vasse River and its catchment through physical changes, diversion and impoundment. There is a strong perception in the community that increasing flows from the Vasse Diversion and removal of the Butter Factory weir boards will improve water quality and mobilise sediments. This approach is limited by flow regimes, flood risks and influence on nutrient loads; and a lack of defined management responsibilities for operation of flow control infrastructure.

Objective:

- Optimise water flow in the Lower Vasse River to balance improvement of water quality, protection of natural values and public amenity, while maintaining flood protection.

4. Sediments

The Lower Vasse River system has accumulated a layer of nutrient rich organic sediments, which contribute nutrients to the water column over summer, driving algal blooms. These sediments provide habitat for beneficial aquatic plants and benthic invertebrates. Sediments are therefore are a key consideration in addressing water quality problems in the Lower Vasse.

Objectives:

- Strategically manage accumulated sediments to protect the natural, cultural and social values of the Lower Vasse River.

5. Amenity, Recreation and Education

A number of trails and public open space areas adjoin the Lower Vasse and these are still regularly used by the community. Poor water quality has greatly reduced the opportunities for recreational activities in and around the river during the warmer months. Access and recreation was rated the highest and the focus area requiring change. There is significant potential for improving amenity and recreational and educational opportunities through enhancing ecology, improving facilities, addressing water quality problems, and developing information material.

Objectives:

- Improve visual amenity, public health and odours for residents and visitors to enjoy the Lower Vasse River.
- Facilitate recreational and educational opportunities, which are compatible with protection of the key values of the Lower Vasse River and enhance community stewardship.
- Enhance public access to the Lower Vasse River and within the foreshore reserve, with a focus on creating linkages to the town centre and surrounding areas while protecting the river's natural values.

6. Culture and Heritage

The river has historically been an iconic feature of the town and focal point for recreational and social events. There is a strong Aboriginal cultural connection to the river and a need for greater recognition of the role of Aboriginal people in future management.

Objective:

- Promote understanding of the Aboriginal and European history and culture of the Lower Vasse River.

7. Governance

The need for a designated manager of the Lower Vasse River was recognised by the independent review of waterways management, and also highlighted during community consultation. The lead role of the City in the future management of the Lower Vasse River will be recognised through endorsement and adoption of this WMP. This will task the City with responsibility for coordinating implementation, however key stakeholders and the community will have ongoing roles in many aspects of the WMP.

Objectives:

- Develop and maintain partnerships and a collaborative approach between key stakeholders and the community when managing the Lower Vasse River.
- Maximise opportunities for protection of the Lower Vasse River as part of future development proposals and changes in land uses.
- Manage the Lower Vasse River with consideration to other water assets, including the Vasse-Wonnerup Wetlands and Geographe Bay.
- Improve knowledge and understanding of key values and management issues of the Lower Vasse River to support adaptive management.

Living Streams

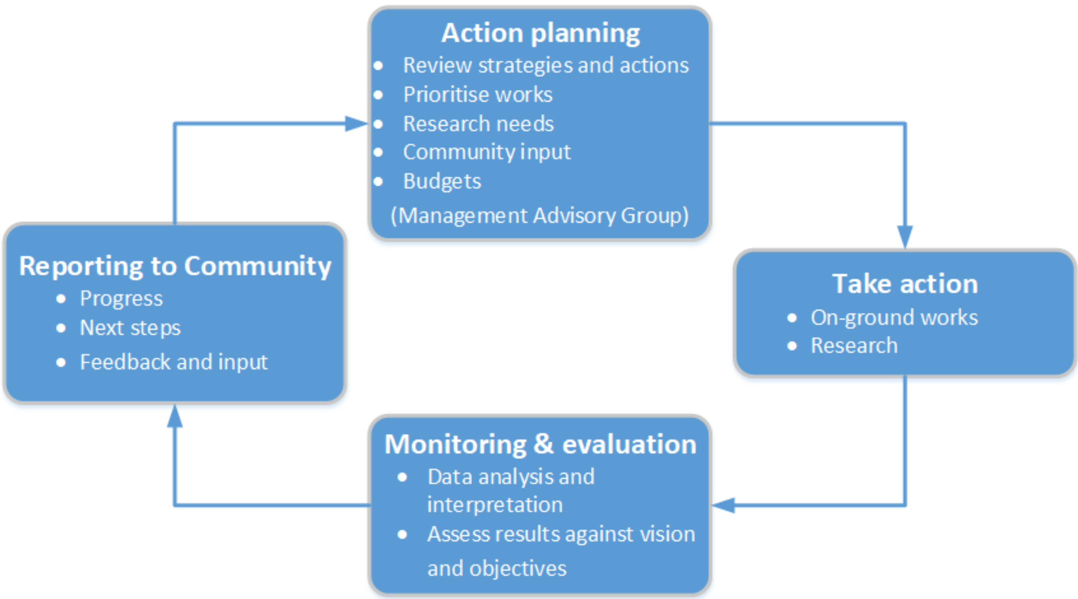
This WMP recommends further development of a Living Stream approach to future management of the Lower Vasse River. The term *Living Streams* describes an approach to managing urban stormwater that creates a complex ecosystem with outcomes for ecology, water quality, water conveyance and amenity. For the Lower Vasse River, this would involve altering the morphology to restore ecological processes and create physical conditions that provide greater resilience to high nutrient conditions. It may also facilitate intervention actions, such as water treatment and sediment removal, in specific areas of the river.

Implementation

The lead role of the City in the future management of the Lower Vasse River will be recognised through endorsement and adoption of this WMP. Other key stakeholders will continue to have important roles in many aspects of implementation, and there is an ongoing need for community reporting and feedback.

There are many management actions recommended in the WMP and currently there is no guaranteed funding mechanisms or timeline for implementation. A framework for implementation is provided that defines the roles and responsibilities of key stakeholders and a process for action planning, works, evaluation and reporting. This will allow ongoing prioritisation and implementation of actions in line with available funding, and building on new information from research, monitoring and outcomes as management progresses.

Implementation process for the Lower Vasse River Waterway Management Plan:



Management strategies and actions for the Lower Vasse River.

Strategies and actions are grouped for the Living Streams approach (LS) and each focus area: Water Quality (WQ); Ecology (E); Water Flow (WF); Sediments (S); Amenity; Recreation and Education (ARE); Culture and Heritage (CH); Governance (G).

Management Strategies	Management Actions
Living streams approach	LS.1 Continue to develop Living Streams planning as a pathway for implementing ecological restoration and water quality improvement works, and assess community support for this approach. LS.2 Incorporate the key principles into restoration planning as part of the Living Streams approach.
Protecting water quality from urban sources	WQ1.1 Quantify nutrient and pollutant exports from Busselton Light industrial area (LIA) to the Lower Vasse River to inform a case for deep sewerage. WQ1.2 Explore options to secure deep sewerage for the Busselton LIA in partnership with Water Corporation. WQ1.3 Assess opportunities for greater connection to existing sewerage infrastructure within the LVR catchment. If there a significant opportunity exists, investigate options and incentives to increase connectivity. WQ1.4 Planning decisions to include appropriate sewerage management requirements and best practice water management, through implementing the *Better Urban Water Management* framework. WQ1.5 Develop a prioritised program for stormwater upgrades to maximise nutrient reduction outcomes. WQ1.6 Support educational campaigns that aim to reduce nutrients in runoff through individual and community actions (e.g. Bay OK). WQ1.7 Support implementation of the Vasse-Wonnerup Wetlands and Geographe Bay Water Quality Improvement Plan (WQIP).
Reducing nutrient inputs from the rural catchment	WQ2.1 Support projects focussed on reducing nutrient exports from rural catchment of the LVR, as recommended in the Vasse-Wonnerup Wetlands and Geographe Bay WQIP (DoW 2010; noting future updates of this document): WQ2.2 Explore opportunities for enhanced nutrient assimilation in rural drains in the LVR catchment, particularly those in reserves.
Water treatment	WQ3.1 Incorporate outcomes from the Water Quality Treatment Trials (2016-2018) into future management planning. WQ3.2 Undertake seasonal water treatments in priority amenity area/s prior to algal bloom establishment, ensuring physical isolation to maximise effectiveness (dependent on outcomes Water Quality Treatment Trials, 2016-2018). WQ3.3 Maintain research partnerships to identify and investigate new technologies to treat water in the future.
Riparian vegetation management	E1.1 Develop and implement a revegetation program for City-managed foreshore reserves, considering recommended rehabilitation areas reported in Ecoedge (2017). E1.2 Continue to impose appropriate conditions on new developments adjacent to the Lower Vasse River that ensure future vesting and revegetation of foreshore reserves. E1.3 Include creation and improvement of habitat for birds and possums in planning riparian revegetation. E1.4 Update the Vasse River Action Plan in partnership with adjacent landholders, and extend this throughout the Lower Vasse River study area.

	E1.5	Minimise fire risks associated with foreshore reserves by: reducing growth of annual grassy weeds; and considering species type, height and planting density when planning revegetation.
Understanding and protecting waterbirds	E2.1	Undertake a survey of waterbirds of the Lower Vasse River and identify important habitat zones, with strong involvement from the community.
	E2.2	Protect identified important bird habitat zones through revegetation and weed control, recognising the current role of weeds as habitat.
	E2.3	Create additional habitat zones for birds by placing large woody debris emerging from the water.
	E2.4	Avoid identified important bird habitat zones when planning future infrastructure, and consider nesting season when planning works.
Controlling invasive species	E3.1	Prevent of further spread of Mexican waterlily through herbicide control and/or shading.
	E3.2	Undertake strategic control of Mexican waterlily to progressively reclaim areas of open water, while minimising adverse impacts and preventing a return to algal blooms in these areas.
	E3.3	Undertake regular feral fish eradication activities in partnership with Murdoch University.
	E3.4	Undertake targeted control of arum lily and Brazilian pepper trees throughout the Lower Vasse River study area.
Optimising flows	WF1.1	Increase flushing of the river by installing a second 900mm culvert at outflow point from Vasse Diversion Drain, in accordance with recommendations from the Reconnecting Rivers Report (DWER 2018).
	WF1.2	Monitor impacts of increasing flows into the Lower Vasse River.
	WF1.3	Undertake intensive monitoring water quality in the Vasse Diversion to support operational guidelines for managing the culvert.
	WF1.4	Develop operational guidelines for the Vasse Diversion culvert that defines responsibilities and provides formal guidance for manipulation of the valve to maximise water quality benefits and minimise risk of flooding.
	WF1.5	Review function of the Butter Factory weir boards to inform their future use and need for replacement.
	WF1.6	Investigate potential for increasing internal circulation in the system during summer to reduce residence time for phytoplankton.
Sediment Removal	S1.1	Undertake a small-scale sediment removal project, using geotextile bags for dewatering and disposal, to assess cost and logistics of this approach.
	S1.2	Determine feasibility of disposal options for future sediment removal: landfill, composting, soil conditioner.
	S1.3	Depending on outcomes of small scale removal, undertake staged removal of sediments in the Lower Vasse River as a component of Living Streams design.
Improving facilities and information	ARE1.1	Review existing facilities and develop a concept plan for strategic pathways and viewing points that connect people with the river.
	ARE1.2	Update the interpretive signage around the river to provide information on of the history, ecology, hydrology and management of the Lower Vasse River.
	ARE1.3	Develop online and printed resources with interesting and important information on ecology, water quality, history and management of the Lower Vasse River.
	ARE1.4	Establish bird watching areas and hides in appropriate places with informational material.
	ARE1.5	Encourage opportunities for citizen science to contribute to understanding and appreciation of the Lower Vasse River.
Public health management	ARE2.1	Continue monitoring phytoplankton species and densities to inform public health notifications.

	ARE2.2	Review algal bloom warning sign protocol and prepare a communication program to inform the community when harmful algal blooms occur.
	ARE2.3	Develop a policy for use of recreational watercrafts in the Lower Vasse River, including consideration of public health constraints.
Recognising Wadandi custodianship	CH1.1	In partnership with Wadandi people, include reference to traditional custodianship of the waterways and land in development of information resources.
	CH1.2	Manage future access in a way that avoids additional disturbance and considers protection of potential sites of significance – however Wadandi activities such as fishing, camping, the gathering of bush foods and family recreational and educational activities, should not be restricted by implementation of this plan.
	CH1.3	Seek to improve partnerships with the Wadandi community to increase their involvement in the management, protection and restoration of the Lower Vasse River.
	CH1.4	Consult further with Wadandi representatives in regards to specific works which result from this plan.
	CH1.5	Support programs that engage the Wadandi community in implementation of works associated with this plan.
Preserving historical values	CH2.1	Identify and ensure appropriate maintenance of sites of historical importance.
	CH2.2	Develop interpretive material to increase understanding of local history, and to promote, appreciate and access historical sites.
Collaborative and adaptive management	G1.1	The City to consider securing management orders over the waterway and adjacent public lands in Lower Vasse River study area, to facilitate implementation of this plan.
	G1.1	Establish a Management Advisory Group comprised of representatives from the City, Department of Water and Environmental Regulation, Department of Biodiversity, Conservation and Attractions, Water Corporation, GeoCatch, Wadandi representatives, and other community representatives.
	G1.2	Continue water quality monitoring in the Lower Vasse River.
	G1.3	Ensure adequate monitoring and reporting of outcomes from management actions, and feedback results into future management actions.
	G1.4	Maintain and develop partnerships with research organisations to improve knowledge and management of the Lower Vasse River.
Optimising planning tools	G2.1	Improve clarity of planning approval requirements for changes to land use and new developments in the agricultural sector (e.g. horticulture, dairies, feedlots).
	G2.2	Assess future development proposals and changes of land-use on adjoining lands with consideration of impacts on the Lower Vasse River.
	G2.3	Include 50m wide foreshore reserves as part of future development adjacent to the river.

1 Introduction

The City of Busselton (the City) has developed this Water Management Plan (WMP) to recommend management actions that will lead to improved water quality and ecological health for the Lower Vasse River. The vision for the Lower Vasse River, developed for this Water Management Plan in partnership with the community and stakeholders, is:

> *The Lower Vasse River is an icon of Busselton, valued and enjoyed by the community, as a healthy waterway linking people and nature.*

1.1 Background to this Waterway Management Plan

The Lower Vasse River is a high profile waterway in Busselton, flowing through the entrance to the town centre, and is a strong part of local history. It has extremely poor water quality as a result of increased nutrient loads form the catchment and changes to hydrology. Seasonal blooms of harmful phytoplankton are a major concern for the community and management. The river has been greatly modified from its original state and ecological health has declined, however it remains an important freshwater habitat supporting aquatic fauna and waterbirds.

This WMP is part of Revitalising Geographe Waterways (RGW), a $15 million program encompassing 30 projects to improve water quality and ecosystem health in key water assets. Within the RGW program, the City was given responsibility to prepare WMPs for the Lower Vasse River and Toby Inlet. The Department of Biodiversity, Conservation and attractions was given responsibility to develop an Operational Plan for the Vasse-Wonnerup Wetlands system.

The RGW program is one of five focus areas of the Vasse Geographe Strategy, a State Government initiative to address water quality in the Geographe Bay catchment (Figure 1). The program also includes three projects directly related to the Lower Vasse River WMP: the Reconnecting Rivers hydrological modelling project; the stormwater upgrades project for Busselton; and water treatment trials in the Lower Vasse River.

The Vasse Geographe Strategy was initiated by an independent review of waterways management (Hart 2014), commissioned by the State Government in response to serious community concerns about water quality issues. The Vasse Geographe Strategy is overseen by the Vasse Taskforce, comprising representatives from:

- Department of Water and Environmental Regulation (DWER)
- City of Busselton (the City)
- Shire of Capel
- Geographe Catchment Council (GeoCatch)
- Department of Biodiversity, Conservation and Attractions (DBCA)
- Department of Primary Industries and Regional Development (DPIRD)
- Department of Planning, Land and Heritage (DPLH)
- South West Catchments Council (SWCC)
- Water Corporation (WCorp)
- Busselton Water (BW)

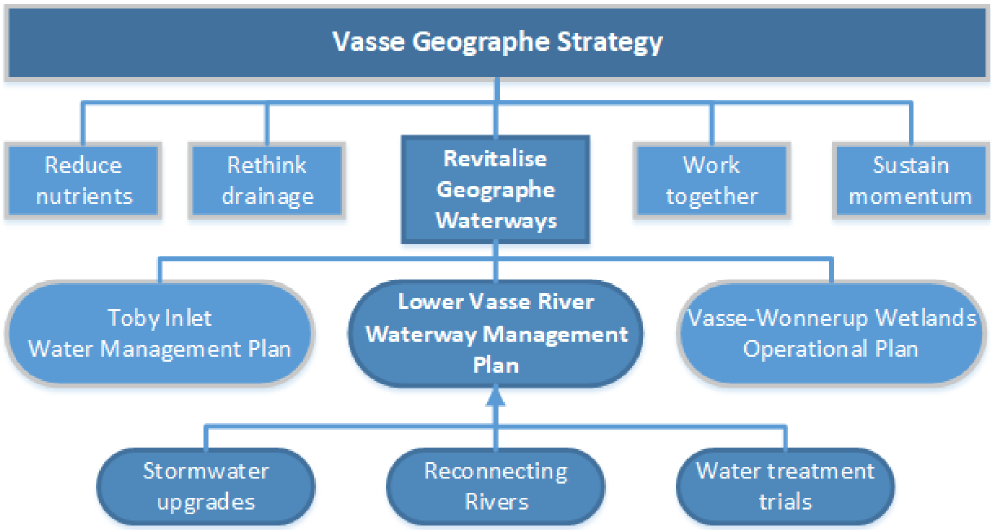


Figure 1. Framework for developing the Lower Vasse Waterway Management Plan.

1.2 Study area description

The study area includes the reach of the Vasse River approximately 5.5km in length, from the Vasse Diversion Drain to the weir boards at the Old Butter Factory, flowing through the centre of Busselton. The river discharges through a wetland area into the upper reach of the Vasse Estuary, which is part of the internationally significant Vasse-Wonnerup Wetland System. The study area includes the river itself and some adjacent areas of public land (Figure 1). Areas of water and unallocated crown land have no management responsibility designated, other areas are foreshore reserves managed by the City.

The lower section of the Vasse River is within Busselton's urban area, with a mix of residential and light industrial uses in the catchment. Upstream of the Busselton Bypass the surrounding land is agricultural, aside from the golf course. Upstream of the intersection with the Vasse Diversion, dairy and beef grazing are the dominant uses in the catchment and are intensifying.

The Vasse River catchment has ephemeral headwaters in the Whicher Scarp to the south, and lowland reaches crossing the Swan Coastal Plain. Extensive clearing and construction of the artificial drainage network during the early 1900s facilitated agricultural development across the Swan Coast Plain areas of the catchment. Native vegetation in these areas is very limited, and much of what remains is therefore of high conservation value. The upper parts of the catchment in the Whicher Scarp still retain substantial areas of remnant vegetation.

The Vasse Diversion diverts flow from approximately 90% of the Vasse River catchment to Geographe Bay. It was constructed in the early 1900s to provide flood protection for Busselton. Flow from this region of the catchment is restricted to a 900mmm pipe at the intersection, which may be open or closed by a manually-operated valve. This diversion drain physically separated the lower reach of the Vasse River, known as the Lower Vasse River, substantially changing the natural hydrological regime. At the downstream end of the study area the river is impounded by a weir, established in the early 1900s to maintain higher summer water levels through the town section for amenity and recreation purposes. Removable weir boards are installed at the end of winter and removed in autumn. The effect of flow diversion and impoundment is essentially an elongated “lake” area from late spring to late autumn. In recent years, the weir boards have become degraded and gradual leaking of water during summer leads to water levels defined by land to the east near Ford Road.

Owing to increased inputs of nutrients from catchment sources, and the still conditions created by impoundment, the Lower Vasse River is eutrophic. Extremely high nutrient concentrations, particularly phosphorus, and ideal physical conditions drive severe seasonal algal blooms for up to seven months from November to May. Algal blooms cause unsightly water discoloration and scums and unpleasant odours. These blooms are often dominated by blue-green algae (cyanobacteria) which are potentially toxic and close the waters to public use.

Despite seasonally poor water quality, the Lower Vasse River retains social and natural values. It provides permanent freshwater habitat and vegetated foreshore areas that support native fauna, including many waterbirds, native fish, oblong turtles, freshwater mussels and western ringtail possums. Many people in the community still enjoy the ecological characteristics amenity of the river.

The isolation of the Lower Vasse River by diversion and impoundment; the conditions of extremely poor water quality experienced; and the high profile location have led to the need for specific management of this area. This is the focus of this WMP.

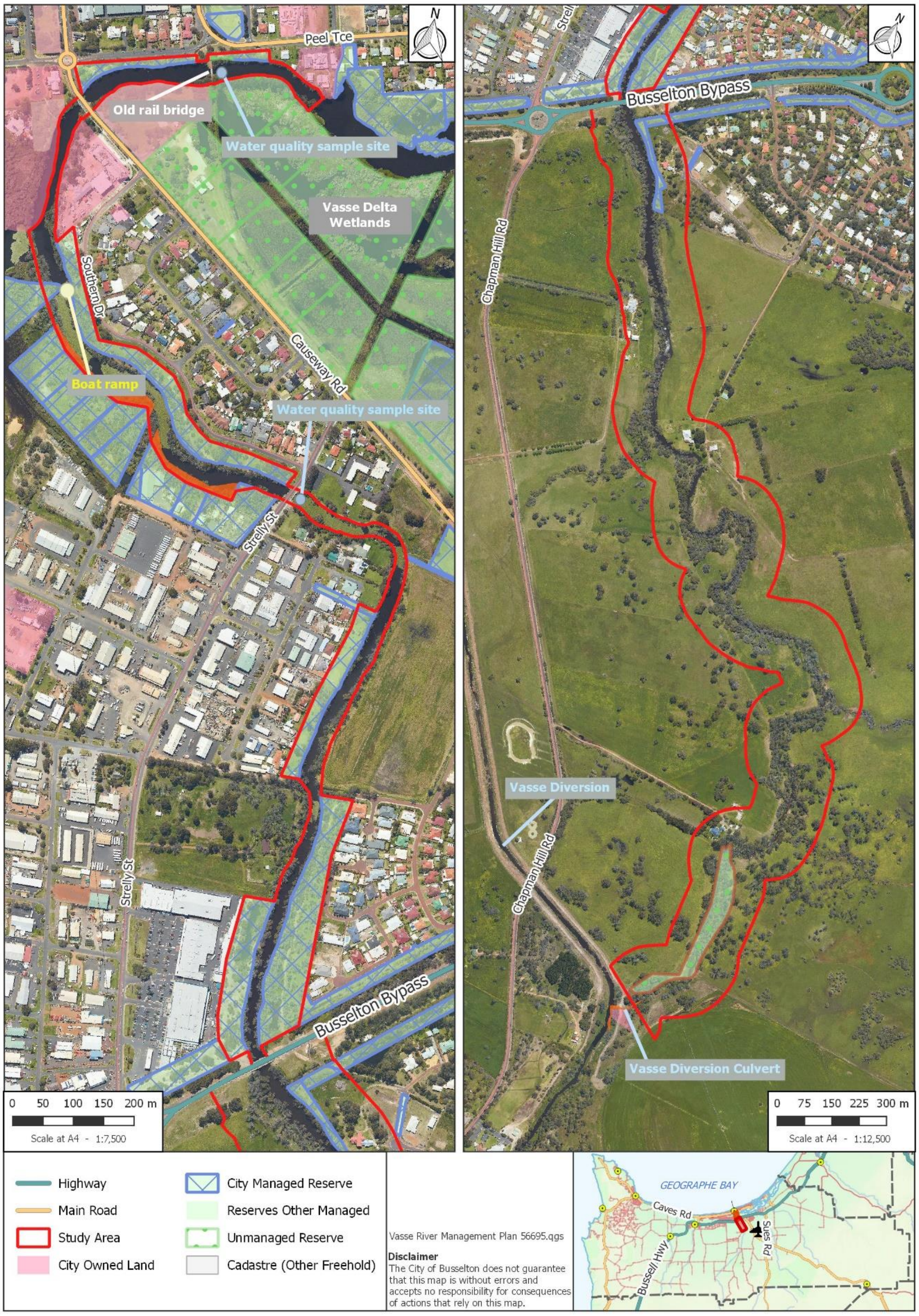


Figure 2. Study area for the Lower Vasse River Waterway Management Plan, showing tenure and landmarks.

1.3 History of management

Poor water quality in the Lower Vasse River has been a focus of management activities for at least two decades. The Lower Vasse River Cleanup Program (LVRCP) commenced in 1999, which implemented a range on-ground works and trials to improve the ecological health of the system (Paice 2005). Key components of the LVRCP were:

- sediment treatment and removal;
- restoring river ecology;
- rural catchment management; and
- urban catchment management.

These approaches had some success and have provided useful information for future work. The revegetation undertaken through this project has doubtless enhanced the ecological values of the river. However water quality remains extremely poor with severe algal blooms recurring each year during the warmer months. A review of the LVRCP recommended priority areas for action as:

- continued partnerships to assess appropriate sediment remediation options;
- maintenance of revegetated areas in terms of weed control;
- continued revegetation with emergent and submerged plants;
- formalise agreed management of water flows through the river to maximise flushing;
- management of the feral goldfish population;
- identifying and addressing point source problems in particular septic tank leachate; and
- ongoing monitoring and evaluation to measure progress towards long term objectives (Paice 2005).

Since the Lower Vasse River Cleanup program, managers have continued to implement nutrient reduction actions in the rural and urban catchments, including river restoration, implementation of best management practices and installation of stormwater treatments. There have also there have been small scale studies to assess potential for improving water quality using other measures such as enzyme treatments, floating islands and establishing aquatic plants.

The independent review of the waterways management (Hart 2014) highlighted the lack of an obvious lead agency. It made the distinction between long-term reduction of nutrients from the overall catchment, and short-term management of the impounded reach Lower Vasse River. It highlighted the need for an operational management plan for this section of the river that would address the dual objectives of achieving good water quality while also preventing flooding in Busselton.

1.4 Process for developing the Waterway Management Plan

The WMP has been developed using a collaborative approach that has allowed for extensive consultation to work towards future management of the Lower Vasse River that aligns with community priorities, is well-understood and accepted, and has significant commitment to implementation by stakeholders. Key stakeholders that contributed to this WMP are:

- City
- Community members
- Aboriginal People
- GeoCatch
- Department of Water and Environmental Regulation
- Department of Biodiversity, Conservation and Attractions
- Water Corporation

The process for developing the WMP is shown in Figure 3. The consultation process has contributed directly to the management issues, vision, management objectives, management strategies and actions for the WMP. Activities undertaken for consultation are outlined in the following sections. The consultation process and the overall WMP have been informed by review of existing information about the Lower Vasse River and new information gained through projects undertaken during the planning process. It is important to note the adaptive nature of this WMP. It has been prepared at a point in time, using the information currently available. Implementation will require an ongoing process of monitoring and evaluation to determine future actions.

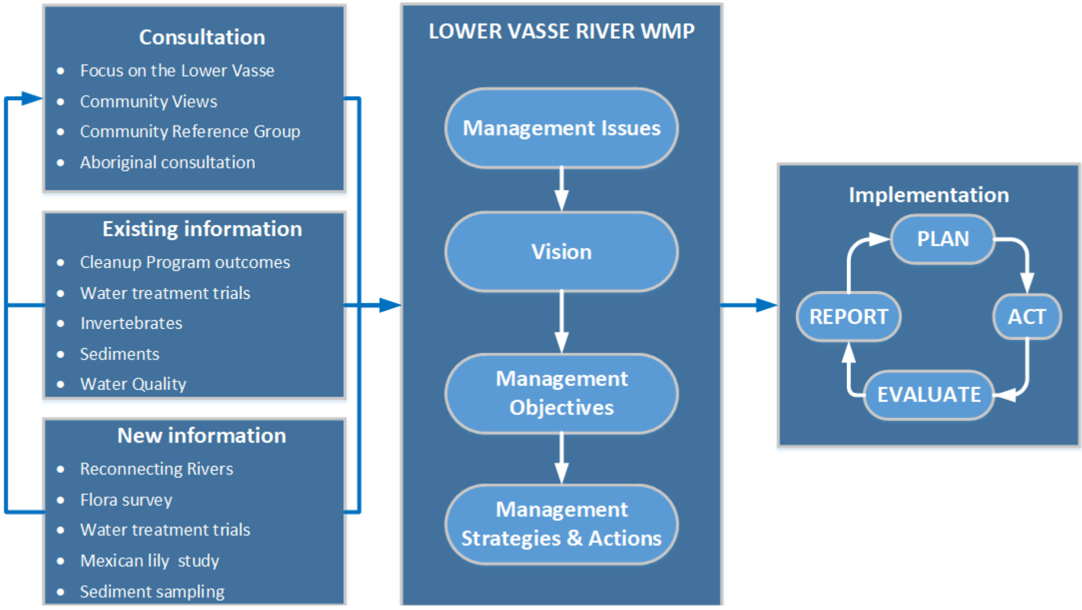


Figure 3. Process for developing the Lower Vasse River Waterway Management Plan

1.4.1 Community consultation

Consultation with stakeholders was an integral part of preparing this WMP. The aims of consultation were:

- To understand community issues and concerns on the Lower Vasse River;
- Gain input, ideas, feedback into future management of the Lower Vasse River;
- To get support from the community on proposed actions; and
- To raise community awareness and understanding of local water quality issues.

Early consultation events were widely advertised to attract a broad representation from the community. The first of these, *Focus on the Lower Vasse* in June 2015, provided current information and sought to identify issues of most importance to the community. The *Community Views* event in March 2016 was also open to whole community and facilitated rating of management issues valued characteristics and desired change (Figure 4; AHA 2016). These results reflected a high level of importance on issues related to the health of the Lower Vasse River and associated amenity (82%). Other issues rated as important were recreation and access, heritage, flood and management. The outcomes of this consultation were used to formally identify key management issues, as outlined in Section 2 of the WMP. Information provided by the community regarding their understanding of the system and suggested management actions were used to develop draft management objectives, and were considered when reviewing management options.

Following initial consultation, the Lower Vasse River Community Reference Group (CRG) was formed to provide ongoing input to WMP. This group was formed by inviting participants of earlier events to nominate for ongoing involvement. It also included representation from the Department of Water and Environmental Regulation and GeoCatch, as key supporting partners in development of the WMP. Facilitated workshops with this group were held to develop the vision, management objectives (AHA 2017a, 2017b) and management strategies and actions (AHA 2018) for the WMP.

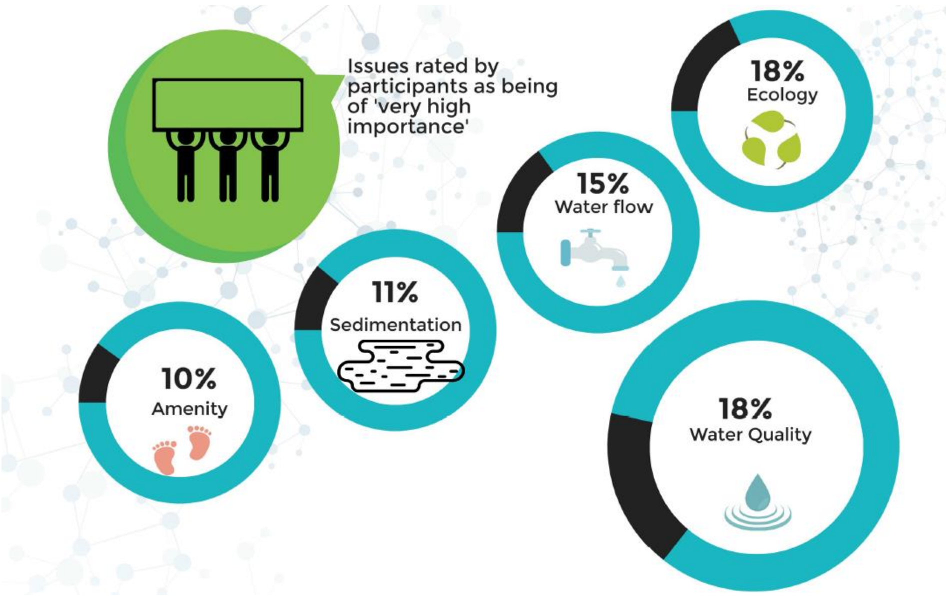


Figure 4. Outcomes of identifying and rating management issues for the Lower Vasse River from the *Community Views* consultation session, March 2016.

1.4.2 Aboriginal consultation

In recognition of Aboriginal (Wadandi) people as the traditional custodians of country, and understanding the significance of waterways to Aboriginal people, additional consultation was undertaken with the South West Boojarah (SWB) and Harris Family native title claim groups to allow their input to the WMP.

The study area is within the South West Boojarah Indigenous Land Use Agreement area which is one of six Agreement areas that form part of the South West Native Title Settlement Area[1].

Presentations were given to the South West Boojarah (SWB) Working Party and subsequent during an Aboriginal heritage survey. An overview of the RGW program and the draft management objectives were presented to the SWB Working Party.

An aboriginal heritage survey was undertaken with representatives of the SWB and the Harris family native title groups in February 2018, encompassing the study areas of the Lower Vasse River and Toby Inlet water management plans and the Vasse Wonnerup Operation Plan. The survey was facilitated by Brad Goode and Associates (BGA) and included briefings and a bus tour of key sites for discussion of scientific investigations, future management actions and the content of the plans (BGA 2018). On-site discussions were held on key potential management actions including sediment removal, water treatment, reshaping and revegetation, Mexican waterlily control.

The representatives highlighted the importance of connectivity of waterways in the landscape from both spiritual and ecological perspectives. They highlighted the importance of managing the headwaters of the river to address the real cause of poor health in the lower reach, relating problems in the Lower Vasse to disruption of connectivity with its catchment. They also acknowledged that it is not practical to return the river’s hydrology to its natural state. The group supported specific works to address sediment and water quality problems, including sediment removal and waterlily control. Information from this consultation has been considered in the development of management strategies and actions in this WMP.

[1] Current information on the South West Native Title Settlement: http://www.noongar.org.au

2 Management Issues

Through the consultation process, management issues were grouped into the following eight key focus area for management:

1. Water quality
2. Ecology
3. Water flow
4. Sedimentation
5. Amenity
6. Recreation and Education
7. Heritage
8. Governance

The most important issues for management the Lower Vasse River as rated through community consultation are water quality, ecology, water flow, and sedimentation. These are key river health issues, which are interconnected and fundamental to ongoing management of the river.

Management strategies which provide outcomes for river health will contribute directly to social issues by improving amenity and increasing opportunities for recreation and education. In turn, facilities to provide for these activities will allow for promotion of cultural heritage values. Governance relates to policy and management responsibilities, which will underlie the implementation of strategies to improve river health.

A summary of key management issues and available information for these focus areas is provided in this section.

2.1 Water quality

2.1.1 Nutrients and algal blooms

The Lower Vasse River is a eutrophic waterway, with very high nutrient concentrations resulting in extremely high densities of phytoplankton (microscopic algae), commonly referred to as algal blooms. These algal blooms persist for up to seven months each year, generally between December and May, resulting in discoloured water, unsightly scums and unpleasant odours. The blooms are dominated by blue-green algae (cyanobacteria), which are potentially toxic to animals and humans (Figure 5). Not surprisingly, water quality is the most significant management issue for the Lower Vasse River.

It is interesting to note that “thick algae” was observed in the river in 1940 (Mouritz, Elphick and Anderson).

Nitrogen and phosphorus are the main nutrients contributing to eutrophication. Nutrients have been regularly sampled by DWER at two sites in the Lower Vasse River (Figure 2):

i. Strelly Street Bridge from 1996 – 2010, and since January 2017 (excluding winter since 2000);
ii. Old rail bridge from 1996 – 2010.

Total nitrogen (TN) concentrations have often exceeded ecosystem protection guidelines in the past (Figure 6a). However, sampling in recent years has lower TN concentrations, particularly at the Strelly Street site. Monthly data for the old rail bridge site shows high TN in winter and a gradual decrease during spring, followed by an increase to very high levels in summer (Figure 6b). Peak TN in summer corresponds to peak algal growth (Figure 6e), and is likely related to the ability of blue-green algae to fix nitrogen from the atmosphere. Very little nitrogen is present in dissolved available forms, which limits the amount available for growth or other types of algae.

Total phosphorus (TP) concentrations in the lower Vasse River are extremely high with annual and monthly means consistently exceeding ecosystem protection guidelines, often by an order of magnitude (Figure 6c, d). Phosphorus concentrations show a seasonal increase from spring to summer and then remain high (Figure 6d). Unlike nitrogen, the phosphorus concentrations are higher at the Strelly St Bridge site upstream, where algal blooms have been less severe in recent years (Figure 6e). This is unusual, as phosphorus is known to promote algal growth. Dissolved phosphorus is consistently high at the Strelly Street site, accounting for an average 48% of TP. At the old rail bridge site, dissolved phosphorus accounts for an average 17% of TP, and decreases over the duration of the season. Dissolved oxygen concentrations are much lower at the Strelly Street site than downstream and this may be linked to higher phosphorus concentrations, as phosphorus is released from sediments under low oxygen conditions.

Chlorophyll a is an indicator of phytoplankton growth, and very high concentrations throughout the river until 2010 reflect seasonal algal blooms. Chlorophyll a has been much lower at the Strelly St Bridge site since sampling recommenced in the 2016-17 season (Figure 6e). It has remained high at the old rail bridge in recent years, showing a seasonal increase in correspondence to increasing algal growth in the summer (Figure 6f). This is also reflected in monitoring of phytoplankton cell densities and species (Figure 8), which shows continuing dominance by blue-green algal blooms at the old rail bridge; but a substantial reduction at Strelly Street. There has been a shift at the Strelly St site to harmless species of green algae, with occasional 'bloom' densities. Lower phytoplankton growth at the Strelly Street site is no doubt due to the recent presence of Mexican waterlily at this site. The waterlily prevents light entering the water column, preventing algal growth. However, as discussed in Section 2.2.3, Mexican waterlily appears to reduce algal growth more broadly.

2.1.2 Nutrient sources

Nutrients in the Lower Vasse River come from surface runoff and groundwater infiltration; and are also released into the water column from the sediment (0). Nutrient sources include residential, commercial, industrial and rural sources in its local catchment area (downstream of the Vasse Diversion), as well as some flows from the Vasse Diversion. In addition to ongoing inputs to the river, nutrients accumulate in the sediments from the ongoing cycle of algal growth and decay, providing an internal source of nutrients (2.4).

Water quality analysis and modelling for the Water Quality Improvement Plan (WQIP) estimated that septic systems in the Busselton light industrial area (LIA) contribute 0.45 tonnes (9.4%) of phosphorus 1.3 tonnes of nitrogen 3.7% to the river annually (DoW 2010). This modelling also predicted that urban expansions in the catchment could result in a 41% increase in phosphorus load and a 23% increase in nitrogen load. Importantly, the WQIP also identified one feedlot as being the largest contributor of phosphorus in the Lower Vasse River catchment (since converted to irrigated horticulture, and likely to remain a significant phosphorus source). Dairy sheds also contribute a significant proportion of nutrients from broader agricultural areas.

Nutrient concentrations in the Vasse Diversion vary widely from acceptable to extremely high, with mean annual concentrations since 2008 of 1.6-2.4 mg/L for TN and 0.03-0.23 mg/L for TP. Nutrient inputs to the Vasse River depend on the operation of the culvert valve connection to allow water to flow through the 900mm pipe at the upper end of the river (Section 2.3). Opening of the valve connection is not formally managed and flows are not formally recorded. There may be potential to optimise management of the valve connection to reduce flows when nutrient levels are high. Community perception is that water flow from the Vasse Diversion to the Lower Vasse River should be maximised to improve water quality by flushing the river.

2.1.3 Downstream impacts

In addition to problems associated with nutrient enrichment within the river itself, high loads of nutrients flowing through the river influence the wetlands and the Vasse Estuary downstream. The WQIP reports that the Lower Vasse River contributes very high nutrient loads to downstream waters relative to its catchment size (DoW 2010); and recommends long-term load reductions of 67% for phosphorus and 70% for nitrogen to meet acceptable loadings for the Vasse-Wonnerup Wetlands. Management actions for the Lower Vasse River need to consider downstream impacts. For example, increasing flows from the Vasse Diversion to the Lower Vasse River would increase nutrient loads from this source to the Vasse Estuary (Section 4.8).

Figure 5. Blue green algal bloom in the Lower Vasse River.

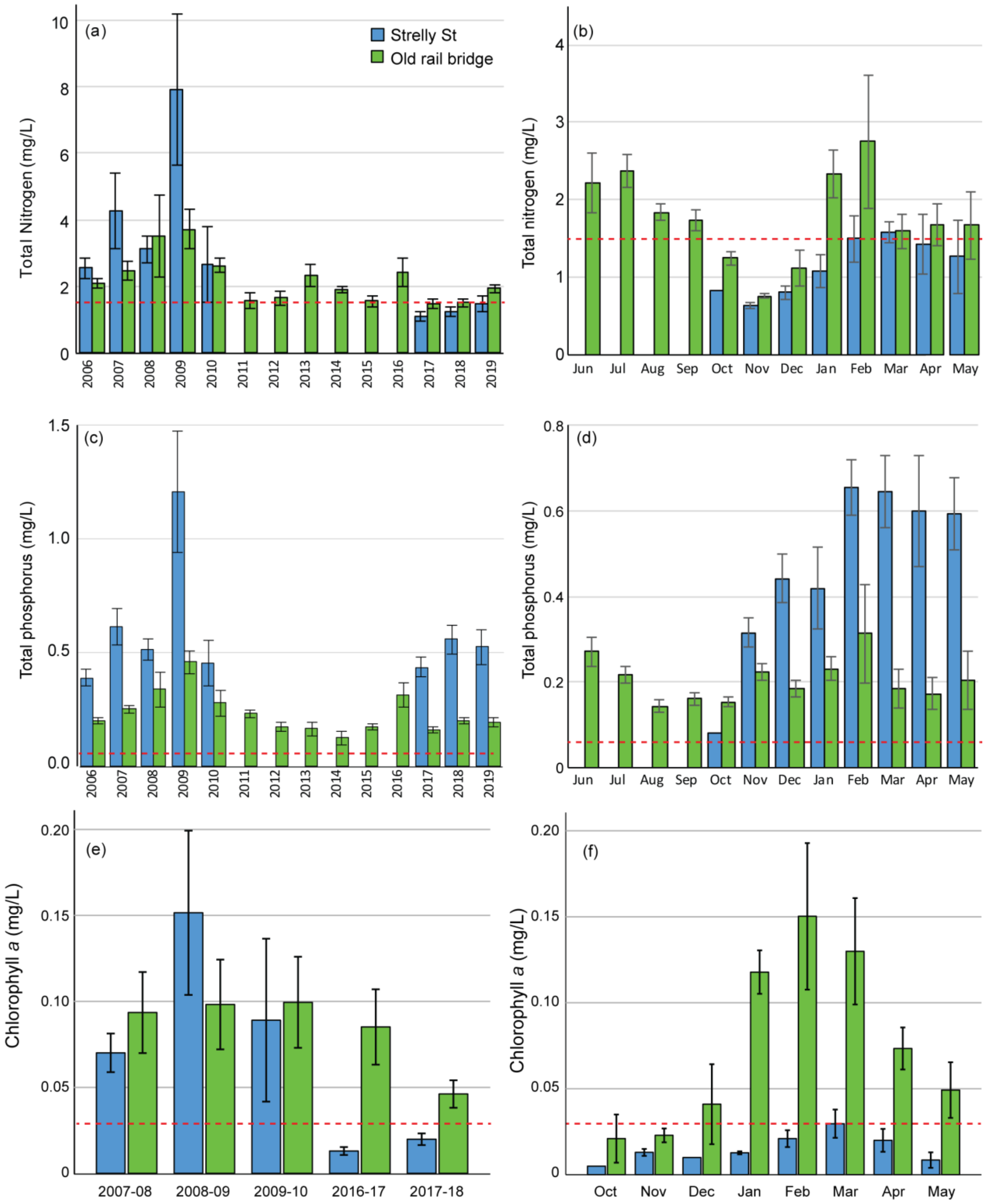


Figure 6. Mean annual and monthly concentrations of total nitrogen (a, b) and total phosphorus (c, d); and mean chlorophyll a across annual spring-summer-autumn sampling seasons (e) and for each month (f). Red dashed lines are guidelines for protection of wetland ecosystems (ANZECC and ARMCANZ 2000). Monthly nutrient data from 2011-2018; monthly chlorophyll *a* data since 2017 (DWER 2018a). Error bars are +/- standard error.

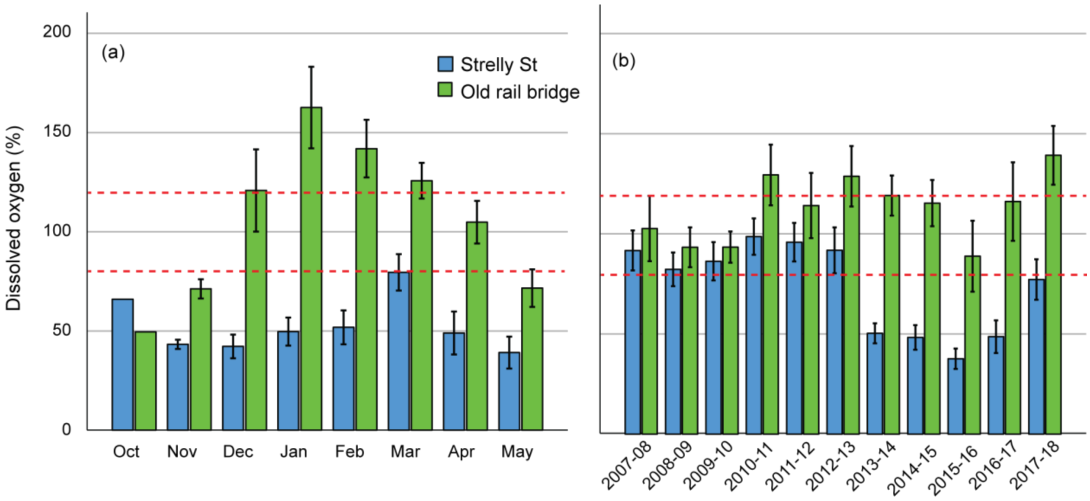


Figure 7. Dissolved oxygen concentrations in the Lower Vasse River: average monthly means for 2016-2018 centred around summer (a); and annual means since 2007-08 (spring-autumn sampling) (DWER 2018a).

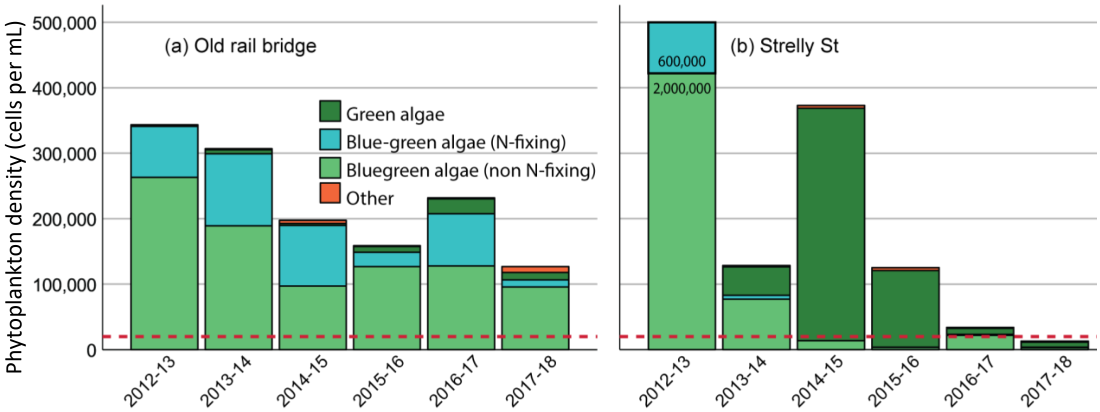


Figure 8. Mean cell densities for main phytoplankton species groups at sampling sites in the Lower Vasse River during spring-summer-autumn seasons since 2012 (DWER 2018b). Red dashed line is the guideline value of 20,000 cells per millilitre for recreational use.

2.2 Ecology

The Lower Vasse River has undergone substantial physical changes through widening and de-snagging, and clearing of surrounding vegetation. This includes a “clean out” by the Public Works Department around 1939 using a dragline. It has also been impacted by altered hydrology and nutrient enrichment. These changes have dramatically affected the river’s ecology. Aboriginal people have stories of fishing and hunting along the Vasse River when water quality was better. However it now has little in-stream habitat and the dominance of phytoplankton during the warmer months supports limited diversity.

Although degraded, it still provides habitat for native freshwater fish, frogs, turtles and invertebrates, and open water areas for waterbirds. The riparian vegetation contributes to aquatic habitats and also supports a range of terrestrial fauna and birds. The permanent fresh waters of the Lower Vasse River provide a unique habitat in a landscape of seasonal wetlands and estuaries.

Ecology was rated as the most important management issue by 18% of *Community Views* participants (AHA 2016). The river environment contributes to local amenity and the birdlife is particularly enjoyed. The study area has been identified as a regional ecological linkage (Molloy et al. 2009, Ecoedge 2017). A summary of the main ecological components of the Lower Vasse River study area and implications for management is provided below.

2.2.1 Vegetation

Native fringing (riparian) vegetation of the Lower Vasse River has been largely cleared, leaving a narrow strip of remnant trees with limited understorey and extensive weed invasion. There are opportunities to enhance vegetation in the study area through weed control and revegetation.

Vegetation along the river provides important habitat for terrestrial fauna, with overhanging trees offering many roosting and nesting sites for waterbirds. In addition to providing habitat benefits, fringing vegetation is a vital component of river health. The important functions include:

- supporting terrestrial and aquatic food webs;
- habitat for terrestrial and aquatic fauna;
- foreshore stabilisation;
- maintaining cooler temperatures
- interception of nutrients and sediments in runoff; and
- nutrient uptake and processing.

The extent and diversity has been increased downstream of the Busselton bypass by revegetation work done for the Lower Vasse River Cleanup program and in new foreshore reserves adjacent to subdivided land. A vegetation survey in the study area in 2017 found only 5.6% of vegetation in good condition, occurring mainly within these revegetated areas (Ecoedge 2017).

The current vegetation includes only 28 native species, including some species in revegetated areas that would not have occurred there naturally. The Ecoedge (2017) survey found no occurrences of threatened or priority flora, although there are nearby occurrences of the Coastal Saltmarsh threatened ecological community (TEC); and the *Eucalyptus rudis*, Marri and Peppermint forest ecological community (Priority 1).

At least 20 species of weeds are present, including 10 of environmental concern, which are mapped in the Ecoedge (2017) survey report. The most widespread problem weeds are Arum Lily, Brazilian pepper tree and Kikuyu (Ecoedge 2017). Kikuyu and other grassy weeds form an extensive component of the understory in much of the study area. Less widespread but potentially invasive weeds include Blue periwinkle, Weeping willow and Watsonia. Within the waterway, Mexican waterlily has infested large areas.

2.2.2 Fire Risk

Management of vegetation needs to address current and future risk of fire, particularly in areas close to buildings and infrastructure. A Bushfire Attack Level assessment can be used to determine suitable setbacks (Calibre 2018). Adequate setbacks to sensitive infrastructures, strategic gaps between vegetated areas limiting width of vegetation can be used to reduce fire risk where required. Selection of species for revegetation that have lower flammability and maintaining moisture content through irrigation can also mitigate risk (Calibre 2018).

2.2.3 Mexican waterlily

Mexican waterlily (*Nymphaea Mexicana*) covers large areas of the Lower Vasse River (Figure 9a,b). Although present in small patches in the river for several years, it underwent rapid expansion during the 2013-2014 spring-summer growing season and has continued to spread gradually since then. In 2017 it covered 23% and 1.15 hectares of water between the Busselton Bypass and the Butter Factory weir.

This is a serious concern for the community and management authorities owing to impacts on visual amenity, loss of open water habitat and possible flow obstruction. Overhanging fringing vegetation supports many roosting and nesting sites for birds. Growth of lilies beneath these sites prevents diving from these platforms and creates a risk for fledglings that may get trapped in the lilies beneath nests. Loss of open waters reduces space for birds to swim and dive and reduces available habitat for fish and turtles.

A study on the impacts of Mexican waterlily in the Lower Vasse River in 2017 investigated the effects of these plants on water quality and ecology (Paice 2018). In addition to the obvious problem of loss of open waters, the lilies result in very low oxygen levels in the water (Figure 10a), presenting a risk for aquatic fauna. Despite this, the structural habitat provided by the lilies supports greater abundance and diversity of aquatic invertebrates than other parts of the river. However this invertebrate population does include large numbers of non-biting midge larvae, which can contribute to nuisance insect problems.

The extensive root mass of the lilies and ongoing growth and decay contributes to a build-up of organic material, creating shallower conditions. This has allowed additional colonisation of semi aquatic plants. Currently, this has been seen the native (though prolific) Slender knotweed, *Persicaria decipiens*), but there is a risk of colonisation by wetland weeds. The reduced depth is now evident upstream of Strelly Street where waterlilies have died back from herbicide use.

Mexican waterlily has also had an effect on nutrient levels and growth of phytoplankton. Since the period of expansion in 2013-14, algal blooms have been greatly reduced in waters upstream of the point of infestation (near the boat ramp area along Southern Drive) (Figure 9c, d, Figure 10c). This is despite very high phosphorus concentrations in these areas; much higher than downstream Figure 10b). The reasons for reduced algal blooms between patches of waterlily are not fully understood. It may be a combination of greater low residence time in sunlit areas owing to lilies and riparian shading; nitrogen limitation; or chemical inhibition.

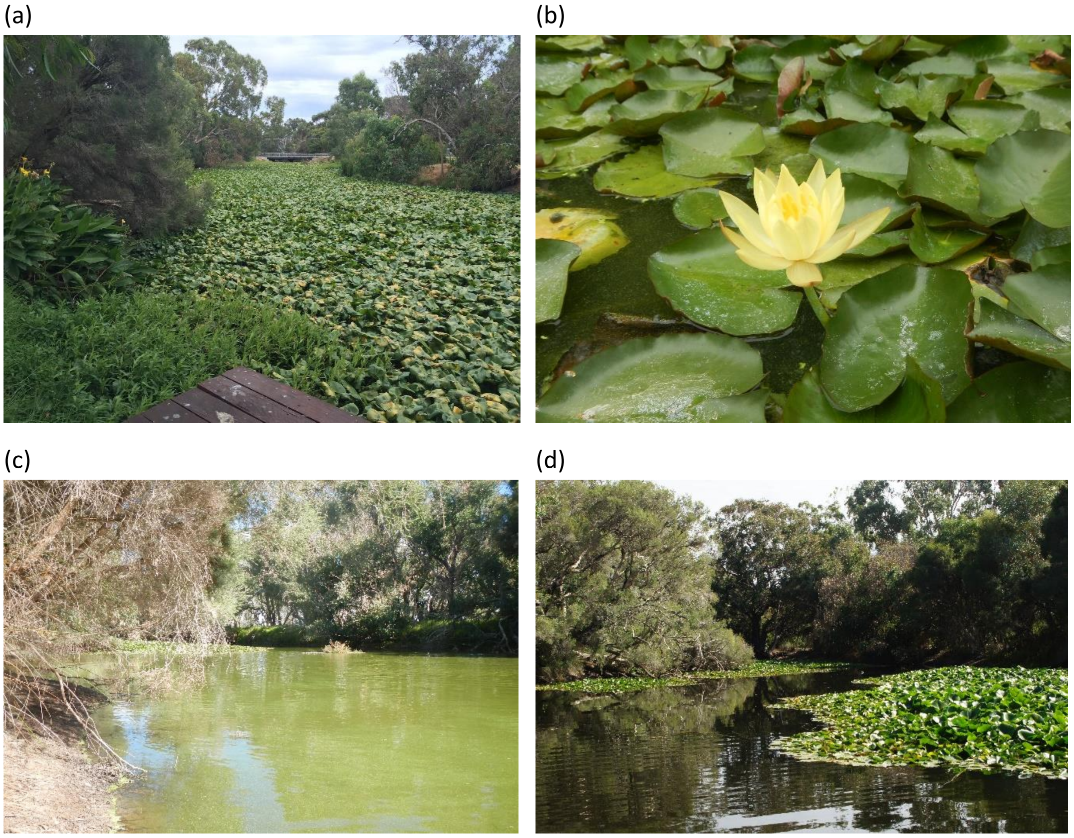


Figure 9. Mexican waterlily in the Lower Vasse River: (a) extensive growth upstream of Strelly Street in March 2017; (b) flower; (c) downstream of infestation in April 2014 showing obvious algal bloom; (d) upstream of infestation in April 2014 (same day) with no algal bloom.

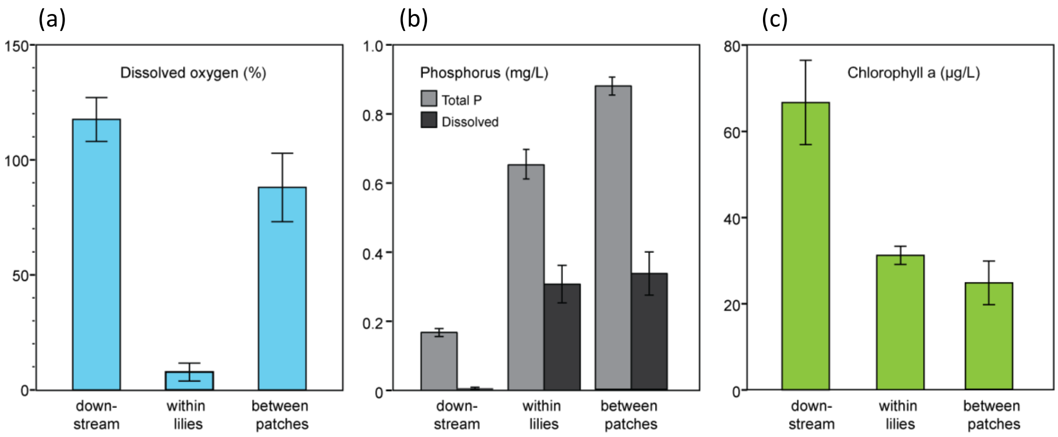


Figure 10. Comparison of water quality in relation to Mexican waterlily in the Lower Vasse River: downstream of the waterlily infestation, within dense waterlily growth, and in areas of open water between patches of waterlily (200-300m reaches) (Paice 2018).

2.2.4 Birds

The birdlife in and around the Lower Vasse River was rated by the community as the most liked characteristic (AHA 2016). Protecting and enhancing habitat for birds and providing opportunities for enjoyment of birdlife should be part of future management.

Table 1 provides a list of bird records available for the Lower Vasse River. There are probably more than this, however limited data is available. There is little formal published information about the birdlife of the Lower Vasse River, and there is scope to improve understanding and to share knowledge. Fostering existing community efforts in birdwatching to capture data would be a good step towards achieving this.

Remnant fringing rushes and overhanging trees provide important nesting and roosting sites. Secluded sections of the river and the southern bank adjacent to Southern Drive support some very dense nesting areas for cormorants, darters, Night heron and Yellow-billed spoonbills. In addition to the areas of remnant native rushes, grassy weeds also provide habitat for birds on the banks of the river, and this should be considered when undertaking weed control.

Threats to birds of the Lower Vasse River include predation by dogs, cats (domestic and feral) and foxes; degradation of vegetation through declining tree health, weed invasion and clearing; and loss of open water habitat by expansion of Mexican waterlily.

Table 1. Bird species recorded in the Lower Vasse River (Birdlife Australia 2018, Birdlife Western Australia 2017; Paice et al. 2016).

Common Name	Scientific Name
Australasian grebe	*Tachybaptus novaehollandiae*
Australasian shoveler	*Anas rhynchotis*
Australian pelican	*Pelecanus conspicillatus*
Australian reed-warbler	*Acrocephalus australis*
Australian spotted crake	*Porzana fluminea*
Australian white ibis	*Threskiornis molucca*
Australian wood duck	*Chenonetta jubata*
Black swan	*Cygnus atratus*
Black-fronted dotterel	*Elseyornis melanops*
Black-winged stilt	*Himantopus himantopus*
Blue-billed duck	*Oxyura australis*
Buff-banded rail	*Gallirallus philippensis*
Darter	*Anhinga melanogaster*
Dusky moorhen	*Gallinula tenebrosa*
Eastern great egret	*Ardea alba modesta*
Eurasian coot	*Fulica atra*
Great egret	*Egretta garzetta*
Grey teal	*Anas gracilis*
Hoary-headed grebe	*Poliocephalus poliocephalus*
Little black cormorant	*Phalacrocorax sulcirostris*
Little grassbird	*Megalurus gramineus*
Little pied cormorant	*Phalacrocorax melanoleucos*
Musk duck	*Biziura lobata*
Nankeen night heron	*Nycticorax caledonicus*
Pacific black duck	*Anas superciliosa*
Purple swamphen	*Porphyrio porphyrio*
Spotless crake	*Porzana tabuensis*
White-faced heron	*Egretta novaehollandiae*
Yellow-billed spoonbill	*Platalea flavipes*

2.2.5 Aquatic fauna

The key management issue for aquatic fauna is degraded habitat, in terms of limited structural habitat and poor water quality. Although a range of aquatic fauna occur in the Lower Vasse River, the degraded conditions no doubt limit the populations it can support. While management should therefore focus on enhancing habitat and reducing threats, such actions may have short term impacts on existing individuals. Nevertheless the Lower Vasse River has been found to have high ecological value worthy of protection, including a fish and crayfish community dominated by native species and with evidence of successful recruitment (DWER 2019).

Fish

Eight native fish species have been recorded in the Lower Vasse River during a fish survey in 2003-2004 and during subsequent goldfish control work: four freshwater species and four estuarine species (Table 2). These species have been heavily impacted by alteration and loss of habitat in the south west region, requiring structural habitat and refuge in permanent freshwaters. These species are generally only found in low numbers in the Lower Vasse River; although higher numbers of the Western pygmy perch and the occurrence of the Mud minnow (listed as vulnerable under Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017) at a site just downstream of the Vasse Diversion outflow suggest better habitat there (Morgan and Beatty 2004). The estuarine Western hardyhead was most abundant downstream of the Butter Factory weir and the survey reported that this structure may impede migration of native fish (Beatty *et al*. 2011).

Two introduced fish species are widespread in the Lower Vasse River: mosquitofish and goldfish. Mosquitofish are small and commonly seen in very large numbers in the river. Significant numbers of large goldfish occur in the Lower Vasse River. They have been noted as being common in the river near town in 1956; and trout were released in the river in 1957 (Mouritz, Elphick and Anderson), but have not been reported since then.

The presence of goldfish is an important issue owing to their contribution to poor water quality and algal blooms. Their benthic foraging disturbs nutrient-rich sediments and there is evidence that growth of blue-green algae is stimulated following ingestion and passage through goldfish (Kolmakov and Gladyshev 2003). A program of annual removal from 2003 to 2013 removed 842 goldfish, some exceeding 40cm in length, from the Vasse River (Beatty et al 2014).

Other aquatic fauna

Southwestern snake-neck turtles (*Chelodina oblonga*, Oblong turtles, Western long-necked turtle) are regularly observed in the Lower Vasse River, although they have not been specifically studied. There is no published information about frogs in the study area. Decapods recorded in the study area are the endemic Gilgie (*Cherax quinquecarinatus*) and the introduced Yabbie (*Cherax destructor*) (Beatty *et al*. 2011).

Carter's freshwater mussel (*Westralunio carterii*) is common in the Lower Vasse River, showing a preference for structured benthic habitats such as bridges (Beatty et al. 2017). It is listed as vulnerable fauna (Schedule 3 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017; IUCN Red List).

Aquatic invertebrates are commonly used as indicators of ecological health. The open waters of the river contain little structural habitat and supports very low diversity of invertebrates, dominated by zooplankton (mostly copepods) and highly mobile predators (of zooplankton) such as backswimmers (Notonectidae) and water boatmen (Corixidae) (Paice et al. 2016). The presence of aquatic plants and waterlilies greatly increases diversity and abundance of aquatic invertebrates in the river, owing to increased structural habitat and alternative food sources. In the case of waterlilies, this included mainly robust species tolerant of poor water quality and low oxygen conditions (Paice et al. 2016). However, growth of submerged plants (as transplants) has been shown to support significantly higher abundance and diversity across a range of functional groups (Paice 2018).

2.2.6 Other fauna

A range of other fauna are known to occur in remnant vegetation in the study area, but have not been formally surveyed. Importantly this includes the Western ringtail possum (Ngwayir, *Pseudocheirus occidentalis*), which is listed as critically endangered fauna (Schedule 1 of the Wildlife Conservation (Specially Protected Fauna) Notice 2017). Grey kangaroos are common in some parts of the study area and adjacent land and the river may provide a corridor for their movement within and increasingly developed landscape. Water rats (Rakali, *Hydromys chrysogaster*) have been anecdotally observed but are not common.

Table 2. Fish in the Lower Vasse River (Morgan and Beatty 2004, Beatty et al. 2011)

Type / Common name	Species	Notes
Native freshwater fish		
Western pygmy perch	*Edelia vittata*	Widely distributed, low numbers
Western minnow	*Galaxias occidentalis*	Few sites, low numbers
Nightfish	*Bostockia porosa*	Few sites, low numbers
Mud minnow	*Galaxiella munda*	Headwater site only, vulnerable
Native estuarine species		
Western hardyhead	*Leptatherina wallacei*	Downstream sites
Swan River goby	*Pseudogobius olorum*	Widely distributed
Sea Mullet		Downstream, low numbers
Black bream	*Acanthopagrus butcheri*	One fish
Introduced fish		
Goldfish	*Carassius auratus*	Widely distributed,
Mosquitofish	*Gambusia holbrooki*	Widely distributed, large numbers

2.3 Water flow

There have been substantial changes to the hydrology of the Lower Vasse River and its catchment. The coastal plain area of the catchment has been modified by a drainage network constructed during the 1920s to facilitate settlement, transport infrastructure and agricultural development (English 1994). This involved widening, straightening and de-snagging of water courses, and construction of artificial channels. Approximately 90% of catchment flows are diverted via the Vasse Diversion Drain, creating a distinct separation of the section known as the Lower Vasse River. Water flow to the Lower Vasse River from the Vasse Diversion is controlled by a manually operated valve on a 900mm pipe.

At the downstream end of the study area the river is impounded by a weir, established around the 1920s to maintain higher summer water levels through the town section for amenity and recreation purposes. Removable weir boards are usually installed at the end of winter and removed in autumn. In recent years, the weir boards have become degraded and gradual leaking of water during summer leads to water levels defined by land to the east near Ford Road.

The Lower Vasse River flows via a wetland area known as the Vasse River Delta into the Vasse Estuary. A surge barrier on the Vasse Estuary exit channel, first constructed in 1908, allows outflow of water but prevents inflow of tidal and storm surge waters. This provides flood protection but has reduced tidal exchange throughout the estuary and the lower reaches of the river.

The modified water flow regime of the Lower Vasse River contributes to poor water quality. The effect of flow diversion and impoundment is essentially an elongated “lake” area from late spring to late autumn. Reduced flow velocity contributes to accumulation of nutrients and organic material from the catchment, and the still conditions during summer promote algal blooms. Recurring algal blooms contribute to the build-up of nutrients in sediments, creating an internal source of nutrients.

There is a perception in the community that increasing flows from the Vasse Diversion and removal of the Butter Factory weir boards will create a flushing effect that will improve water quality and mobilise the accumulated sediments. Management of these structures has been restricted by limited understanding of the outcomes and constraints of this approach; and a lack of defined management responsibilities for operation.

(a) (b)

Figure 11. Flow management structures for the Lower Vasse River: (a) the valve controlling flow from the Vasse Diversion to the Lower Vasse River via a 900mm pipe; (b) the weir and removable boards at the Butter Factory.

2.4 Sediments

Sediments

The Lower Vasse River has, over several decades, accumulated a layer of nutrient rich organic sediments, generally about 0.5m thick but up to 1m in some parts (Apex 2012). Sediments accumulate from inputs of organic material from the catchment and from ongoing growth and decay of phytoplankton cells within algal blooms. Low oxygen levels and resuspension of sediments when disturbed releases nutrients to the water column over summer, contributing to algal blooms. Sediments are therefore are a key consideration in addressing water quality problems in the Lower Vasse.

There is a perception by the community that the soft organic sediments in the Lower Vasse River contribute to poor water quality, and general support for sediment removal. However there are many constraints to this management option relating to the pollution content of sediments and potential for acidification; and the high costs associated with removal and disposal. Sediment removal is discussed further in Section 4.11.

The presence of soft organic sediments impacts ecology in other ways. They provide a poor substratum for growth of beneficial aquatic plants, and poor habitat for benthic invertebrates other than worms and midge larvae. This limits biodiversity within the river system and contributes to the dominance of phytoplankton in primary production. Sediment accumulation has reduced the depth of the river over time, filling in deeper habitats and contributing to warm conditions that favour algal growth.

The bathymetry of the river (Figure 12) shows the gradual increase in depth moving downstream. There are two areas that are notably deeper: downstream of the Causeway Road bridge and downstream of the Butter factory weir. This suggests scouring of sediments downstream of these constrictions, which may indicate some potential for controlling sediment using flow regimes.

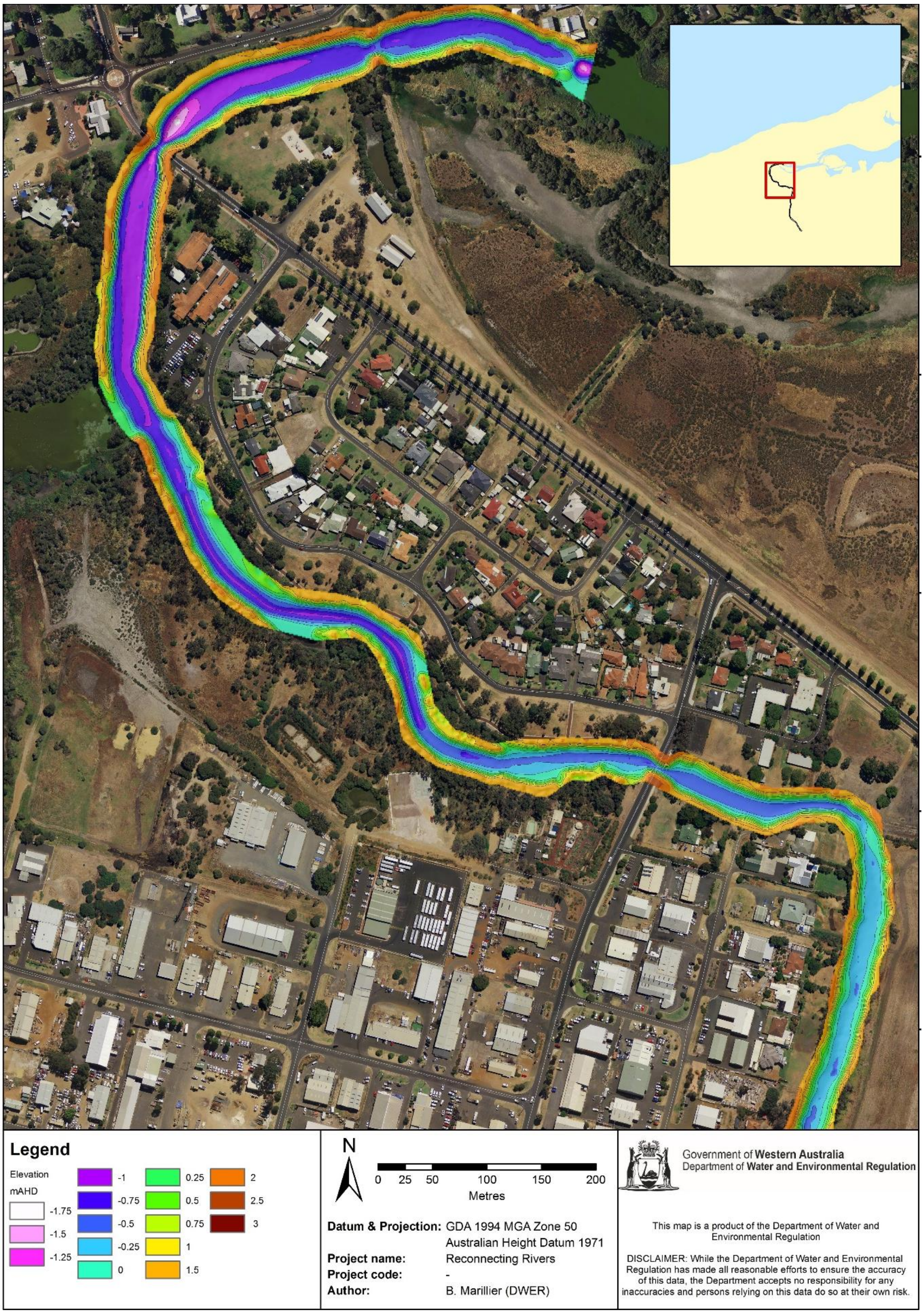


Figure 12. Lower Vasse River bathymetry from Butter Factory weir boards to Isaac Street reserve.

2.5 Amenity

Amenity describes the attractiveness of a place, and for the Lower Vasse River this is directly related to water quality. Algal blooms cause obvious green discoloration of the water, unsightly scums and unpleasant odours. There is concern that the poor amenity of the river during peak the tourist season creates a poor impression at the entrance to Busselton.

Despite poor water quality, natural values of the river environment, particularly the bird life, are still enjoyed by many in the community. Amenity is closely linked to the adjacent reserve and opportunities for recreation and access, which can enhance enjoyment of the Lower Vasse River.

2.6 Recreation and education

Poor water quality has greatly reduced the opportunities for recreational activities in the river during the warmer months. Persistent and severe algal blooms, often dominated by harmful blue-green species (cyanobacteria), cause closure of the water to public use. Access and recreation was rated highest as the focus area requiring change (AHA 2016.

Although algal blooms are seasonal, permanent warning signs are in place to advise against contact with the water. There is potential for recreational use of the water when there are no algal blooms, however signage does not indicate any safe period for contact.

In the past, the waters were used more extensively for recreation. In the 1940s the paddle wheel steamer *Jumna* carried passengers between the town and the Cattle Chosen homestead (Mouritz, Elphick and Anderson). There are anecdotes of canoeing, swimming and fishing and in the past. Whiting, Mulloway, Bream and Mullet have been anecdotally caught in the lower reach. Mullet and Black bream were caught during recent fish sampling but people no longer fish for them.

The Busselton Festival started in 1964, and crowning of the Festival Queen on the river bank opposite the City Administration building. The Festival Queen travelled on a barge from the boat ramp upstream and the community gathered on the banks to watch. At some point this ceremony ceased, though it is not clear when, probably due to poor water quality during the summer festival. In the 1970s there were paddle-boats on the river in town.

Regardless of water quality and restrictions on recreation within the river, a number of trails and public open space areas adjoin the Lower Vasse, which are still regularly used by the community. Rotary Park provides good public infrastructure near the river. Algal blooms and associated odours associated with a do impact use of these areas at times. There is significant potential for improved recreational, amenity and cultural connection with the river through enhancing and protecting natural values and improving facilities. Clearly though, addressing water quality is essential for improving recreational opportunities.

2.7 Culture and heritage

The river is highly valued by the local community and has historically been an iconic feature of the town and focal point for recreational and social events. There is a strong Aboriginal cultural connection to the river and many historical features. Heritage was rated as an issue of very high importance by the community.

2.7.1 Aboriginal heritage

The Lower Vasse River holds significant value for the local Wadandi people. There is a strong spiritual connection with all waterways in the area associated with the Waugul, and they are seen as a fundamental part of all life (Huxtable 2018). In pre European times, Aboriginal People used the Vasse River and its natural resources extensively.

With European settlement and alterations to the landscape, traditional uses of the river have been substantially impacted.

> *Before all the drains were put in the Vasse River was a system of walk trails. The old people would follow the river down to here, singing songs of the elders. We utilised the bush for medicine and food. It's a supermarket, everything we need is right here, the country provides everything we need.*
>
> (I. Webb, as cited in Huxtable 2018)

During consultation, Aboriginal representatives highlighted the importance of connectivity of waterways in the landscape from both spiritual and ecological perspectives. They highlighted the importance of managing the headwaters of the river to address the real cause of poor health in the lower reach, relating problems in the Lower Vasse to disruption of connectivity with its catchment. Representatives also acknowledged the need for intervention to improve the health of the river.

In a formal management sense, the study area is within the South West Boojarah Indigenous Land Use Agreement area within the South West Native Title Settlement Area[2]. An area encompassing the New River wetland area, including part of the study area, is a registered site under the *Aboriginal Heritage Act 1972.* In addition, there may be sites of cultural significance which are not reported or registered for cultural and political reasons. This will necessitate further consultation as specific management actions are developed.

2.7.2 European history

The presence of the Vasse River influenced the decision for settlement, and the development of Busselton and many aspects of social life have long been centred around it (Mouritz, Elphick and Anderson). Prior to settlement the Vasse River was one waterway from its headwaters to Wonnerup, but has been dramatically altered. History shows a connection to the river for many people. Some important historical features and activities associated with the Lower Vasse River are listed below (from Mouritz, Elphick and Anderson).

- Early settlers moved north from the Blackwood River and via the Vasse River towards Busselton.
- The old rail bridge was constructed in 1890, with rail connections to Bunbury, Nannup and Karridale, servicing the timber industry.

[2] Current information on the South West Native Title Settlement: http://www.noongar.org.au

- During the 1830s, the river was used to move goods from the jetty site, via what is now Queen Street, to Cattle Chosen to build the homestead. The small paddle replica paddle steamer *Jumna* transported people from St Mary's Church to Cattle Chosen; this included voyages for many prominent visitors to Busselton.
- The Busselton Festival commenced in 1964, with the crowning ceremony on the banks of the Vasse River a special event.
- The Butter Factory was transferred from Strelly Street to its current site in the banks of the river in 1918, and ceased production in 1975.
- The footbridge near Peel Terrace was built by the local council in 1972.

2.8 Governance

There are two key issues for the Lower Vasse River with regards to governance:

- defining roles and responsibilities for future management; and
- minimising impacts from planning for future developments and land use change.

Management of diffuse and point sources of nutrients from agricultural and urban catchments of the Lower Vasse River is a shared responsibility across GeoCatch, DWER, DPIRD, the City and industry groups. The independent review of water asset management (Hart 2014) recognised this joint responsibility. The Water Quality Improvement Plan (WQIP) provides load reduction targets, management recommendations and identifies key organisations responsible for implementation.

The independent review identified a clear need for a designated manager of the Lower Vasse River 'lake' section. There has been a lack of leadership and funding since the Lower Vasse River Cleanup Program, and thus little progress with management since this program was completed. This issue was also evident during community consultation (AHA 2016). One of guiding principles of the Vasse Geographe Strategy is the appointment of designated lead managers for key water assets. The independent Review (Hart 2014) recommended the City becomes the lead management agency, with continuing assistance from DWER.

The Lower Vase River catchment area will undergo considerable expansion of urban and industrial areas in the future, as identified in the current Draft Local Planning Strategy (CoB 2016). This could result in significant increases in nutrient loads to the Lower Vasse River, and downstream environments (Section 2.1). The City will have an important role in minimising nutrient exports from future developments and land use change; and effectively managing foreshore reserve areas with regard to the vision for the Lower Vasse River. Development is also expected to result in considerable new areas of foreshore reserve being managed by the City (i.e. areas identified as Parks and Recreation in Figure 13).

Figure 13. Draft Local Planning Strategy (2016) land use within the Lower Vasse River study area.

3 Management Objectives

This section presents sixteen management objectives across the eight the focus areas. These were developing in partnership with community members and provide good guidance on the expectations of future management of the Lower Vasse River.

3.1 Water quality

1. Reduce nutrients flowing into the Lower Vasse River from all existing sources to improve water quality and reduce the frequency and severity of toxic algal blooms.

2. Minimise any additional nutrients flowing into the Lower Vasse River from new developments and agricultural intensification.

3. Utilise science and innovative technologies to improve water quality in the Lower Vasse River.

3.2 Ecology

4. Protect and enhance native aquatic and terrestrial habitats in the Lower Vasse River and the foreshore reserve.

5. Reduce the impact of threatening processes on the natural values of the Lower Vasse River and the foreshore reserve.

6. Balance mitigation of fire risks with the protection of natural values of the Lower Vasse River foreshore reserve.

3.3 Water flow

7. Optimise water flow in the Lower Vasse River to balance improvement of water quality, protection of natural values and public amenity, while maintaining flood protection.

3.4 Sediments

8. Strategically manage accumulated sediments to protect the natural and social values of the Lower Vasse River.

3.5 Amenity

9. Improve visual amenity, public health and odours for residents and visitors to enjoy the Lower Vasse River.

10. Facilitate recreational and educational opportunities, which are compatible with protection of the key values of the Lower Vasse River and enhance community stewardship.

3.6 Recreation and education

11. Enhance public access to the Lower Vasse River and within the foreshore reserve, with a focus on creating linkages to the town centre and surrounding areas while protecting the river's natural values.

3.7 Culture and heritage

12. Promote understanding of the Aboriginal and European history and culture of the Lower Vasse River.

3.8 Governance

13. Develop and maintain partnerships and a collaborative approach between key stakeholders and the community when managing the Lower Vasse River.

14. Maximise opportunities for protection of the Lower Vasse River as part of future development proposals and changes in land uses.

15. Manage the Lower Vasse River with consideration to other water assets, including the Vasse-Wonnerup Wetlands and Geographe Bay.

16. Improve knowledge and understanding of key values and management issues of the Lower Vasse River to support adaptive management.

4 Review of Management Options

Development of management strategies for the Lower Vasse River has involved consideration of a range of potential initiatives. Some are fundamental approaches such as catchment nutrient reduction and riparian vegetation management. Intervention options have also been considered to directly manage water quality problems. These options are important due to the long-term nature of achieving nutrient load reductions, and the potential for ongoing release of nutrients from accumulated sediments.

The independent review identified the need for solutions that directly reduce nutrient availability for algal growth, alter physical conditions to make it more difficult for algae to grow, or dredging the sediments (Hart 2014). In addition, the *Community Views* session also provided suggestions for future management options (Figure 14). These reflect long-held community opinions and are aligned well with the options considered for inclusion in the management strategies and actions in this WMP.

This section outlines existing information, challenges and likely outcomes from potential management options. This review was an integral step in the development of strategies and actions for the WMP, outlined in Section 5.

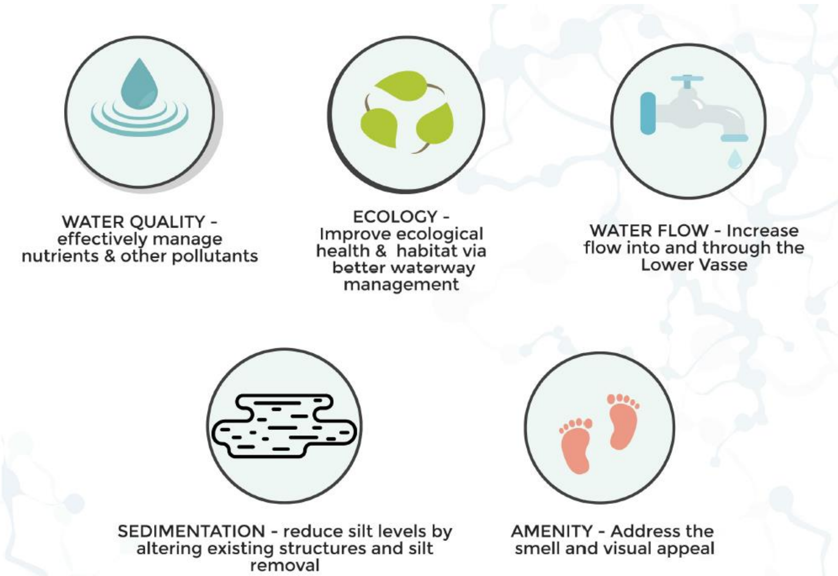


Figure 14. Suggestions for the future management of the Lower Vasse River from the *Community Views* session (AHA 2016).

4.1 Living Streams

The term *living streams* describes an approach to managing urban stormwater that creates a complex ecosystem with outcomes for ecology, water quality, water conveyance and amenity. Although traditionally applied to urban stormwater drains, this approach of restructuring the ecosystem is also relevant to restoration of the Lower Vasse River. In this case it would involve altering the morphology to restore ecological processes and create physical conditions that provide greater resilience to high nutrient conditions.

A living streams approach would see creation of diverse habitats including seasonally dry areas, river pools, channels, floodplain areas, riffle zones and islands (floating and grounded). Creation of these habitats would have clear outcomes for ecology, and the potential to provide significant water quality benefits. Compartmentalising the river by creating seasonally dry areas during summer also provides opportunities to stage works and target intervention actions. Figure 15 provides an example of changes to river form with a living streams approach.

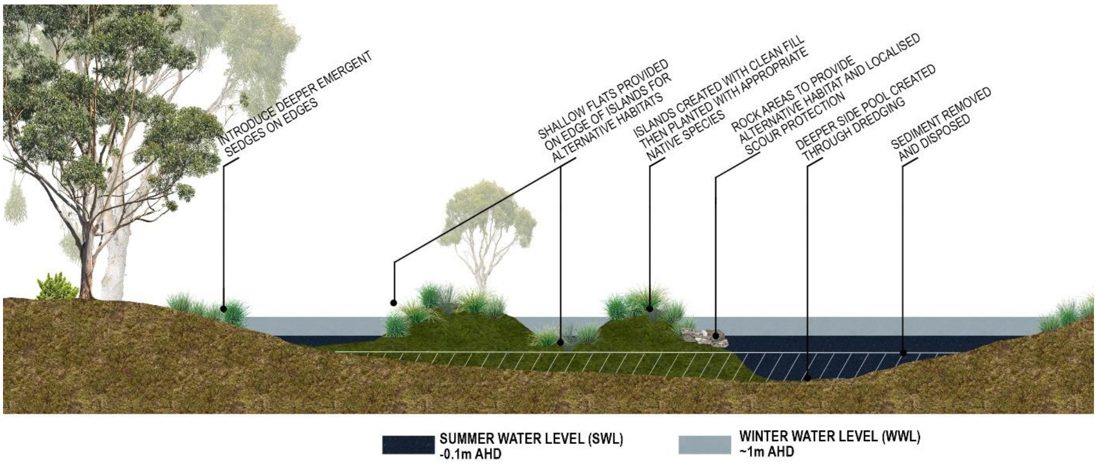


Figure 15. An example of altered river morphology with a living streams approach. More diverse habitats would be created including channels, pools, islands and seasonally dry areas.

4.1.1 Ecological outcomes

As outlined in Section 0, the Lower Vasse River supports many terrestrial and aquatic fauna despite its degraded status. The living stream approach would create new riparian habitat to support birds and possible other terrestrial fauna. Within the river, the increased surface area and diversity of aquatic habitats and food sources is likely to have a profound effect on aquatic invertebrate communities. This has been shown in the river in regard to aquatic plants (Paice et al. 2016, Paice 2018). Physical substrates (e.g. rocks, sand, and logs) and varied flow conditions will also support greater diversity. The plant and invertebrate communities in turn provide food resources for fish and birds.

4.1.2 Water quality outcomes

Potential water quality benefits of ecosystem restructuring through a living streams approach are summarised below. While these mechanisms may not achieve significant water quality improvements individually, combined they have potential to create a more complex ecosystem that is less prone to seasonal dominance by phytoplankton. Enhanced nutrient processing capacity may also benefit downstream wetlands.

a) Aquatic plants: Modifying the depth profile and enhancing substrate can provide more favourable sediment and depth conditions for anchorage and growth of beneficial aquatic plants (macrophytes). These plants may re-establish naturally or can be transplanted. A macrophyte restoration trial in the river in 2012 did not result in water quality improvement (Paice et al. 2016), however the mechanisms by which these plants contribute to water quality are well known throughout the world (Van Donk and Van de Bund 2002; Davis et al. 2010). Interestingly the Mexican waterlily has shown water quality benefits, although it is not clear how. Aquatic plants contribute to improved water quality through:
   - competing with algae for nutrients, both directly and by supporting biofilm;
   - stabilising and oxygenating the sediments;
   - supporting organisms that graze on algae; and
   - chemical inhibition (allelopathy).

b) Freshwater mussels: Carter's Freshwater Mussel (*Westralunio carteri*) is a listed threatened species known to occur in the river. Modifying substrate or providing additional substrate could increase mussel populations. They are thought to play an important role in maintaining water quality in refuge pools through filtration (Caraco et al. 2006). Mussels in the Lower Vasse River have a habitat preference for bridge sites and river edges, which are more shaded and stable.

c) Benthic algae: Increasing surface area by creating a more complex river form with greater rock and wood surfaces would allow benthic algal populations to establish. These communities are alternative primary producers to phytoplankton, competing for nutrients and providing an important food source for aquatic fauna, so that nutrients are incorporated into the food web. Emergent wood and rock materials also provide habitat for birds.

d) Emergent plants: Reshaping river banks could provide ledges for establishment of more emergent plants through revegetation. These plants use up nutrients, shade the water, trap sediments and provide excellent habitat and food for waterbirds. They are more beneficial than rushes on the upper banks because of stronger interaction with river sediment and water column. Some emergent plant beds have been created in previous restoration efforts, but they are confined to very thin riparian strips.

e) Floating islands: There have been a number of vegetated floating islands trialled in the Lower Vasse River. These islands provide habitat, both above and below the water and may contribute to nutrient uptake and processing through growth of plants and associated biofilm. Some products include a nutrient holding media in the island structure, although effectiveness is uncertain. These structures also provide an immediate shading benefit, restricting algal growth. This shading function may also be useful in restricting the spread of waterlilies (4.5).

f) Changing morphology: Physical modifications that increase surface area and creates seasonal separate wetland compartments may have several advantages, including:

- greater resilience to higher nutrient loading due to greater surface area for beneficial processes;
- higher levels of shading, providing less favourable conditions for algal blooms;
- reduced wind fetch and thus nutrient-release and turbidity from resuspension of sediments;
- potential for water circulation within or between pools, reducing residence time for development of algal blooms; and
- opportunities for targeted interventions to address water quality such as sediment removal (Section 4.11) and water treatment (Section 4.3).

4.1.3 Challenges

Modification of river morphology as part of a living stream approach would involve extensive earthworks that affect hydrology (and flooding) and existing riparian and aquatic habitats. Design will need to address constraints of these issues, and several approvals will be required (Calibre 2018). In particular, Carter's Freshwater Mussels occur in the river. This is a recently listed (2018) threatened species[3] and so will require approval and management of in-river works to minimise mortality and create a net benefit for this species.

Implementation of living streams works would involve considerable cost associated with sediment removal and infill. It has been difficult to develop reliable costings for this approach, owing to variation in potential designs; and uncertainty in volumes and methodology for sediment removal and disposal, and materials used for infill. Costs and uncertainty can be addressed through staging of works, allowing development of reliable methods and better understanding of materials. Adaptive implementation in stages based on results will improve overall outcomes.

4.2 Reducing nutrient sources

Management of nutrient inputs from urban and agricultural catchment areas is addressed in the Water Quality Improvement Plan (WQIP, DoW 2010), which is currently being reviewed. The WQIP outlines management measures and provides recommendations, which are included in the Management Strategies for this WMP (WQ1 and WQ2).

A large proportion of the catchment with agricultural landuse (approximately 90%) is currently diverted via the Vasse Diversion. Nonetheless, flows from the broader rural catchment do impact water quality in the Lower Vasse River. Increasing flows from the Vasse Diversion to the Lower Vasse River (Section 4.8) would increase nutrient loads from this source. There are also some rural land use activities remaining in the Lower Vasse River catchment area.

GeoCatch, supported by DWER, has a strong focus on nutrient reduction in agricultural areas, supporting implementation of best management practices for fertiliser use and dairy effluent management, and soil amendments. They also promote and assist riparian management and stock control on waterways. There are opportunities to improve management of the extensive modified drainage networks, which rapidly convey nutrients and sediments within the catchment. This is the

[3] Listed as threatened under Wildlife Conservation Act 1950 (Western Australia); listed as vulnerable under Environmental Protection and Biodiversity Conservation Act (1999) (Commonwealth); listed as vulnerable under Global IUCN Red List of Threatened Species.

focus of the *Rethink Drainage* action area for the RGW program. These management initiatives are important to the long-term reduction of nutrient contributions to the Lower Vasse River from rural sources.

Much of the Lower Vasse River catchment is urban, and these areas will continue to expand with future development, creating new sources of nutrients. In existing urban areas, the City has worked in partnership with GeoCatch to implement significant stormwater management upgrades throughout the Busselton CBD and LIA areas (Appendix 3). These include:

- biofiltration beds
- rain gardens (Figure 16)
- enhancement of natural wetlands
- constructed wetlands
- vegetated swales
- biofiltration swales
- detention basins

There may be more opportunities for stormwater upgrades in the Lower Vasse River catchment, and a process to identify and prioritise future projects would be beneficial.

Inclusion of best practice water management technologies in new developments will be essential to minimise future nutrient inputs. The City has a key role through its planning and development approvals processes to ensure this occurs. The *Better Urban Water Management Framework* (BUWMF) provides guidance ensure consideration of water resource management in the planning process (Section 4.13).

Sewerage infrastructure has a major role in protecting water quality in the Lower Vasse River, diverting nutrient- and pollutant-rich waters to the Busselton Wastewater Treatment Plant. Not all properties are connected to existing sewerage infrastructure, and there may be opportunities to increase connections within the Lower Vasse River urban catchment areas, reducing nutrient exports from these areas.

The Busselton Light Industrial Area (LIA) is currently not connected to sewerage infrastructure. Septic tanks in the LIA are estimated to contribute about 10% of the phosphorus load and 4% of the nitrogen load to the Lower Vasse River annually (DoW 2010). However, there is limited data available to base these estimates on. Development of infill sewerage infrastructure in the LIA has a high potential cost and requires clear evidence to be progressed. This would be assisted by investigation of nutrient and pollutant exports, and an audit of waste in relation to acceptable criteria.

Figure 16. Example of a rain garden for stormwater quality management, at the City Administration building.

4.3 Water treatment

Reducing nutrient inputs is a fundamental management approach, but significant reduction in nutrient loading from diffuse sources in the catchment is difficult to achieve and takes many years. In highly eutrophic systems, such as the Lower Vasse River, reducing nutrient inputs alone is unlikely to prevent algal blooms because of the ongoing supply of nutrients form the sediments. Intervention options to limit nutrients available to algae and to treat algal blooms may be necessary to achieve short term water quality improvement. The main limitations of these options are uncertainty in effectiveness, costs of large scale treatment, and short-term effectiveness.

4.3.1 Water treatment using specialised clays

"Water treatment trials" in the Lower Vasse River have focussed on specialised clays. Covering the sediments with specially-developed material can prevent nutrient release and reduce nutrients available for algal growth. These products are applied as a slurry and settle through the water column to form a layer on the surface of the sediments. Applied in this way, these products can bind to and sink nutrients and algal cells as they settle through the water column (Figure 17). There are a number of clay products used commercially and experimentally in a global context. Three have been trialled in the Lower Vasse River: Phoslock™, flocculating clays, and hydrotalcite clay.

From 2001-2004, three trials of Phoslock™ were completed. Application during an existing algal bloom can substantially reduce available phosphorus but had no effect on the algal bloom. Application prior to establishment of the algal bloom reduced both phosphorus levels and limited algal growth by 80%, although a less severe algal bloom still occurred (Robb et al. 2003). Application rates for Phoslock™ are well-understood and it is a commercially available product. It needs to be applied prior to establishment of an algal bloom, to restrict growth by reducing phosphorus availability.

Two types of flocculating clays have been trialled in the Lower Vasse River. Application of a clay mixture containing polyaluminium chloride in April 2000 had no overall positive effect on river appearance. An experimental clay product was applied to a small contained area in February 2002, which did show visible improvement in water quality, but little monitoring was done.

Hydrotalcite clay (HT clay) has been the focus of more recent trials in the Lower Vasse River. Like Phoslock, this product is applied as a slurry and designed to strip phosphorus from the water column and trap phosphorus by forming a layer on the sediment surface. A mesocosm study was undertaken during 2006-17; followed by a larger scale field experiment in 2017-18. The results of these trials indicate reductions in phosphorus concentrations and algal growth (DWER 2018c). Unfortunately observed water quality remained poor in the trial areas, with the water still having a green appearance. More work is required to determine appropriate dosage levels, and this product is not widely available.

In general terms, these products have not demonstrated prevention of algal blooms, but have shown some success in reducing algal growth. Their effectiveness is limited by ongoing external nutrient inputs, so ongoing applications are needed and they are costly. DWER currently recommend annual treatment of the lower reach of the river with Phoslock™, at an estimated cost of $120,000 per year.

Targeted treatment may be possible in smaller, seasonally-isolated areas following implementation of living streams works. This would make multiple applications more affordable. An ongoing interest in future development of these products should be maintained as they are improved and developed commercially.

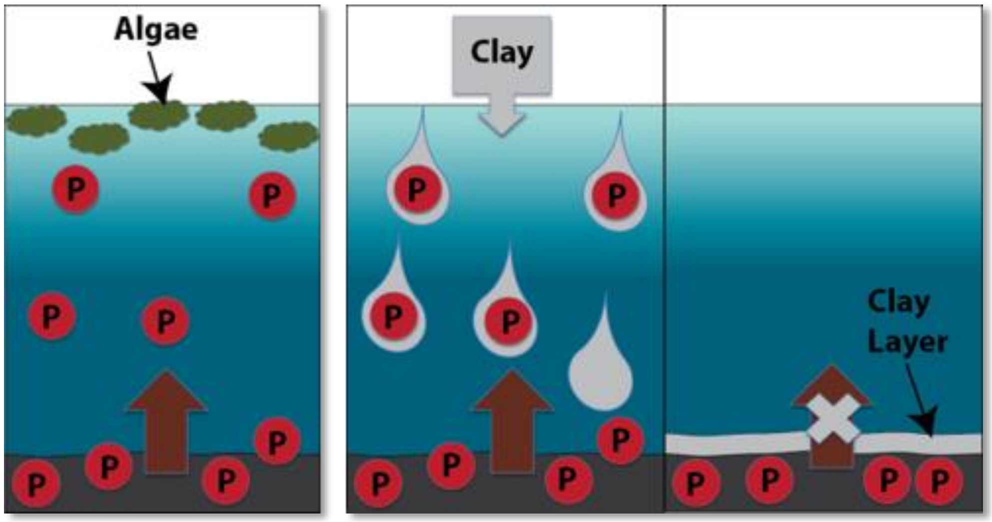


Figure 17. Phosphorus-binding clay products such as Phoslock® or the new HT-clay lock up phosphorus, making it unavailable to algae. Phosphorus is removed as the clay settles through the water and it also forms a protective layer on the sediments, reducing phosphorus release. Figure Courtesy DWER.

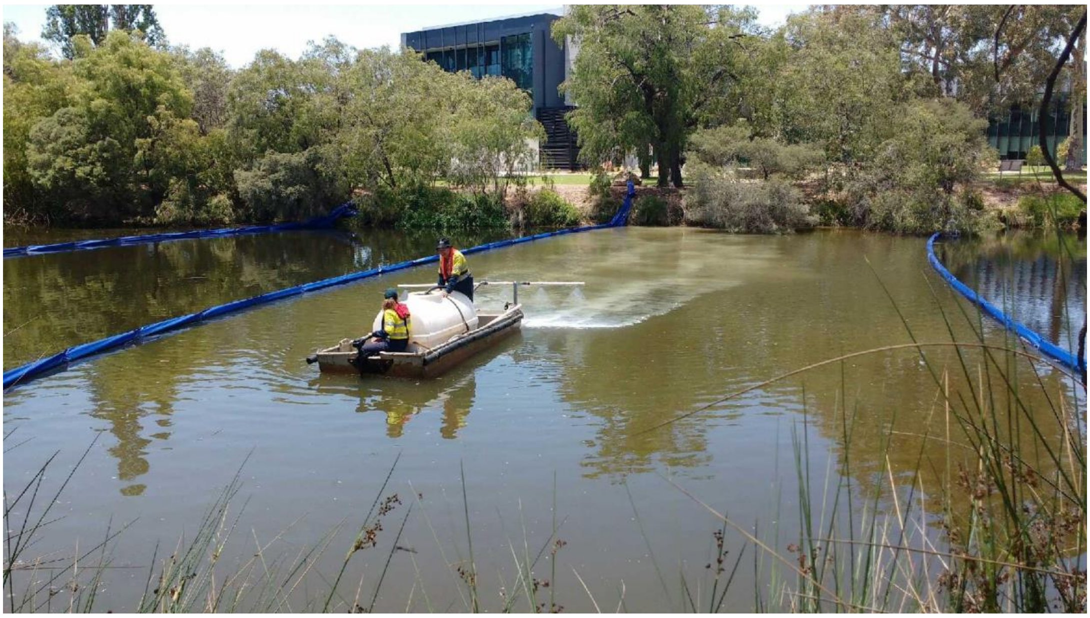


Figure 18. HT clay being applied in the Lower Vasse River during the 2017-18 trial.

4.3.2 Oxygenation and aeration

Oxygen is important for aquatic fauna and also influences nutrient availability. Low oxygen levels can be artificially increased by pumping oxygen gas into the water and by aeration. Both these methods will result in increased oxygen levels in the water, although oxygenation is more effective and aeration may increase nitrogen concentrations (due to nitrogen content of air). Increasing oxygen levels improves conditions for aquatic fauna and promotes aerobic biological processes, which can address odour issues.

Low oxygen conditions at the bottom of the water facilitate release of phosphorus from the sediments, which contributes to algal blooms (Boulton et al. 2014). This situation occurs when there is little mixing and the water column is stratified. In this situation, oxygenation, aeration or artificial circulation can reduce phosphorus release from sediments into the water.

The Lower Vasse River is not stratified, and has high oxygen levels throughout the water column during summer when the algal bloom is established. Algal blooms increase oxygen levels to above 100% during the day through photosynthesis. Although respiration at night consumes oxygen, it does not cause deoxygenation. The water is shallow enough to be mixed by the wind. Oxygenation and aeration of the water column would therefore not address nutrient problems in the Lower Vasse River when an algal bloom is established. The sediment is anoxic, but these methods do not oxygenate the sediments, and an attempt to do so would cause considerable resuspension of sediments.

Oxygenation was trialled in the Lower Vasse River during the summer of 1998-99 to determine the effectiveness of the process and water quality outcomes. There was no effect on the established algal bloom, although increased oxygen levels were observed and considered beneficial for aquatic fauna. Greater understanding of oxygen fluctuations prior to the onset of the algal bloom when oxygen levels would help assess potential advantages of oxygenation lower in the Lower Vasse River.

In addition to increasing oxygen levels, mixing of the water through aeration combined with sufficient circulation may influence algal growth by reducing the residence time. Phytoplankton thrive in the still conditions of the Lower Vasse River during summer. Movement of water within the system has potential to limit algal blooms by physical disturbance and reducing water temperatures (Cha et al. 2017). Artificial mixing is a common management practice in lake restoration, both to address stratification problems and to restrict growth by entraining phytoplankton in flow, and can restrict growth of scum-forming blue-green algae (Visser et al. 2016).

4.3.3 Water treatment using microbiological products

A number of commercial products exist that claim to improve water quality through the introduction or enhancement of micro-organisms. There are no scientific studies available on the effectiveness of these products. Current evidence is anecdotal only and while some benefits may have been observed in small-scale situations they have not been formally reported.

The City supported trials of two such products in the Lower Vasse River during the summer of 2012-2013:

- A microbiological culture pad product that provides high surface area and trace elements to increase the population of beneficial microbes (*Archaea* microbes and *Bacillus* bacteria).
- An enzyme protein product designed to promote bacterial growth and activity.

Water quality monitoring over three months did not show any significant effects of these treatments, however there were several limitations of the trials. There was no aeration, which is generally recommended in combination with these treatments. The trials did not take place under conditions of severe algal blooms expected, owing to the effect of Mexican waterlily downstream.

Enhanced nitrification and denitrification is described as the beneficial process by which these products improve water quality, and some effect on available nitrogen was found for the enzyme product. The Lower Vasse River generally has very low available nitrogen, which favours blue green algae because they can obtain nitrogen from the atmosphere through fixation. This product may influence the phytoplankton community by increasing available nitrogen. Reducing phosphorus availability is very important for limiting algal growth, and these products do not achieve this.

There are no published studies of the effective use of microbiological products to control algal blooms at the lake scale. They may be more effective in small isolated systems such as ponds and dams.

4.3.4 Barley Straw

Addition of barley straw is considered a preventative method for algal control that has been used extensively in farm dams and canals. Decomposing straw has been shown to inhibit algal growth in laboratory conditions (Gibson et al. 1990) and reduce filamentous algal growth in canals in years following placement (Welch et al. 1990). Barley straw bales and extracts are marketed for use in algae prevention.

In April 2000, straw bales were placed in the Lower Vasse River upstream of the Causeway Rd bridge to assess their effect on algal blooms. No effect on water quality was observed, however it is uncertain that Barely straw was used. Potential future use should consider it may be most effective at small scales; in a preventative approach; and that straw must be decomposing. It may be more effective for filamentous algae rather than phytoplankton.

4.3.5 Algaecides

A number of algaecides are marketed for treating algae, usually copper-based, but are generally not recommended for natural systems due to their toxicity to non-target plants and aquatic fauna. Hydrogen peroxide is marketed as an algaecide which has high specificity for blue-green algae and no residual impacts on the environment as it breaks down to hydrogen and oxygen gases. Some research supports its potential as a management tool for algal blooms (Matthijs et al. 2012, Bauza et al. 2014). It has been used to control blue-green algae in small lakes and wastewater treatment ponds, but is not widely used for larger systems for a number of reasons:

- difficulty in achieving and maintaining required concentrations throughout water body;
- potential impact of hydrogen sulphide on other organisms, mainly zooplankton;
- potential for release of toxins such as microcystins from dying algal cells;
- lack of residual effect (regrowth of algae following treatment).

Trials of hydrogen peroxide in Lake Torrens[4] in South Australia have not been formally reported. Information provided suggests effective reduction of blue-green algae at H_2O_2 concentrations of 2-5 mg/L, with no impacts on aquatic fauna. However these trials were conducted at low algal cell densities (below algal bloom levels), and the current recommendation is for small scale use in combination with other methods. SA Water continues to investigate this method for reservoir management.

4.3.6 Ultrasound

Ultrasonic control of phytoplankton is commonly used for pond environments and works by destruction of algal cells. Its effectiveness has been demonstrated in small scale studies and laboratory experiments, but upscaling this treatment to field conditions is challenging (Park et al. 2017). Frequency, intensity and exposure are important factors in effectiveness, and may have variable effects on different algal species. There has been a successful trial in a 9000m^3 pond in combination with pumping, but could not differentiate the effects of ultrasound and the pumps (Ahn et al. 2007).

4.4 Riparian vegetation management

In addition to the conservation value of the flora itself, fringing vegetation of wetland areas is a vital component of river health. Functions include:

- supporting terrestrial and aquatic food webs;
- habitat for terrestrial and aquatic fauna;
- foreshore stabilisation;
- shading and maintaining cooler temperatures
- interception of nutrients and sediments in runoff; and
- nutrient uptake and processing.

Riparian vegetation along the Lower Vasse River provides important bird habitat and forms part of a regional ecological linkage mapped along the length of the study area (Ecoedge 2017). However the vegetation is mostly degraded with low species diversity and extensive weed invasion. There has been

[4] Information from unpublished report and discussions with local NRM group Natural Resources Adelaide and Mt Lofty Ranges.

considerable riparian revegetation on the Lower Vasse River banks since 1999, and these areas provide the best condition riparian vegetation. This demonstrates successful revegetation, but these areas need more active weed control and could be enhanced with infill planting.

Extensive areas of public lands provide good opportunities for revegetation. Ecoedge (2017) suggests five key areas for rehabilitation based on size, accessibility and level of competition with existing plants (Appendix 3. Additional areas of City-managed foreshore reserve are being created through new developments, providing new opportunities for improving riparian vegetation. The littoral zone[5] could be expanded in some areas through a living streams approach, including zones of seasonal and permanent inundation, requiring a specialised suite of species. A species list for revegetation for terrestrial and aquatic areas is provided in Appendix 4.

Outside of urban areas there is still stock access to some foreshore areas, damaging fringing vegetation and directly contributing wastes to the river. The *Vasse River Action Plan* study area extends from the headwaters in the Whicher Range to Fairlawn Road (Scott 2000). It provides an assessment of foreshore condition and identifies areas requiring management of stock access, weed control, erosion control and revegetation. A review of implementation of the Action Plan and an update of the foreshores assessment and associated management recommendations for the Lower Vasse River WMP study area would assist in planning and undertaking restoration activities. This would also set a baseline for future monitoring of progress and outcomes. River action planning should also include consideration of future development and provide information to assist in planning for additional foreshore reserves.

Figure 19. Improving riparian revegetation through weed control and infill planting.

Figure 20. Floating island on the Lower Vasse River installed in 2002.

[5] The ecological zone in freshwater systems close to the shoreline where sufficient light extends to the bottom for plant growth (Boulton et al. 2014).

4.5 Floating Islands

Floating islands are also known as constructed floating wetlands, as they are designed to provide the ecological engineering benefits of constructed wetlands designed for water quality improvement. They are used in water treatment systems, particularly in China, and can contribute to restoration of natural waterbodies, however their effectiveness in pollutant removal is lower at larger scales (Bi et al. 2019). Floating islands have potential to remove nutrients from the water column, and they provide ecological benefits of habitat and shading.

Islands consist of a floating frame or structure supporting a contained media within which plant roots can grow. The plants and media combined enhance microbial processes that have potential to reduce nutrients in the water column. They may be more effective at nitrogen reduction than phosphorus: nitrogen is removed via enhanced nitrification and denitrification, while phosphorus is stored internally and remains potentially available. As plants grow they take up nutrients from the water, however this only contributes to ongoing nutrient removal plants are regularly harvested.

The shading effect of floating islands has immediate benefits of reducing lower water temperatures and light availability to algae, although the scale of islands needed for this to limit algal blooms may be unfeasible. The structures have potential for use in restricting growth of Mexican waterlily by shading, while retaining beneficial biological processes. Islands and the roots below provide structural habitat for aquatic invertebrates, increasing biodiversity and improving food resources for other aquatic fauna. They also provide refuge from heat and predation from waterbirds.

Some small floating islands have been placed in the river in the past. In 2002 a small reed raft was made from a PVC frame with plastic mesh base (Figure 20). Plant growth was rapid, and the structure was subsequently used for nesting. This ‘island’ remains in the river today and has become rooted to the bottom of the river. Swans have recently been observed nesting on it. In 2012 floating islands were installed in a curtained off area to assess water quality benefits. The trial did not take place under conditions of severe algal blooms expected, owing to the effect of Mexican waterlily downstream. No significant effects on water quality were found in this trial, however the beneficial ecological processes associated with floating islands are well-established.

4.6 Managing waterlilies

The extensive cover of waterlilies in the river has negative impacts on oxygen levels and open water habitat; however they appear to have had a beneficial effect on water quality, inhibiting the development of algal blooms in open water areas upstream of the point of infestation (near the boat ramp) (Paice 2018). The structural habitat of the waterlilies also supports aquatic invertebrates, despite low oxygen levels.

Although unintentional, this is an example of “ecological engineering”, whereby a change in the ecology has provided water quality benefits. The reasons for reduced algal blooms between patches of waterlily are not fully understood. It is not a result of reduced phosphorus concentrations, as phosphorus was actually extremely high in areas with low algal growth. It may be a combination of greater low residence time in sunlit areas owing to lilies and riparian shading; nitrogen limitation; or chemical inhibition (allelopathy). Understanding the mechanisms by which waterlilies inhibit algal growth may provide important insights to future management, and warrants further research. It would also be valuable to investigate the potential to achieve similar inhibition using native aquatic plant species, such as *Cycnogeton* spp., *Potamogeton* spp., *Liparophyllum* spp. and *Ottelia ovalifolia*.

Reduced algal growth was observed following a rapid expansion of waterlily cover in 2013-2014 (Figure 9), at considerably lower levels of cover than subsequent years. This suggests that water quality benefits can be maintained with some control of waterlily. Large scale control would likely see a return to widespread seasonal algal blooms; and also presents risks of widespread deoxygenation following plant die-off. Paice (2018) recommends strategic control of waterlily to gradually reclaim open waters between lily patches, targeting important waterbird habitat, and to prevent invasion of new areas. Although outside the study area of the WMP, the downstream Lower Vasse River delta wetlands are at particular risk and should be targeted for waterlily control.

4.7 Controlling feral fish

The two main feral fish species in the Lower Vasse River are goldfish and mosquitofish. There is little that can be done to control mosquitofish populations. Goldfish are known to feed in at the bottom of the river, disturbing sediments and so contributing to nutrient release and turbidity. There is also evidence that passage through goldfish stomachs can increase the growth rate of blue-green algal cells.

Although eradication of goldfish is difficult, population numbers were successfully reduced through an annual electrofishing program from 2003 to 2013 (Beatty et al 2014). The resumption of this program should be considered. Compartmentalising the river may provide opportunities for effective targeted goldfish removal.

4.8 Increasing flow inputs from the Vasse Diversion

Reduction in catchment flows due to interception by the Vasse Diversion, together with impoundment by the Butter Factory weir boards have substantially altered hydrology of the Lower Vasse River. The effect on nutrient concentrations is complex due to variation in nutrient concentrations and the combined results of flow volume and velocity, assimilation within the system and outflows. Although nutrient loads may have decreased due to lower volumes, this does not translate to lower nutrient concentrations.

The impounded conditions and accumulated sediments in the lower ‘lake’ section of the river promote algal blooms which causes a seasonal increase in nutrient concentrations over summer when there is negligible flow (Section 2.1.1). Flushing of the river may be important for removing nutrients and organic material that accumulate in during summer (Figure 6).

There is strong support from the community for increasing flow into the Lower Vasse River from the Vasse Diversion with the aim of improving water quality. Altering flows has potential to improve water quality where it dilutes nutrient concentrations or reduces residence time for growth of algal blooms. But outcomes need to be considered in the context of flood protection and impacts on nutrient loads to downstream wetland ecosystems. This option of altering flows was investigated by the *Reconnecting Rivers* study (DWER 2018b), which used hydrological modelling to determine the outcomes from a range of reconnection scenarios. The main findings of the *Reconnecting Rivers* study in relation to the Lower Vasse River were:

- the Vasse surge barrier is essential for flood prevention in Busselton;

- additional flows from the Vasse Diversion would increase nutrient loads to the Lower Vasse River and Vasse Estuary;
- an additional 900mm culvert at the Vasse Diversion offtake to the Lower Vasse River is feasible without increased flood risk and without unacceptable additional nutrient loads to the Vasse Estuary;
- the equivalent of three 900mm culverts or full reconnection of the Vasse Diversion would cause unacceptable flood risk and increase in nutrient loads to the Vasse Estuary;
- additional flows from the Vasse Diversion only has a significant effect on flows during winter;
- the potential effect of an additional culvert on summer water quality in the Lower Vasse River is small because of a lack of flow;

The study recommended that the Vasse Diversion Drain offtake structure be upgraded to an equivalent of two 900mm culverts (i.e. double its current capacity), with the ability to control flow. This infrastructure has been designed and works are currently scheduled for 2019. *Reconnecting Rivers* also recommended the development of an operational strategy to manage the culverts, with defined roles and responsibilities and consideration of how nutrient concentrations could be minimised. A greater understanding of relationships between water flow and water quality wold be beneficial to inform optimal operation of the culvert with regard to nutrient management.

4.9 Improving summer flows

There is no flow from the Vasse Diversion in the warmer months to address water quality problems during the algal bloom season through dilution and water movement (DWER 2018b). There are limited other options for creating summer flows with other water sources. These are summarised as follows:

- Storage of water for summer release: A dam to hold water for summer release would need a capacity of 18GL and cover an area of 9km^2. Water stored in such a reservoir is at risk of experiencing similar water quality problems to the Lower Vasse River. Using the Vasse Diversion or existing flood detention basins is not viable as it would compromise their flood protection function (DWER 2018b).

- Busselton Wastewater Treatment Plant discharge: This option would reduce water residence time and may decrease phosphorus concentrations with limited increase in loads to downstream wetlands (DWER 2018b). This option may be considered further, but its practicality is limited by need for substantial infrastructure and future competition for this water resource.

- Busselton Water operations: There may be potential for backwash inputs, but this has not yet been assessed.

- Internal artificial circulation: Movement of water within the system has potential to limit algal blooms by physical disturbance, reducing water temperatures. Temperature and residence time can be key factors controlling algal blooms in impounded rivers suggests (Cha et al. 2017). This approach may provide opportunities for external treatment techniques associated with recirculation (e. g. filtration via treatment wetlands). This option has not been assessed.

4.10 Removal of the Butter Factory weir boards

The Butter Factory weir structure and boards were installed around 1918 to retain water levels in Busselton for amenity and recreation outcomes. There are mixed perceptions regarding their necessity: that removal would improve water quality in the river through flushing; that they are not necessary and greater drying would be beneficial; and that maximising depth is important to improve water quality by creating cooler conditions.

Current management practice is to remove the weir boards in winter, and reinstall them in October to maintain water levels. However, the wooden boards currently leak, so higher water levels are only maintained temporarily. From around December, the extent of water is determined by land elevation, and currently restricted by a point further downstream near Ford Rd.

Modelling through the Reconnecting Rivers project indicated that removal of the weir functionality would not create a flooding risk; and would not result in drying out of the river. This approach may have the following outcomes:

- water levels in the Lower Vasse River would become lower earlier, by up to eight weeks;
- water would continue to flow into the downstream wetlands for a longer period, rather than being held back, influencing nutrient load;
- potential effects on goldfish movement.

An important operational issue at present is the safety of City staff during the installation and removal of the weir boards. A decision is required as to their future use, because if they are necessary part of river management they will need to be replaced and the mechanism for their installation and removal upgraded.

4.11 Sediment removal

Regardless of potential reductions in nutrient loads, the organic sediment in the Lower Vasse River provides an ongoing internal source of nutrients loading that can continue to drive algal blooms. Phosphorus is released from the sediments under low-oxygen conditions, and nutrients are also resuspended from the sediments when disturbed by flows and wind. Increasing phosphorus concentrations over the summer months may be a result of sediment-nutrient release. Note that specialised clay products are a form of sediment treatment that prevents phosphorus release (Section 4.3).

Sediment removal has long been viewed by many stakeholders as an essential part of future management. It was highlighted as a key management action during community consultation (AHA 2016). As a stand-alone method it would probably not prevent algal blooms, because nutrient concentrations in surface and groundwater inputs are sufficient for excessive algal growth. However, “resetting” the river through removal of organic sediments does have potential outcomes for water quality and ecology.

Outcomes of sediment removal for river health are complex. Increasing depth may create cooler temperatures but can also result in stratification if there is little mixing of the water, so there may be little temperature-related control of algae. Deeper waters may also reduce resuspension of nutrients from the riverbed. However, shallow waters may also be less prone to algae blooms owing to more favourable conditions for aquatic plants and benthic algae. Rather than removing all soft sediments from the river, creation of deeper pools and channel habitats in some areas as part of a living stream approach is considered more feasible (Section 0).

A section of the river upstream of Causeway Rd Bridge was dredged in March 2001. This work has increased the depth of the river in this section, however a large amount of soft sediment remains, at thickness similar to other parts of the river, and water quality remains poor (Paice 2005). In this case a mini-dredge was used to pump material to a holding dam, allowed to settle overnight and then overlying water was returned to the river. Sediment from the dam was disposed of at a gravel pit.

4.11.1 Removal method

Sediments in the Lower Vasse River are very fine and contain a high moisture content, and so require pumping from the river rather than excavation. The method used in 2001 was effective in removing some sediment and allowing it to dry out sufficiently for excavation. However drying took a considerable length of time and the total amount removed was dependent on the capacity of the holding dam. A more recently developed option is pumping sediments into porous geotextile bags placed nearby (Figure 21); with addition of a polymer to expel the water from the bags, which flows back into the river. This approach allows additional sediment to be pumped from the river as the volume of water is removed from collected sediments. This is considered the most feasible option for sediment removal from the river, and a proposal for a trial is currently being developed.

4.11.2 Disposal options

Disposal of dredged sediment is challenging in terms of potentially very large volumes, involving considerable transport costs; and limitations on disposal site owing to potential acidification and nutrient and pollutant content. To inform disposal options, the City undertook sampling of between the boat ramp on Southern Drive and the Butter Factory weir in March 2018, with assistance from DWER.

Levels of heavy metals and organic and inorganic contaminants were below threshold levels for disposal at a Class I landfill facility, with the exception of lead (Table 3). Although lead content levels were above threshold values for waste not requiring a leach test, subsequent leachate testing results showed levels were well below the Class I concentration limit.

The average depth of soft sediment in core samples was 488mm, with these sediments dominated by fine silts and clays (71.4%). Sample analysis found no existing acidity (mean pH 7.0), and low acid volatile sulphur (<0.005 %S) but indicated sulfidic soils with very high potential acidity. Net acidity varied greatly, ranging from 449 to 1511 with a mean value of 980 mole H+/Tonne dry weight. This is well above the acid sulphate soils 'action criterion' of 62 mole H+/T for fine texture materials (DER 2015). When sulfidic soils are exposed to air, oxidation can result in acidification. This has been demonstrated for the dredged material from 2001 at the gravel pit, which has a pH of around 4. The average lime dosing required to buffer potential acidification is 74kg/Tonne dry weight.

Soil characteristics do show that dredged material could be disposed of at a Class I landfill facility, such as the City's Vidler Road Waste Facility. However the high nutrient and organic content of the material suggests potential for reuse of the material as a component of compost. Composting can further dilute concentrations of pollutants. This approach would require a trial and further testing of the material to ensure it is safe for any proposed end use.

4.11.3 Risks

The main risks associated with sediment removal are:

- potential impact on benthic organisms;

- short term effects on water quality;
- acidification of sulfidic sediments; and

In the Lower Vasse River the soft sediment layer general provides poor habitat for benthic organisms. However the threatened Carter's Freshwater Mussel (*Westralunio carteri*) is known to occur. Mussels in the Lower Vasse River have a habitat preference for bridge sites and river edges, which are more shaded and stable. Key habitat areas could be avoided and work could be offset by overall habitat improvement; but nonetheless sediment removal work would need to consider and manage impacts on this species and be approved under state and federal legislation.

There is some risk of increased nutrient concentrations in the vicinity of dredging operations disturbance of nutrient rich sediments. Given the severe water quality problems currently experienced in the river this is not considered to be a serious risk. However the connectivity to the Vasse Estuary downstream does raise the issue of impacts on nutrient loads. This could be avoided by undertaking work when the river is disconnected from the downstream system.

The soft sediments in the Lower Vasse River are sulfidic and laboratory analysis and the pH of the old dredge spoil do indicate that oxidation would cause acidification. Severe acidification can have direct impacts on aquatic flora and fauna, lead to contamination of water resources, and cause corrosion of infrastructure. Exposure of the sediments to oxygen in the water column or air would be avoided using the geotextile bag method, preventing oxidation during the removal process. The sediments are not monosulfidic (indicated by low acid volatile sulphur); so do not pose the risk of rapid acidification and associated deoxygenation of the water column with potential heavy metal release. Sediments would require lime dosing for disposal.

Table 3. Comparison of pollutant content of Lower Vasse River sediments to threshold values for Class I landfill (sampling by City, March 2018).

Analyte	mean	Class I landfill threshold[1]	Units
Arsenic	<5	14	mg/kg
Beryllium	0.1	2	mg/kg
Cadmium	0.34	0.4	mg/kg
Chromium	6.6	10	mg/kg
Lead	35	2	mg/kg
Lead leachate	<0.01	0.1	mg/L
Mercury	0.04	0.2	mg/kg
Molybdenum	<2	10	mg/kg
Nickel	2.00	4	mg/kg
Silver	<1	20	mg/kg
Fluoride	137	300	mg/kg
Cyanide - Total	<1	16	mg/kg
Petroleum hydrocarbons C_{6-9}	<0.2	2800	mg/kg
Petroleum hydrocarbons – other	19.5	450[2]	mg/kg

[1] Landfill Waste Classification and Waste Definitions (DEC 2009)
[2] minimum threshold value for range of petroleum hydrocarbons
< indicates value below limit of detection
Phenol and pesticide suite also analysed, all results below limit of detection

4.11.4 Costs

There is uncertainty around costs for sediment removal, related to volumes of material and potential shrinkage, method of removal and options for disposal. Further work is required to provide accurate estimates of sediment and determine sound methods for removal and disposal. Removal also needs to consider appropriate locations and whether it could be staged in association with a living streams design approach. The removal trial currently being developed (see 4.11.1) will inform future costings of this management option.

Figure 21. Geotextile bags used for sediment removal via dredging.

4.12 Recreation and access management

Recreational opportunities for the Lower Vasse River are mainly walking and riding along the river and bird watching. Feeding of ducks and other birds near Peel Terrace is also common, but is discouraged owing to potential impacts on water quality and bird behaviour. Recreation is clearly limited by water quality problems. Algal blooms pose a health risk that prevents direct contact activities such as swimming and use of paddle craft; and at times cause poor odours that limit activities near the water. Management actions that address water quality are thus essential to improve recreational opportunities.

There is potential to improve access and facilities for recreation and enjoyment during periods where algal blooms do not occur, or do not cause offensive odours. Community consultation indicated access and recreation as the area of management where the community would most like to see change (AHA 2016). Examples include additional pathways, boardwalks, viewing platforms, seating, bird hides and picnic areas. Upgrading of interpretive signage would also encourage people to the river and enhance their experience. There are existing pathways along the river in the vicinity of Peel Terrace and

Southern Drive, and among the nearby New River Wetlands: the City is currently developing plans for an extension to this network.

There is also a need to review the use of permanent warning signs around the river, which discourage activities when there is no public health risk. This is particularly important if water quality improvements are achieved.

There is significant potential for improved recreational, amenity and cultural connection with the river. Although poor water quality does limit these outcomes, it does not prevent it. Enhancing ecological values of the river and opportunities for community connection can be achieved independent of water quality improvement. Furthermore, there are many months of the year when water quality does not pose a health risk. Clearly though, water quality improvement is a key aspect of enhancing recreational opportunities.

Interpretive signage along the Lower Vasse River between the old Rail Bridge and Rotary Park was developed as part of the Lower Vasse River Cleanup Program, in the early 2000s. These signs are still in place but are outdated: some are no longer visible and some are no longer relevant. Improved interpretive facilities and information would engage more of the community and enhance appreciation and understanding of the river and its management.

4.13 Governance options

The independent review of water asset management (Hart 2014) highlighted the need for the Lower Vasse River to have a designated manager. The City was recognised as the most appropriate manager, and this has been supported by the Western Australian Government in its response to the review. It is sensible that the City adopts this role given the high public profile of the river as a part of Busselton's town centre; and the large areas of foreshore reserves under the City's management control. Although the City is responsible for overall implementation of management actions, several key stakeholders also have important roles, outlined below. These roles and responsibilities are also summarised in Table 4, in Section 6.

The flow control structures at the Vasse Diversion connection and the Butter Factory, considered vital components of river management, are generally operated by the City. However, this infrastructure is owned by the Water Corporation. The Water Corporation has given the City permission to operate these mechanisms for water quality purposes, however some uncertainty remains in relation to flood protection.

The City also has an important role in its planning capacity. The *Optimising Planning Tools* project was completed by the City, for the RGW Program, to review the potential role of planning in water resource protection (Hosken 2018). Proposals for changes in land use and new developments can trigger the imposition of new environmental protection requirements at the approval stage. This applies to both urban and rural development.

The Lower Vasse River catchment area will undergo considerable expansion of urban and industrial areas in the future, which will increase potential nutrient and pollutant sources. Continued implementation of best practice stormwater management designs, and long term maintenance of infrastructure by the City is essential to minimise water quality impacts from future developments. Future residential development will provide opportunities for improving foreshore environments as new reserves are vested in the City. Consideration of water quality protection and surface water management in the planning process is guided by *Better Urban Water Management* document (WAPC 2008). There is potential to require new developments to demonstrate that nutrient and contaminant levels will not exceed background levels, but this would require amendment of the City's Local Planning Scheme and is restricted by a lack of water quality standards.

In rural areas, the current trend of intensification of agriculture is likely to continue into the future. Although there is a requirement for planning approval for intensive agricultural uses such as horticulture and feedlots, development applications for these land use changes are generally not submitted to the City. Improved clarity of planning approval requirements for changes in agricultural land use and new agricultural developments may increase opportunities for waterway protection requirements. The development of industry best management practices (BMPs) would provide useful criteria for planning assessment.

The City's management responsibility is generally limited to the study area and does not extend into the broader catchment. Ongoing management initiatives in the catchment, in particular to address issues of nutrient enrichment and sedimentation, are a fundamental component of waterways management. GeoCatch, with the support of DWER, is the lead manager for catchment management. The Water Corporation has management responsibility for its rural drainage network.

DWER has an ongoing role in providing support for the management of the Lower Vasse River through continued involvement in water science, modelling and monitoring. If the implementation of this WMP is to be funded through ongoing investment in a broader program for Geographe Bay catchment waterways, DWER is likely to continue to have an important project management and networking role.

The community is also an important stakeholder with potential roles in management decisions, advocacy, implementation of on-ground works and contribution to community science. Many interested community members have provided valuable assistance during the preparation of this WMP and would be valuable in ongoing collaboration during implementation. The City has a strong 'Friends of' approach to reserves management, which may facilitate volunteer involvement in actions and monitoring. Aboriginal people have expressed a desire to participate in management decisions and on-ground projects.

4.14 Research and monitoring needs

Research and monitoring are needed to enable assessment and reporting on progress of management initiatives and to fill knowledge gaps. Research outcomes need to feed back into management planning through an adaptive process. The key research areas for the Lower Vasse River are summarised below.

Water quality: Ongoing water quality monitoring is an essential part of long-term assessment and reporting for waterway health. Future research into different water treatment options to reduce nutrient availability and reduce algal growth may provide important management tools. Short-term Intensive monitoring of nutrient concentrations and flows to the river from the Vasse Diversion Drain to improve understanding of the first flush dynamics of the system would inform operation of culverts.

Water flow: Investigation of the relationship between nutrient and flows in the Vasse Diversion will help inform management decisions around operation of the culvert connection. When the culvert is upgraded, inclusion of flow monitoring in the design would support future decisions in optimising flow. Better understanding of the effects of the Butter Factory weir on water levels and water quality is also needed to determine the need for upgrading this structure.

Birds: Despite being one of the most valued characteristics of the river, bird populations and key habitat areas are not well understood. Better knowledge of birds would assist in prioritising management actions (e.g. habitat restoration) and in developing information resources for visitors. There is an opportunity for development of community-based sampling to address this gap.

Mussels: Freshwater mussels occur in the river, and have recently been added to specially protected fauna lists at the state, federal and global levels. A better understanding is needed of the mussel population, habitat requirements, potential contribution to water quality and potential impacts of management initiatives.

Mexican waterlily: The reasons for reduced algal blooms between patches of waterlily are not fully understood, and research into the mechanisms for this would provide insights for broader river management.

Sediments: Sediment removal is potentially a major part of future management of the river to address internal nutrient sources. More work is needed to develop methods of removal, determine costs, and examine potential outcomes for water quality and impacts on existing ecological values.

5 Management Strategies and Actions

The management strategies and actions included here have been developed to work towards meeting the management objectives and vision for the Lower Vasse River. Specific actions have been grouped into strategies for each of the management focus areas, although many have potential outcomes for several objectives. Living Streams is included separately, because it is an approach to management that influences implementation of actions for a number of focus areas. A framework for implementation of the WMP is provided in Section 6, including the roles and responsibilities of key stakeholders; definition of management areas; and a process for ongoing action planning, reporting and review.

5.1 Living Streams

Living Streams is separated from the management focus areas because it provides an overarching pathway for implementing management actions related to water quality and ecology. It involves altering the morphology and physical characteristics of the river to restore ecological processes and create less favourable conditions for algal blooms. It may also facilitate intervention actions, such as water treatment and sediment removal, in specific areas of the river.

5.1.1 Strategy LS1: Living streams approach

A living streams approach would see creation of diverse habitats including seasonally dry areas, river pools, channels, floodplain areas, riffle zones and islands (floating and grounded). In addition to outcomes for biodiversity in the river, these habitats would be designed to maximise potential benefits to water quality.

Management actions:

LS.3 Continue to develop Living Streams planning as a pathway for implementing ecological restoration and water quality improvement works, and assess community support for this approach.

LS.4 Incorporate the following principles into restoration planning as part of the Living Streams approach:

- maximise shading;
- enhance substrate to provide more favourable sediment and depth conditions for anchorage and growth of beneficial aquatic plants;
- modify depth contours to support more in-stream vegetation, including emergent and submerged plants, to enhance nutrient uptake and cycling;
- provide greater surface area for benthic algal populations to develop as alternative primary producers to phytoplankton;
- reduce the size of open water areas to increase resilience to nutrient loading;
- enhance habitat for freshwater mussels to maximise their role in maintaining water quality;
- reduce residence time for algal growth through flow management.

5.2 Water quality

Nutrients are a key driver of algal blooms, so ongoing load reduction actions are a fundamental part of management. However, it often takes a long time to achieve load reductions, and they may be counteracted by new developments and changes to land use. Algal blooms can also be addressed through interventions that limit nutrient availability or directly target algal blooms. They may also be managed by creating less favourable physical conditions for phytoplankton; or restoring ecosystem functions such as nutrient cycling and food web processes.

Catchment management actions in this section are closely linked with recommendations in the Water Quality Improvement Plan (WQIP: DoW 2010), which are included for reference.

5.2.1 Strategy WQ1: Protecting water quality from urban sources

The Busselton Light Industrial Area (LIA) has been identified as a potentially significant source of nutrients and pollutants to the Lower Vasse River. This strategy is focussed on improving understanding of this problem to guide future management. It also includes actions to maintain and expand best practice stormwater management to improve water quality.

Management actions:

WQ1.8 Quantify nutrient and pollutant exports from Busselton LIA to the Lower Vasse River to inform a case for deep sewerage.

WQ1.9 Explore options to secure deep sewerage for the Busselton LIA in partnership with Water Corporation.

WQ1.10 Assess opportunities for greater connection to existing sewerage infrastructure within the Lower Vasse River catchment. If there a significant opportunity exists, investigate options and incentives to increase connectivity.

WQ1.11 Planning decisions to include appropriate sewerage management requirements and best practice water management, through implementing the *Better Urban Water Management* framework.

WQ1.12 Develop a prioritised program for stormwater WSUD upgrades to maximise nutrient reduction outcomes.

WQ1.13 Support educational campaigns that aim to reduce nutrients in runoff through individual and community actions (e.g. Bay OK).

WQ1.14 Support implementation of the Vasse-Wonnerup Wetlands and Geographe Bay WQIP (DoW 2010).

5.2.2 Strategy WQ2: Reducing nutrient inputs from the rural catchment

Agricultural activities in the Vasse River catchment influence nutrient inputs via the Vasse Diversion culvert, which may increase when the culvert capacity is increased (see Water Flows). There are also some rural land use activities remaining in the Lower Vasse River catchment area. This strategy reflects catchment management initiatives recommended in the WQIP, and future management direction in improving rural drainage.

Management actions:

WQ2.3 Support projects focussed on reducing nutrient exports from rural catchment of the Lower Vasse River, as recommended in the Vasse-Wonnerup Wetlands and Geographe Bay WQIP (DoW 2010):

- *Improve fertiliser management throughout the catchment*
- *Improve effluent management at dairy sheds and feedlots*
- *Implement riparian management and stock control on streams and drains*
- *Use soil amendments on sandy soils*
- *Use perennial pastures when suitable*

WQ2.4 Explore opportunities for enhanced nutrient assimilation in rural drains in the Lower Vasse River catchment, particularly those in reserves.

5.2.3 Strategy WQ3: Water treatment

Even when substantial reductions in nutrient loads are achieved, algal blooms often persist owing to ongoing internal nutrient supply. This strategy includes remediation approaches that address in-situ water quality, by treating water to reduce nutrient levels and algal blooms.

Management actions:

WQ3.4 Incorporate outcomes from the Water Quality Treatment Trials (2016-2018) into future management planning.

WQ3.5 Undertake seasonal water treatments in priority amenity area/s prior to algal bloom establishment, ensuring physical isolation to maximise effectiveness (dependent on outcomes Water Quality Treatment Trials, 2016-2018).

WQ3.6 Maintain research partnerships to identify and investigate new technologies to treat water in the future.

5.3 Ecology

5.3.1 Strategy E1: Riparian vegetation management

Riparian vegetation provides important habitat and supports ecosystem functions that maintain water quality. This strategy directs weed control and revegetation to improve and expand vegetated areas.

Management actions:

E1.6 Develop and implement a revegetation program for City-managed foreshore reserves, considering recommended rehabilitation areas reported in Ecoedge (2017).

E1.7 Continue to impose appropriate conditions on new developments adjacent to the Lower Vasse River that ensure future vesting and revegetation of foreshore reserves.

E1.8 Include creation and improvement of habitat for birds and possums in planning riparian revegetation.

E1.9 Update the Vasse River Action Plan in partnership with adjacent landholders, and extend this throughout the Lower Vasse River study area.

E1.10 Minimise fire risks associated with foreshore reserves by: reducing growth of annual grassy weeds; and considering species type, height and planting density when planning revegetation.

5.3.2 Strategy E2: Understanding and protecting waterbirds

Although there is high community appreciation of waterbirds in and around the Lower Vasse River, there is little formal understanding of bird populations and key habitats. This strategy will improve knowledge to guide protection and enhancement of bird habitat. There is potential for community contribution to this through a citizen science approach.

Management actions:

E2.5 Undertake a survey of waterbirds of the Lower Vasse River and identify important habitat zones, with strong involvement from the community.

E2.6 Protect identified important bird habitat zones through revegetation and weed control, recognising the current role of weeds as habitat.

E2.7 Create additional habitat zones for birds by placing large woody debris emerging from the water.

E2.8 Avoid identified important bird habitat zones when planning future infrastructure, and consider nesting season when planning works.

5.3.3 Strategy E3.1 Controlling invasive species

Mexican waterlily and feral goldfish are significant invasive species in the Lower Vasse River, impacting substantially on ecology and water quality. This strategy supports ongoing control programs for these species, but recognises the role of waterlily in reducing algal blooms.

Management actions:

E3.5 Prevent of further spread of Mexican waterlily through herbicide control and/or shading.

E3.6 Undertake strategic control of Mexican waterlily to progressively reclaim areas of open water, while minimising adverse impacts and preventing a return to algal blooms in these areas.

E3.7 Undertake regular feral fish eradication activities in partnership with Murdoch University.

E3.8 Undertake targeted control of arum lily and Brazilian pepper trees throughout the Lower Vasse River study area.

5.4 Water flow

5.4.1 Strategy WF1: Optimising flows

This strategy considers potential for water quality outcomes by manipulating flow inputs from the Vasse Diversion Drain, and by increasing summer flows. Increased flow inputs from the Vasse Diversion Drain require careful consideration of nutrient loads and flood protection. While there are limited sources of summer flow, there is scope to further investigate options and benefits of internal water circulation. This could be made more feasible through the Living Streams approach.

Management actions:

WF1.7 Increase flushing of the river by installing a second 900mm culvert at outflow point from Vasse Diversion Drain, in accordance with recommendations from the Reconnecting Rivers Report (DWER 2018).

WF1.8 Monitor impacts of increasing flows into the Lower Vasse River.

WF1.9 Undertake intensive monitoring water quality in the Vasse Diversion to support operational guidelines for managing the culvert.

WF1.10 Develop operational guidelines for the Vasse Diversion culvert that defines responsibilities and provides formal guidance for manipulation of the valve to maximise water quality benefits and minimise risk of flooding.

WF1.11 Review function of the Butter Factory weir boards to inform their future use and need for replacement.

WF1.12 Investigate potential for increasing internal circulation in the system during summer to reduce residence time for phytoplankton.

5.5 Sediments

5.5.1 Strategy S1: Sediment removal

The accumulated organic sediment in the Lower Vasse River provides an ongoing internal source of nutrients that drive algal blooms. These sediments also create a hostile environment for beneficial native aquatic plants and benthic aquatic fauna. This strategy includes removing sediment through an adaptive approach over time and considers alternatives to removal.

Management actions:

S1.4 Undertake a small-scale sediment removal project, using geotextile bags for dewatering and disposal, to assess cost and logistics of this approach.

S1.5 Determine feasibility of disposal options for future sediment removal: landfill, composting, soil conditioner.

G2.4 Depending on outcomes of small scale removal, undertake staged removal of sediments in the Lower Vasse River as a component of Living Streams design.

5.6 Amenity, recreation and education

5.6.1 Strategy ARE1: Improving facilities and information

Management actions:

ARE1.6 Review existing facilities and develop a concept plan for strategic pathways and viewing points that connect people with the river.

ARE1.7 Update the interpretive signage around the river to provide information on of the history, ecology, hydrology and management of the Lower Vasse River.

ARE1.8 Develop online and printed resources with interesting and important information on ecology, water quality, history and management of the Lower Vasse River.

ARE1.9 Establish bird watching areas and hides in appropriate places with informational material.

ARE1.10 Encourage opportunities for citizen science to contribute to understanding and appreciation of the Lower Vasse River.

5.6.2 Strategy ARE1: Public health management

There are many months of the year when algal blooms are not present and some areas do not experience regular summer algal blooms. The current approach of leaving warning signs in place throughout the year contributes to poor public perception of river health, and is not appropriate in terms of actual risk.

Management actions:

ARE2.4 Continue monitoring phytoplankton species and densities to inform public health notifications.

ARE2.5 Review algal bloom warning sign protocol and prepare a communication program to inform the community when harmful algal blooms occur.

ARE2.6 Develop a policy for use of recreational watercrafts in the Lower Vasse River, including consideration of public health constraints.

5.7 Culture and Heritage

5.7.1 Strategy CH1: Recognising Wadandi custodianship

Wadandi people have a strong connection to the Lower Vasse River and have considerable interest in its future management. This strategy will improve involvement of the Wadandi community in decisions and actions on river health and cultural connection.

Management actions:

CH1.6 In partnership with Wadandi people, include reference to traditional custodianship of the waterways and land in development of information resources.

CH1.7 Manage future access in a way that avoids additional disturbance and considers protection of potential sites of significance – however Wadandi activities such as fishing, camping, the gathering of bush foods and family recreational and educational activities, should not be restricted by implementation of this plan.

CH1.8 Seek to improve partnerships with the Wadandi community to increase their involvement in the management, protection and restoration of the Lower Vasse River.

CH1.9 Consult further with Wadandi representatives in regards to specific works which result from this plan.

CH1.10 Support programs that engage the Wadandi community in implementation of works associated with this plan.

5.7.2 Strategy CH2: Preserving historical values

Working towards the vision will improve community perception of the Lower Vasse River as an iconic and historical feature of the Busselton. The history of the river should be preserved in terms of physical structures and records of information.

Management actions:

CH2.3 Identify and ensure appropriate maintenance of sites of historical importance.

CH2.4 Develop interpretive material to increase understanding of local history, and to promote, appreciate and access historical sites.

5.8 Governance

5.8.1 Strategy G1: Collaborative and adaptive management

The City has coordinated the development of this WMP and has overall responsibility for implementation, but partnerships with other stakeholders will be essential to achieve many management actions and assess their outcomes. This strategy provides for a collaborative approach to management and will ensure outcomes of actions and new research inform future decisions. Roles and responsibilities of key stakeholders are defined in Table 4.

Management actions:

G1.2 The City to consider securing management orders over the waterway and adjacent public lands in Lower Vasse River study area, to facilitate implementation of this plan.

G1.5 Establish a Management Advisory Group comprised of representatives from the City, Department of Water and Environmental Regulation, Department of Biodiversity, Conservation and Attractions, Water Corporation of WA, GeoCatch, Wadandi representatives, and other community representatives.

G1.6 Continue water quality monitoring in the Lower Vasse River.

G1.7 Ensure adequate monitoring and reporting of outcomes from management actions, and feedback results into future management actions.

G1.8 Maintain and develop partnerships with research organisations to improve knowledge and management of the Lower Vasse River.

5.8.2 Strategy G2: Optimising planning tools

There is potential for the City to facilitate improved management through the planning and development framework. This strategy builds on the *Optimising Planning Tools* project, which outlines the potential use of planning tools in water quality protection.

Management actions:

G2.5 Improve clarity of planning approval requirements for changes to land use and new developments in the agricultural sector (e.g. horticulture, dairies, feedlots).

G2.6 Assess future development proposals and changes of land-use on adjoining lands with consideration of impacts on the Lower Vasse River.

G2.7 Include 50m wide foreshore reserves as part of future development adjacent to the river.

6 Implementation

6.1 Roles and responsibilities

The lead role of the City in the future management of the Lower Vasse River will be recognised through endorsement and adoption of this WMP. This will task the City with responsibility for coordinating implementation, however key stakeholders will have ongoing roles in many aspects of the WMP. These roles and responsibilities are defined in Table 5.

As captured in action G1.1 a Management Advisory Group is recommended to oversee implementation of this WMP, comprised of representatives from the City, Department of Water and Environmental Regulation, Department of Biodiversity, Conservation and Attractions, Water Corporation of WA, GeoCatch, Wadandi representatives and broader community representatives.

6.2 Management areas

In planning for implementation of management actions, it is helpful to define specific management areas of the catchment and river/foreshore, based on the characteristics of the areas and thus the actions that will be applicable. These are described as follows:

River and foreshore areas:

A. From the Butter Factory weir to Strelly Street, with significant areas of public reserve
B. From Strelly Street to Busselton Bypass, with adjacent residential and commercial areas and less prominent reserves
C. From Busselton Bypass to the Vasse Diversion, with adjacent rural properties

Catchment areas:

A. Busselton light industrial area
B. Other residential and commercial areas
C. Rural areas downstream of the Vasse Diversion
D. Rural catchment upstream of the Vasse Diversion

6.3 Implementation process

An adaptive process of action planning, works, evaluation and reporting is recommended for the WMP, summarised by Figure 22. The strategies and actions presented provide the basis for planning actions for a specified period of time, dependent on achievable priority works and research within available budgets. This would be a key role of the Management Advisory Group. Outcomes of these actions are measured through adequate monitoring, with results assessed in terms of progress towards the management objectives and vision. Reporting of outcomes to the community is essential to maintain community support and this forum would provide an opportunity to gain input to the next action planning cycle.

Figure 22. Implementation process for the Lower Vasse River Waterway Management Plan.

Table 4. Roles and responsibilities of key stakeholders for implementation of the Lower Vasse River Waterway Management Plan.

Stakeholder	Roles and Responsibilities
City	Overall implementation of the WMP. Management of reserves. Stormwater infrastructure upgrades and maintenance. Operation of the Vasse Diversion culvert. Operation of the Butter factory Weir boards. Support to community groups.
Department of Water and Environmental Regulation	Monitoring of water quality. Technical contributions to management decisions. Coordination of future investment in waterways management through Revitalising Geographe Waterways.
GeoCatch	Support to private landholders to improve land and waterway management in the catchment. Educational programs to minimise nutrient and sediment loads. Education, habitat restoration, and community group support for protection of Western Ringtail Possums.
Water Corporation	Managing flooding risk. Support to operational decisions for the Vasse Diversion culvert. Sewerage infrastructure development. Rural drainage maintenance, with potential to improve sediment trapping and nutrient assimilation.
Department of Biodiversity, Conservation and Attractions	Coordinate native wildlife management programs and implement recovery plans for native flora and fauna of conservation significance. Provide guidance and direction to community group in relation to the protection and conservation of Western Ringtail Possums. Providing information about native flora and fauna.
South West Boojarah Working Party	Advocating protection and enhancement of the Vasse River. Providing input to management decisions that affect environmental and cultural values. Engagement and participation of Aboriginal people in management decisions and actions.
Friends of reserves groups	Future role in local-level advocacy and management actions.

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8 Appendices

Appendix 1. List of vascular flora found within the Survey Area of the Lower Vasse River (Ecoedge 2017).

FAMILY	LATIN NAME	COMMON NAME	NATURALISED	PLANTED
Anacardiaceae	*Schinus terebinthifolius*	Pepper Tree	*	
Apiaceae	*Centella asiatica*	Centella		
Apocynaceae	*Vinca major*	Blue Periwinkle	*	
Araceae	*Zantedeschia aethiopica*	Arum Lily	*	
Asteraceae	*Lactuca saligna*	Wild Lettuce	*	
Asteraceae	*Sonchus asper*	Rough Sowthistle	*	
Casuarinaceae	*Allocasuarina fraseriana*	Sheoak		
Cyperaceae	*Carex divisa*	Divided Sedge	*	
Cyperaceae	*Ficinia nodosa*	Knotted Club Rush		
Cyperaceae	*Gahnia trifida*	Coast Saw-sedge		
Cyperaceae	*Lepidosperma gladiatum*	Coast Sword-sedge		
Dennstaedtiaceae	*Pteridium esculentum*	Bracken		
Dilleniaceae	*Hibbertia cuneiformis*	Cutleaf Hibbertia		
Euphorbiaceae	*Euphorbia terracina*	Geraldton Carnation Weed	*	
Fabaceae	*Acacia saligna*	Orange Wattle		
Fabaceae	*Lupinus cosentinii*	Blue Lupin	*	
Fabaceae	*Vicia sativa*	Common Vetch	*	
Fabaceae	*Viminaria juncea*	Swishbush		
Goodeniaceae	*Dampiera alata*	Winged-stem Dampiera		
Haemodoraceae	*Anigozanthos flavidus*	Tall Kangaroo Paw		
Juncaceae	*Juncus kraussii*	Sea Rush		
Juncaceae	*Juncus pallidus*	Pale Rush		
Menyanthaceae	*Liparophyllum lasiospermum*			
Moraceae	*Ficus carica*	Common Fig	*	
Myrtaceae	*Agonis flexuosa*	Peppermint		
Myrtaceae	*Astartea scoparia*	Common Astartea		
Myrtaceae	*Calothamnus quadrifidus*	One-sided Bottlebrush		x

FAMILY	LATIN NAME	COMMON NAME	NATURALISED	PLANTED
Myrtaceae	*Corymbia calophylla*	Marri		
Myrtaceae	*Eucalyptus citriodora*	Lemon-scented Gum	*	x
Myrtaceae	*Eucalyptus rudis*	Flooded Gum		
Myrtaceae	*Kunzea glabrescens*	Spearwood		?
Myrtaceae	*Melaleuca cuticularis*	Saltwater Paperbark		
Myrtaceae	*Melaleuca huegelii*	Chenille Honeymyrtle		x
Myrtaceae	*Melaleuca rhaphiophylla*	Swamp Paperbark		
Myrtaceae	*Melaleuca viminea*	Mohan		
Myrtaceae	*Taxandria parviceps*			
Papaveraceae	*Fumaria muralis*	Wall Fumitory	*	
Poaceae	*Bromus diandrus*	Great Brome	*	
Poaceae	*Cenchrus clandestinus*	Kikuyu Grass	*	
Poaceae	*Cortaderia selloana*	Pampas Grass	*	
Poaceae	*Cynodon dactylon*	Couch	*	
Poaceae	*Ehrharta calycina*	Perennial Veldt Grass	*	
Poaceae	*Ehrharta longiflora*	Annual Veldt Grass	*	
Poaceae	*Holcus lanatus*	Yorkshire Fog	*	
Poaceae	*Phleum pratense*	Timothy	*	
Polygonaceae	*Persicaria hydropiper*	Water Pepper		
Polygonaceae	*Rumex conglomeratus*	Clustered Dock	*	
Proteaceae	*Banksia grandis*	Bull Banksia		
Proteaceae	*Banksia littoralis*	Swamp Banksia		
Salicaceae	*Salix babylonica*	Weeping Willow	*	
Solonaceae	*Solanum linnaeanum*	Apple of Sodom	*	
Typhaceae	*Typha orientalis*	Typha		

Appendix 2. Summary of Water Sensitive Urban Design infrastructure

WSUD infrastructure implemented in the Lower Vasse River Catchment

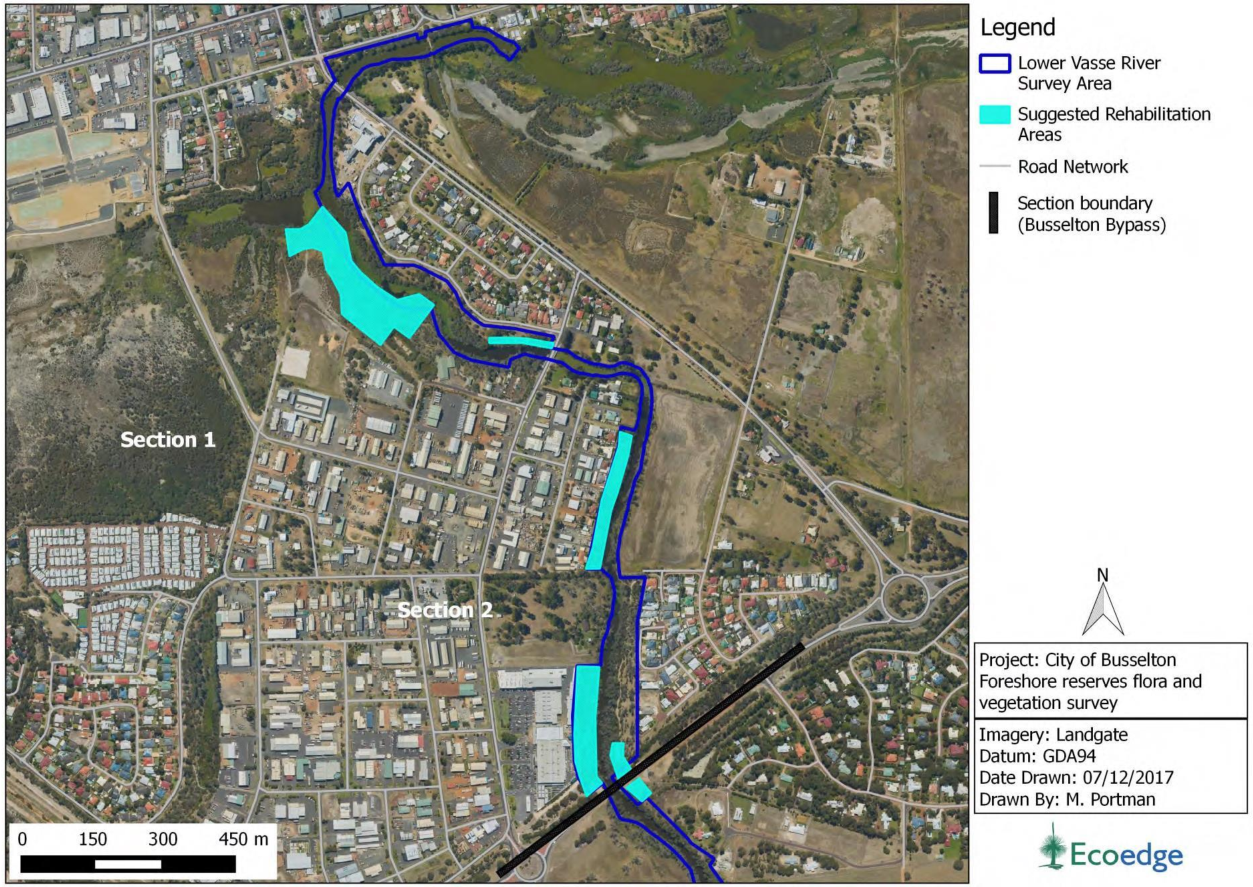
Description
CBD area
Kent Street streetscaping Kent Street biofiltration bed
Coles Carpark Bio-filtration Gardens
Woolworths carpark – Rain Gardens and soak wells
Queen Street/Prince Street Bio-filtration beds
Busselton Community Resource Centre Rain Gardens
Busselton Community Youth Centre Rain gardens– High and Jolliffe Street Busselton
Queen Street Outfall – Natural wetlands
Busselton LIA
Frederick Street – Artificial ponds and vegetated swales
College Avenue – Constructed wetland
College – Cook connector drain
Bunnings Carpark – detention ponds
Fairlawn road – Vegetated Swale
Strelly Street – Demonstration – Biofiltration swales and rain gardens Urban Drainage Pilot Project - Details on Strelly Street biofiltration swales
Community Garden – Vegetated swales and detention ponds
Bunbury Street/Roe Terrace – Vegetated detention pond and constructed wetland
Roe Terrace – Vegetated Swale
Bunbury/Barlee Street – Bio-filtration basin

Locations of WSUD in Busselton CBD:

Locations of WSUD in Busselton LIA:

Appendix 3. Recommended revegetation areas for the Lower Vasse River Study area

Recommended rehabilitation areas identified the 2017 vegetation survey (Ecoedge 2017). Note the western foreshore area to the south was revegetated in June 2018.



Appendix 4. Suggested species for revegetation of the Lower Vasse River

Revegetation species list for damp and terrestrial areas (Ecoedge 2017).

Family	Species	Common Name	Habitat	Form
Cyperaceae	*Ficinia nodosa*	Knotted Club Rush	Damp	Rush
Cyperaceae	*Gahnia trifida*	Coast Saw-sedge	Damp	Sedge
Cyperaceae	*Lepidosperma gladiatum*	Coast Sword-sedge	Damp	Sedge
Cyperaceae	*Lepidosperma squamatum*		Dry	Sedge
Dennstaedtiaceae	*Pteridium esculentum*	Bracken	Dry	Herb
Dilleniaceae	*Hibbertia cuneiformis*	Cutleaf Hibbertia	Dry	Shrub
Dilleniaceae	*Hibbertia diamesogenos*		Dry	Shrub
Ericaceae	*Astroloma ciliatum*	Candle Cranberry	Dry	Shrub
Fabaceae	*Acacia saligna*	Orange Wattle	Damp	Shrub
Fabaceae	*Hardenbergia comptoniana*	Native Wisteria	Dry	Climber
Fabaceae	*Jacksonia gracillima*		Dry	Shrub
Fabaceae	*Viminaria juncea*	Swishbush	Damp	Shrub
Goodeniaceae	*Dampiera alata*	Winged-stem Dampiera	Damp	Shrub
Haemodoraceae	*Anigozanthos flavidus*	Tall Kangaroo Paw	Dry	Herb
Hemerocallidaceae	*Agrostocrinum scabrum*	Blue Grass Lily	Dry	Herb
Juncaceae	*Juncus kraussii*	Sea Rush	Damp	Rush
Juncaceae	*Juncus pallidus*	Pale Rush	Damp	Rush
Myrtaceae	*Agonis flexuosa*	Peppermint	Dry	Tree
Myrtaceae	*Astartea scoparia*	Common Astartea	Damp	Shrub
Myrtaceae	*Calothamnus sanguineus*	Silky-leaved Blood flower	Dry	Shrub
Myrtaceae	*Eucalyptus rudis*	Flooded Gum	Damp	Tree
Myrtaceae	*Hypocalymma angustifolium*	White Myrtle	Damp	Shrub
Myrtaceae	*Kunzea glabrescens*	Spearwood	Dry	Shrub
Myrtaceae	*Melaleuca cuticularis*	Saltwater Paperbark	Damp/ Saline	Tree
Poaceae	*Austrostipa flavescens*		Dry	Herb
Proteaceae	*Conospermum caeruleum* ssp. *marginatum*	Blue Brother	Dry	Shrub
Proteaceae	*Xylomelum occidentale*	Woody Pear	Dry	Tree
Santalaceae	*Exocarpos odoratus*	Scented Ballart	Damp	Shrub
Thymelaeaceae	*Pimelea angustifolia*	Narrow-leaved Pimelea	Dry	Shrub

List of emergent and submerged species for restoration of seasonally and permanently inundated areas (littoral zone).

Species	Common Name	Habitat	Form
Centella asiatica	Native celery, Gotu-cola	seasonally emergent	groundcover
Cotula coron			
Melaleuca raphiophylla	Swamp paperbark	seasonally emergent	tree
Eleocharis acuta	Common spike-rush	seasonally-permanent emergent	Rush
Schoenoplectus vallidus		seasonally-permanent emergent	rush
Baumea articulata	Jointed twigrush	seasonally-permanent emergent	rush
Baumea juncea		seasonally emergent	rush
Baumea rubiginosa		seasonally emergent	
Liparophyllum sp		seasonally emergent	broad leaf
Cycnogeton huegelii	Water ribbons	submerged – seasonally emergent aquatic	narrow leaves
Cycnogeton procera	Water ribbons	submerged aquatic	narrow leaves
Potamogeton crispus	Curly pondweed	submerged aquatic	branched macrophyte
Potamogeton ochreatus		submerged aquatic	branched macrophyte
Potamogeton drummondii		submerged aquatic	submerged and floating leaves
Ottelia ovalifoloa	Swamp lily	submerged aquatic	submerged and floating leaves
Stuckenia pectinatus		submerged aquatic	branched macrophyte

Independent Review of the Current and Future Management of Water Assets in the Geographe Catchment, WA

Final Report

Professor Barry T Hart
with assistance from Dr Bonnie Bonneville

March 2014

Executive Summary

This Final Report contains the finding of an independent review of the management of water-related assets in the Geographe catchment, undertaken by Professor Barry Hart, Director of Water Science Pty Ltd.

The review focused on governance structures and management priorities in three areas: (a) management of the Vasse-Wonnerup Ramsar wetlands, (b) overall water quality management in the Geographe catchment contributing to Geographe Bay, and (c) water quality management of local waterways, including the Lower Vasse River, Vasse Diversion Drain and Toby Inlet.

The review has undertaken considerable consultation with the community, key agencies, local government and industry, including two visits to the Busselton region by Prof Hart and the preparation of two previous reports for comment: an *Issues Paper* released on 5 December 2013 and a *Discussion Document* released on 3 February 2014.

The Final Report contains three main sections covering:

- The water-related assets, issues they face and their current management arrangements,
- An assessment of the effectiveness of the current management against eight assessment criteria,
- Possible future management options, including recommendtions and priority actions.

A summary of the key aspects in these sections is provided below.

Assets, issues, current management and assessment of current arrangements

Geographe catchment - Water quality management in the Geographe catchment is directed by an very useful WQIP plan developed in 2009, which is underpinned by the need to introduce a range of (voluntary) BMPs to achieve the desired reduction in nutrient losses from agricultural and urban land. GeoCatch and DoW, with significant contributions from SWCC, are the principal organisations implementing the Geographe WQIP, with useful assistance from DAFWA, CoB and SoC, some industry groups (Western Dairy, fertiliser industry) and SWCC (provide some funding. The focus of the WQIP in the agricultural areas is on implementing three BMPs – riparian zone revegetation and fencing, dairy shed effluent management and fertiliser management. There is evidence that GeoCatch have attempted to focus this implementation in the priority catchments feeding into the Vasse-Wonnerup wetlands (e.g. Upper Vasse/Vasse Diversion Drain, Lower Vasse, Sabina, Abba and Ludlow Rivers). However, there does not appear to be a documented strategic approach to target these catchments.

The WQIP is largely single purpose (reduction of nutrient loads), and is not a catchment management plan. Some obvious improvements have been made in the management of dairy shed effluent, streambank fencing and revegetation, and stock exclusion from waterways. Considerable efforts have also occurred in improving fertiliser management, but there is no evidence yet that this effort has resulted in farmers using less fertiliser. However, overall the implementation of BMPs over the past 4 years has been minimal due primarily to a lack of adequate funding, and in agricultural areas also to the fact that uptake of BMPs by farmers is voluntary. There appears to be no consistent program of incentive payments currently available to assist farmers to introduce BMPs. The program is heavily reliant on State and Federal NRM funding for support. Additionally, there appears to be no regulation (or enforcement) that requires farmers to contain and treat polluted runoff from dairy sheds or to keep cattle out of waterways.

Vasse-Wonnerup wetlands – These Ramsar-listed wetlands are now very different to before European settlement. They now receive much less freshwater inflow as a result of the extensive catchment drainage network, are cut off from the ocean by floodgates, and receive excessive amounts of nutrients from the catchment (Lower Vasse, Lower Sabina and Ludlow Rivers), the sediments and cattle grazing in the immediate vicinity of the wetlands themselves. These high nutrient concentrations are resulting in increased growth of macroalgae, and at times toxic blue-green algae, that are unsightly and can cause additional problems (e.g. fish kills) when they die. However, despite these changes, the wetlands still have high biodiversity and ecological values; they support a great abundance and variety of waterbirds, and have good populations of macrophytes (e.g. *Ruppia megacarpa*), fish and macroinvertebrates. Currently, there is no comprehensive management plan for these wetlands despite the fact that they are Ramsar-listed.

A new emergency 'Fish Kill Mitigation and Response Plan' has been developed and is in place for the 2013-14 summer, with DoW as the coordinator. This new incident response plan has clear trigger criteria, monitoring requirements and agreed response actions, but has yet to be fully implemented. A comprehensive long-term strategic management plan for the Ramsar-listed Vasse-Wonnerup Wetlands is also needed. Management objectives should include: water bird habitat, biodiversity, ecological condition, cultural values, recreation, aesthetics, flood protection and operation of the floodgates.

Lower Vasse River – This river now receives only a fraction of its original flow, since the major part of the catchment is cut off by the Vasse Diversion Drain. But it does receive an excessive nutrient load from agricultural and urban sources. In Busselton, the Lower Vasse River is maintained as a 'lake' for recreational and aesthetic purposes by a set of barriers (boards) located at the Butter Factory. This 'lake' is eutrophic and regularly experiences algal blooms over summer, which reduces the recreational and amenity value of the 'lake' and causes offensive odours. The current management of the Lower Vasse River, and particularly the 'lake' section in Busselton is far from ideal; there is no comprehensive management plan and no obvious lead agency.

The WQIP provides a useful management plan for the overall Lower Vasse River catchment, focused as it is on the long-term reduction of nutrients from agricultural and urban areas. However, the short-term management of the 'lake' is more problematic. The major algal blooms associated with this part of the river are due to excessive nutrients, a lack of adequate flow, particularly in summer, and the fact that the river is dammed. The question of who should manage the 'lake' section of the Lower Vasse River (CoB or DoW) needs to be resolved.

Vasse Diversion Drain – This Drain captures most of the Vasse River flow, approximately half the flow of the Sabina River, and most of the flow of treated effluent from the Busselton wastewater treatment plant. It is extremely important in providing 1-in-100 year flood protection to Busselton. The Water Corporation effectively manage the drainage and flood-protection functions of the Vasse Diversion Drain, however, but have no legislative requirement to consider the water quality in the drain. Currently, the Vasse Diversion Drain does not achieve the nutrient targets established by the WQIP, and is discharging excessive amounts of TP and TN to Geographe Bay. It is possible that the newly formed Busselton Water Corporation may take over responsibility for the Vasse Diversion Drain (and other drainage assets in the Geographe catchment), and include water quality and nutrient reduction as management objectives in addition to drainage and flood protection.

Toby Inlet - Toby Inlet is highly valued for recreation and aesthetics, but currently experiences regular blooms of macroalgae and phytoplankton, and offensive odours when these algal blooms die. These issues are the result of excessive nutrient inputs to the estuary, and a lack of adequate flushing. The Station Gully Drain and associated causeway, that pass through the eastern end of the Inlet, is a major reason for the poor flushing. This could be largely resolved by the removal of the causeway or the enlargement of the culvert in the causeway. Management of Toby Inlet is minimalist at best. The community-based Toby Inlet Catchment Group have developed a Management Plan for Toby Inlet, and could do a serviceable job of managing the Inlet if they had more funding and greater backup from CoB and DoW.

Possible future management options

After consideration of the roles and responsibilities of the key organisations, three options for possible future management structures were proposed (see Figure for details):

- Option1 – the establishment of a single Geographe Catchment and Wetland Management Authority that would manage all the assets,
- Option 2 – the establishment of an overall lead agency to coordinate the separate asset management arrangements,
- Option 3 – the establishment of separate asset management arrangements with no coordination.

After consideration of the advantages and disadvantages of each option, this review recommends Option 1 – a single Geographe Catchment and Wetland Management Authority. However, as this option seems unlikely to be favoured by the current WA Government, Option 2 is recommended.

The review has also concluded that which ever management option is adopted, it will need to be adequately resourced for at least a decade in order to make a significant improvement in the condition of the Geographe catchment key water-related assets. It is estimated that funding of the order of $3-5 million per year will be required.

Recommendations

Rec1: That the Minister adopt management Option 1 (see Figure).

Rec 2: In the event that Rec 1 is not accepted, that the Minister adopt management Option 2 (Figure). The Minister should consider in order the lead coordinating body being (a) DoW, (b) a restructured GeoCatch, and (c) a Ministerial Task Force with transition to a corporate model involving BWC (see Section 4.3.2 for details). Whatever form of lead *coordinatng body is agreed, this body should have the necessary powers to be able to exercise its functions effectively. This could take the form of an authority from the Monister for Water, or all three Ministers involved (Water, Environment and Agriculture/Fisheries).*

Rec 3: In the event that Rec 2 is accepted, that the arrangements outlined in Section 4.3.2 be established for the management of (a) the Geographe catchment (including waterways and rural drainage network), (b) the Vasse-Wonnerup wetlands, and (c) the Lower Vasse River and Toby Inlet.

Rec 4: That high priority be placed on the immediate development and implementation of a non-statutory management plan for the Vasse-Wonnerup wetlands, that incorportates both the VETWG and the emergency 'Fish Kill Mitigation and Response Plan'.

Rec 5: That until the Vasse-Wonnerup wetlands management plan is established, VETWG be retained (with DoW as chair) to implement the emergency 'Fish Kill Mitigation and Response Plan'.

Rec 6: That the lead agency for each of the water-related assets report annually to the community on both the asset condition (health) and effectiveness of management (perhaps using a simple Report Card format).

Rec 7: That an independent review of the Geographe catchment drainage network be commissioned to assess (a) its current and future relevance, including the current relevance of the '72 hour rule', (b) what might be done to make this drainage network more effective at reducing nutrients in addition to its flood protection and land drainage functions, (c) the potential for reengineering the drainage system to reconnect natural waterways adversely affected by drains and to provide more freshwater inflow into the Vasse-Wonnerup wetlands and the Lower Vasse River, and (d) the potential to modify the Station Gully drain so that additional water enters Toby Inlet.

Rec 8: That the current Geographe Water Quality Improvement Plan be reviewed with a view to updating it and expanding it into a broader Catchment Management Plan, and that the implemetation of this new plan be empowered by the Minister for Water.

Rec 9: That DoW continue to provide the science to underpin the management of the Geographe catchment waterways, Vasse-Wonnerup wetlands and Toby Inlet, including the current water quality monitoring program, catchment modeling, and scientific investigations.

Rec 10: That a research plan be developed for water-related assets in the Geographe catchment to identify the key knowledge needs, and the organisations able to conduct the necessary research (e.g. universities, CSIRO, DoW, DFAWA).

Rec 11: That DAFWA (in collaboration with DoW) undertake a program to better assess the effectiveness of the current agricultural BMPs.

Rec 12: That regulations be introduced to ensure best management practices related to dairies and dairy shed effluent are adopted.

Rec 13: That the WA Government establish a fund of $30 million over 10-years to provide core funding for the enhanced management of the water-related assets of the Geographe catchment, including the Vasse-Wonnerup wetlands.

Rec 14: That as part of this fund, the WA Government consider the options listed in Section 4.4 (namely a bid to the 'Royalties for Regions' fund, introduction of a 'catchment levy' on all ratepayers in the Geographe catchment, introduction of a special 'environmental levy' on urban ratepayers by CoB, introduction of a 'fertiliser levy' with the funds going to assist in the implementation of better fertiliser management in the Geographe catchment, and reintroduce a 'drainage levy' for rural properties to assist in the restructuring of the existing drainage network).

Priority actions

This independent review was commissioned largely because of the concern of the Busselton community at what they saw as the lack of an agreed lead agency, and a lack coordination and action by the agencies involved in the management of the Vasse-Wonnerup wetlands. It will be important that the community are convinced that urgent action is being taken on those issues of concern to them. This need is reflected in the priority actions listed below.

1. *Agree to develop and implement a non-statutory strategic management plan for the Vasse-Wonnerup wetlands, that incorporates both the VETWG and the emergency 'Fish Kill Mitigation and Response Plan' (Rec 4). This Plan must include consideration of the most*

appropriate operation of the floodgates and the desirability and feasibility of dredging the Vasse wetland.

2. *Agree that, until the Vasse-Wonnerup wetlands management plan is operational, VETWG be retained (with DoW as chair) to implement the emergency 'Fish Kill Mitigation and Response Plan' (Rec 5).*
3. *Decide upon the future overall management structure, including its resourcing, and implement the necessary arrangements (Recs 1, 2, 3, 4, 5, 13, 14).*
4. *Review the existing WQIP with a view to broadening it into a catchment and wetland management plan (Rec 8).*
5. *Establish an independent review of the Geographe rural drainage network (Rec 7).*
6. *Introduce regulations to ensure BMP for dairies are adopted (Rec 12).*

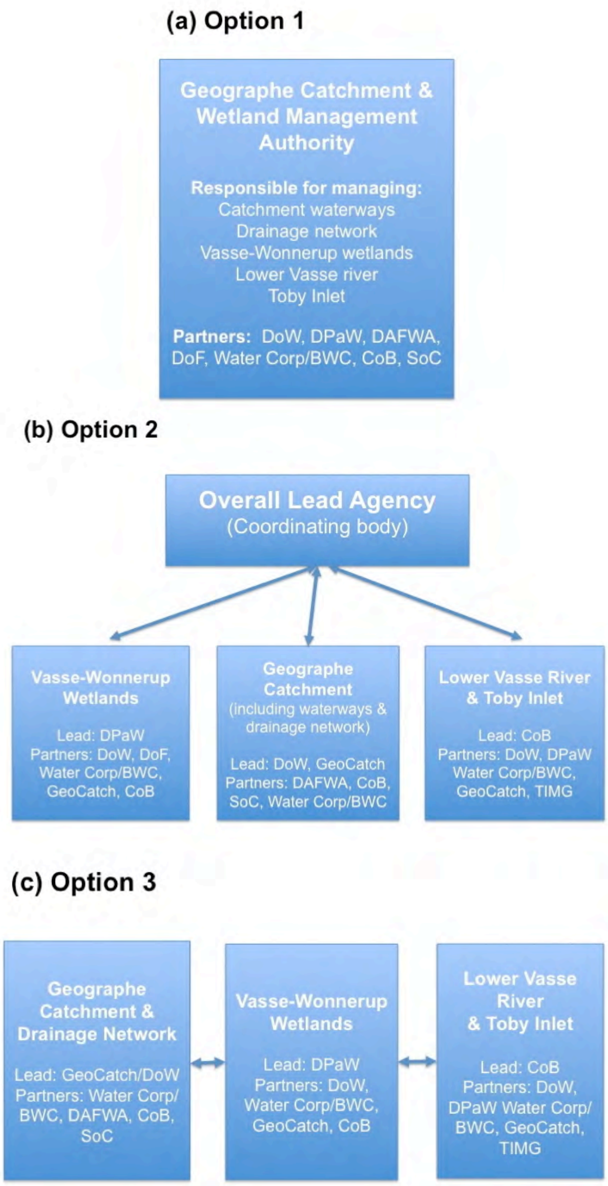


Figure: Diagram showing the main features of the three management options

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Abbreviations

BMP	Best Management Practice
BWC	Busselton Water Corporation
CoB	City of Busselton
DAFWA	Department of Agriculture and Food
DoF	Department of Fisheries
DoW	Department of Water
DPaW	Department of Parks and Wildlife
GeoCatch	Geographe Catchment Council
SoC	Shire of Capel
SWCC	South West Catchment Council
TICG	Toby Inlet Catchment Group
VETWG	Vasse Estuary Technical Working Group
Water Corp	Water Corporation
WQIP	Water Quality Improvement Plan

Somebody said that it couldn't be done,
But he with a chuckle replied
That 'Maybe it couldn't' but he would be one
Who wouldn't say so till he'd tried.
So he buckled right in with the trace of a grin
On his face. If he worried, he hid it.
He started to sing as he tackled the thing
That couldn't be done, and he did it!
Edgar Albert Guest[1]

1. Introduction

The Lower Vasse River, Toby Inlet and the Vasse-Wonnerup Wetlands have experienced poor water quality over the past 20-30 years, resulting in persistent algal blooms and occasional fish kills.

The need for better management of the Geographe catchment and associated rivers, wetlands and estuaries was recognised over 15 years ago with the estabishment of GeoCatch in 1997. GeoCatch was set up specifically as the management entity to lead and coordinate management of eutrophication (excessive nutrients) in the catchment. Their first action was to develop the *Lower Vasse River Cleanup Program* (including the *Vasse River Action Plan*) in partnership with the Waters and Rivers Commission (now DoW) and the Shire of Bussleton (now CoB). The overall aim of this Program was to improve the ecological health of the Lower Vasse River. The large number of on-ground actions successfully undertaken were reviewed in 2005 (Paice, 2005).

An important learning from this Program was that without whole-of-catchment actions to reduce nutrient loads, it was unlikely that the ecological health of the Lower Vasse River and the Vasse-Wonnerup wetlands would be improved. Fortuitously, at about this time the Commonwealth government commenced a national program under its *Coastal Catchments Initiative*, to fund the development of water quality improvement plans for many coastal catchment around Australia.

Given the experience gained through the *Lower Vasse River Cleanup Program,* the region was well placed to develop the *Vasse-Wonnerup Wetlands and Geographe Bay Water Quality Improvement Plan* (WQIP, DoW 2010a), to provide a whole-of-catchment approach to improving water quality. This WQIP was completed by DoW in 2009, and until recently the implementation of the Plan, largely by GeoCatch and DoW, has been funded by the Commonwealth and Western Australian governments.

The WQIP contains good information on the main sources of nutrients (the main cause of the poor water quality), the high priority management actions to reduce these nutrient loads, and targets to be achieved over the first 10-years and beyond. And although there has been considerable on-ground action aimed at introducing Best Management Practices (BMP) in agricultural and urban areas, it is not surprising that water quality still remains a major concern across the Geographe catchment. Experience in other regions of Australia and overseas suggests that it takes considerable time and investment to reduce nutrients from agricultural catchments – there is no 'quick fix'.

However, despite the usefulness of the WQIP, community and local government concern about the continuing poor water quality has increased over recent years, with this concern significantly heightened by the major fish kill event that occurred in the Vasse-Wonnerup Wetlands in April 2013. Another fish kill occurred in the Vasse Wetland in Februsary 2014.

In response to these concerns, the (then) Minister for Water, the Honourable Terry Redman MLA, announced the decision to undertake an independent review of waterways management efforts in the Vasse-Wonnerup Wetlands and Geographe catchment in August 2013. This recommendation was supported by an interagency workshop, coordinated by DoW in May 2013, as a critical step towards improving water quality management in this catchment.

Professor Barry Hart, Director of Water Science Pty Ltd, was engaged by DoW in October 2013 to undertake this independent review of the management of water assets in the Geographe catchment.

[1] Thanks to Jocelyn Elphick for this ditty.

The Terms of Reference require the review to focus on governance structure and management priorities within three areas:

- Overall water quality management of the catchment contributing to Geographe Bay,
- Management of the Vasse-Wonnerup Ramsar Wetlands, and
- Water quality management of local waterways, including the Lower Vasse River, Vasse Diversion drain and Toby Inlet.

The outcomes of this review were expected to provide:

- An evaluation of the current roles and responsibilities of key organisations involved in managing the above assets, which identified the positive and negative aspects of the current governance frameworks,
- Recommended options for alternative governance model(s) and management arrangements for future management of the three areas of this review, which may include a lead agency for each asset type, management body (with or without statutory responsibility), or an alternative model, and
- Priority actions to improve the management and condition of the three areas.

Two previous reports have been provided for community, key agency, local government and industry comment, these being:

- ***Issues Paper*** (Hart, 2013) released on 5 December 2013 following a visit by Professor Hart to the Geographe region in the period 13-18 November 2013 (Hart, 2013). This Issues Paper aimed to provide the community and key organisations with confidence that the independent review was underway and progressing well. It contained a summary of the stakeholder discussions and key issues identified by the community and key agencies to date, that were conveyed to Professor Hart when he visited the Geographe region. A small number of comments were received on the Issues Paper.

- ***Discussion Document*** (Hart, 2014) released on 3 February 2014 to provided the community, key agencies, local government and industry with: (a) information on the water-related assets, the issues they face and their current management arrangements, (b) an assessment of the effectiveness of the current management of these assets, and (c) possible future management options. The Discussion Document was available for 3 weeks to allow comment from the community, agencies, local government and industry. Professor Hart also visited the region in the period 10-13 February 2014 for a further round of discussions based on the information in the Discussion Document. A considerable number of comments and submissions were received (Appendix A).

The feedback and submissions on the Discussion Document were considered in the preparation of this Final Report.

This Final Report covers the water-related assets, the issues they are facing, and the current management arrangements in Section 2, and an assessment of the effectiveness of the current management against eight assessment criteria in Section 3. Section 4 contains governance options (models) for more effective future management arrangement, and then in Section 5 my recommendations for the best management model and a list the priority actions to put this new governance structure in place.

Professor Hart is most grateful for the assistance and information provided by all agencies and organisations, in particular DoW and GeoCatch, and from several members of the community. Dr Kath Lynch coordinated the collection of information, organised my visits, and generally contributed to the smooth running of this review.

2. Water Assets, Issues and Current Management

2.1 General

This section covers the key characteristics, current issues and current management of each of the three components of the study region – the Geographe Catchment, the Vasse-Wonnerup Wetlands and the local waterways (including the Lower Vasse River, Vasse Diversion drain and Toby Inlet).

The Geographe Catchment is located approximately 250 km south of Perth and occupies an area of approximately 2,000 km^2 between Bunbury and Cape Naturaliste. The catchment is bounded by the Darling Range, the Whicher Range and the Leeuwin-Naturaliste Ridge (Figure 1). Below these ridges is the southern-most part of the Swan coastal plain extending south and west to Dunsborough. This coastal plain is characterised by predominantly sandy-loam soils as well as poorly drained flats and wetlands.

The catchment has been extensively cleared and developed for agriculture. The predominant land uses being dairy, beef cattle grazing, forestry, horticulture and viticulture. Additionally, the region is rapidly becoming more urbanised, experiencing one of the highest rates of urban expansion in Australia, primarily because of the desirable lifestyle and holiday opportunities in the region. The major urban centres in the catchment are Busselton, Dunsbourough and Capel. The high urban growth rate is predicted to continue over the next 20 to 30 years.

The Geographe catchment has a number of important water assets, the most important being the Vasse-Wonnerup Wetlands, located just east of Busselton (Figure 1). These wetlands were listed as a Ramsar site in June 1990, largely on the basis that they are an important habitat for waterbirds (WRM, 2007).

There are 16 major waterways in the Geographe Catchment, with all but one (Capel River) being ephemeral and only flowing between June and October in most years (Figure 1). Before European settlement very few of these waterways flowed directly into Geographe Bay. Instead they flowed first into an extensive chain of wetlands stretching along the coast that emptied into the Vasse or Wonnerup estuaries, and then into Geographe Bay (Lane et al., 1997).

Currently, only the Lower Vasse, Lower Sabina, Abba and Ludlow rivers drain into the Vasse-Wonnerup Wetlands, with all other waterways flowing directly into Geographe Bay either through their natural outlets or artificially constructed drains[2]. Additionally, most of the Vasse River and approximately half the Sabina River are diverted directly to Geographe Bay via the Vasse Diversion Drain (Figure 2 & 7).

This review is focused on the Vasse-Wonnerup Wetlands, Toby Inlet and the catchment waterways, particularly the Lower Vasse River and Vasse Diversion Drain.

2.2 Geographe Catchment

2.2.1 System

The general features of the Geographe Catchment system have been summarised above. As noted, the catchment has been extensively developed for agriculture (mainly dairy production and beef cattle grazing), and is becoming more urbanised.

This agriculture and urbanisation, together with associated modification to waterways and the development of an extensive drainage network, has had two major adverse effects on the water assets. First, the ecological and water quality condition of the catchment's waterways are significantly degraded, and second the ecological and water quality condition of the downstream assets, particularly the Vasse-Wonnerup Wetlands, Toby Inlet and the Lower Vasse River, are also significantly degraded.

The major cause of this degradation is the excessive nutrient (mainly total phosphorus (TP) and total nitrogen (TN)) and organic matter loads entering them, but also because of a general reduction in freshwater inflows. The main activities contributing nutrients include: dairy shed effluent, fertiliser over-use, cattle grazing and un-sewered urban areas.

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[2] At the western end of the catchment a network of seasonal streams flow into Toby Inlet before draining into Geographe Bay.

Figure 1: Map showing the Geographe catchment, rivers and wetlands

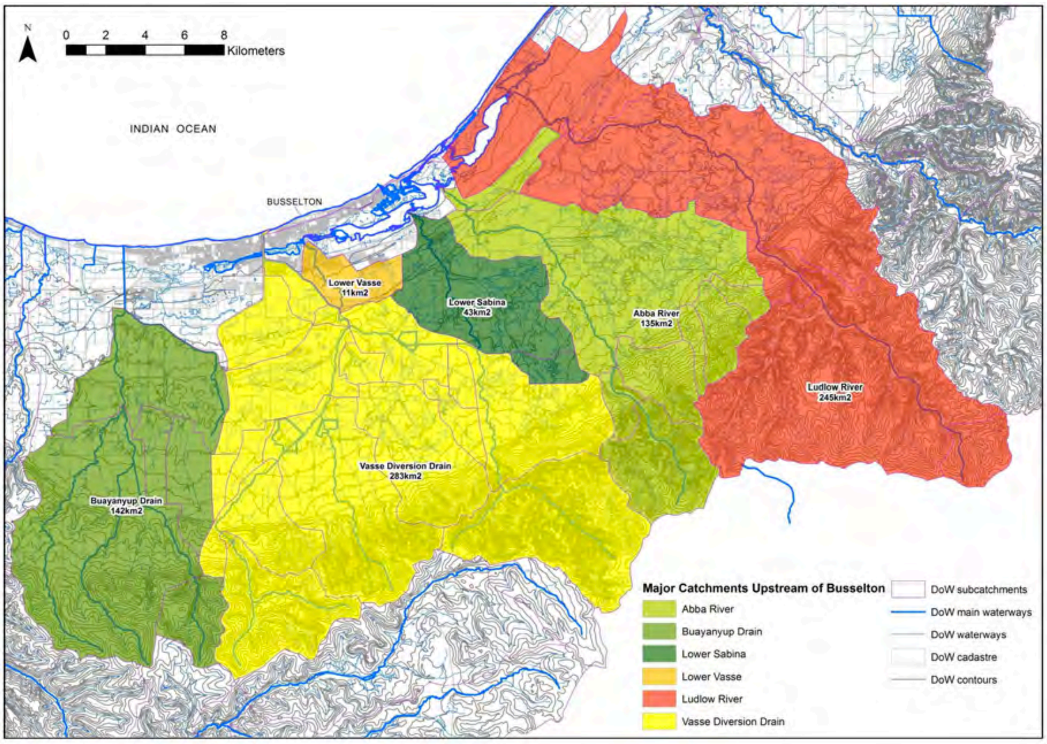


Figure 2: Map showing the rivers entering the Vasse-Wonnerup wetlands

Hydrology and drainage

European settlement resulted in many changes to the catchment's hydrology, particularly because of extensive clearing and drainage of the catchment. Catchment clearing caused increased runoff and large increases in river flows, and made the construction of artificial drainage necessary.

Drainage of the landscape started as early as the 1880s when the Capel River was diverted from the Wonnerup Inlet into Geographe Bay through the Higgins Cut. From this time until the 1950s, a series of hydrological alterations were made, with drainage works escalating during the 1920s and again in the 1950s (WRM, 2007). These works included the construction of floodgates on the Vasse and Wonnerup Wetlands to prevent saltwater incursion, a network of small drains to remove water from farmland, and a series of large arterial drains and river diversions to discharge surface flow directly to Geographe Bay (English, 1994; Water Corp, 2013).

The drainage system enabled farming of coastal areas that were previously inundated during winter, reduced saltwater incursion into pasture that bordered the estuaries, and protected the growing town of Busselton from flooding – thereby allowing it to expand into floodplain areas.

Additionally, over time most of the natural watercourses have been modified through diversion, channel straightening, de-snagging, enlargement of the channel and creation of levee banks. Also, as a result of the artificial drainage systems, many of the catchment's wetlands have been subsumed by agricultural and urban land uses. The remaining wetlands are generally in poor condition due to the impacts of the surrounding land uses and most are located on private land (DoW, 2010a).

The combined effect of catchment clearing, modification of waterways, removal of wetlands and the construction of effective drainage channels, has meant that the capacity of the catchment to retain sediment and nutrients has been significantly diminished. As a result both Geographe Bay and the Vasse-Wonnerup Wetlands now receive large loads of nutrients and organic matter delivered by the waterways during winter (DoW, 2010a).

Land use

The Geographe catchment is an important and productive agricultural area, with the main agricultural industries being dairy and beef cattle, forestry, horticulture and viticulture.

Additionally, the Geographe region has one of the highest rates of urban expansion in Australia. The desirable lifestyle and holiday opportunities available in the region have created a large rate of growth and development over the past 10 years. The high urban growth rate is likely to continue during the next 20 to 30 years. Population in Busselton is projected to increase from approximately 32,000 residents in 2011 to approximately 50,000 residents by 2031, and in Capel the increase over the same period is projected to be around 13,000 to 18,000 residents.

Water Quality Improvement Plan

As noted earlier, the development of the *Vasse-Wonnerup Wetlands and Geographe Bay Water Quality Improvement Plan* (DoW 2010a), and its implementation since 2009, followed almost a decade of action by GeoCatch, DoW and CoB through the *Lower Vasse River Cleanup Program* (Paice, 2005).

This WQIP is now guiding much of the current management of waterways in the Geographe catchment. As the title indicates, this Plan is focused largely on water quality and not more broadly on the ecological condition of these assets, although some actions in the Plan (e.g. riparian zone revegetation, environmental flows) will contribute to improved ecological health. It should be noted that the relatively narrow focus of these WQIPs resulted from the rather constrained format required by the Commonwealth government.

It is expected that the 5-year review of this WQIP will consider widening its scope to include broader issues of catchment management and waterway health, as is occurring with more recent WQIPs being developed by DoW (e.g. the Leschenault Estuary WQIP, Hughues-dit-Ciles et al., 2012).

However, despite its relatively narrow focus, the current WQIP does a very good job in identifying the main problems (excess nutrients from agricultural and urban areas entering the Vasse-Wonnerup Wetlands and Geographe Bay) and the actions required to reduce these nutrient inputs (introduce Best Management Practices (BMP)). It also provides targets for the reductions in the major nutrient loads (phosphorus and nitrogen) in the catchment rivers, which if met should protect the ecological condition of the downstream waterbodies, such as the Vasse-Wonnerup Wetlands.

A hydrologic and nutrient model was used by the Department of Water to determine current nutrient loads, load targets, load-reduction targets, nutrient sources and priority sub-catchments for remediation in the Geographe catchment (DoW, 2009).

The main nutrient sources in this catchment are cattle grazing for beef and dairy, which contributes on average 25 % and 40 % respectively of the nutrient loads from all sub-catchments (DoW, 2009). This is largely because these farms occupy the majority of the fertilised land area in the Geographe catchment (DoW, 2009). The highest nutrient export rates are from those areas surrounding the Lower Sabina River, the Vasse Diversion Drain, and the Buayanyup River in the centre of the Geographe catchment. High exports also occur in the Gynudup Brook catchment and the coastline in urban regions (DoW, 2009).

Estimated nutrient loads entering the Vasse-Wonnerup Wetlands are approximately 16 tonne/y of phosphorus and 134 tonne/y of nitrogen (DoW, 2010a). The majority of the nutrient loads entering the Vasse-Wonnerup Wetlands are delivered by the rivers that flow into the wetlands (i.e. Lower Vasse, Lower Sabina, Abba and Ludlow) (DoW, 2009). The Lower Vasse and Lower Sabina catchments contribute a disproportionately high load compared with the larger Abba and Ludlow catchments (DoW, 2010a).

Dairy farming activities (e.g. cattle grazing and dairy sheds) upstream are the main source of nutrients (Table 1), particularly in the Lower Sabina catchment where 61% of TP and 81% of TN loads are apportioned to dairy cattle grazing. Beef cattle grazing on the fringes of the Vasse-Wonnerup Wetlands is estimated to account for 10% of the TP and 5% of the TN loads to these wetlands. Point sources, such as dairy-sheds, feedlots, land-fill sites and waste-water treatment plants, are also significant sources of nutrients to the Vasse-Wonnerup Wetlands, particularly from the Lower Vasse and Abba catchments (Table 1). Urban runoff and septic tank seepage were also significant sources of TP in the Lower Vasse River, which flows through the Busselton Township (Table 1).

Future land use changes from cattle grazing to urban centres, are predicted to occur during the next 25 years, and are likely to increase the TP and TN loads due to an increase in fertiliser input rate (DoW, 2009). Wastewater treatment plants are also expected to double in capacity in the next 25 years (DoW, 2009).

To achieve a healthy Vasse-Wonnerup Wetland ecosystem, the WQIP indicates that TP concentrations in the streams entering the wetlands should be less than 0.1 mg/L and TN concentrations should be less than 1.0 mg/L. When the WQIP was developed it was not possible to set nutrient targets for the Vasse-Wonnerup wetland system because there were no generally agreed management objectives for this system.

Water quality modeling of runoff from the catchment indicates that to achieve these targets, the annual load of TP and TN entering the wetlands each need to be reduced by around 41 % and 55 % of the current loads respectively (to 9.2 tonne/y and 60 tonne/y respectively - see Table 2 for catchment targets). However, it was decided that this was unachievable in the short-term and interim reduction targets have been established, which require a reduction of 23% in the TP load and 36% in the TN load over a 10-year period (to 12 tonne/y and 85 tonne/y respectively).

Priority sub-catchments identified for remediation through on-ground works, such as fertiliser management, dairy effluent upgrades and riparian management, include the catchments of the Lower Sabina River, Lower Vasse River, Ludlow River and Vasse Diversion Drain (Figure 2). Although a number of on-ground works have been undertaken over the last decade, and particularly since 2009, water quality is still poor in most rivers and fail to reach water quality targets (Table 2).

The nutrient concentrations and loads in the different catchment waterways vary considerably depending on land use. To assist in prioritizing management actions, the WQIP categorised the different waterways into one of three categories, related to their current nutrient status, these being (Figure 2):

- Protection – for all waterways that currently meet both the nitrogen and phosphorus criteria,
- Intervention – for all waterways that currently meet the phosphorus criteria, but do not meet the nitrogen criteria,
- Recovery – for all waterways that do not meet either of the nitrogen or phosphorus criteria.

Note that the Lower Vasse River, Lower Sabina River and Ludlow River, all of which flow into the Vasse-Wonnerup Wetlands, are in the most polluted category – these are referred to as 'priority catchments' in this report.

Table 1: Main sources of nutrients (percentage) to rivers that flow into Vasse-Wonnerup wetlands (Adapted from DoW 2009). The top three sources are in bold. Note: some of these figures will have changed due to there being less dairies and other changes.

Sub-atchment	Current (tonnes/year)	Poicnt Sources	Septic Tanks	Horticulture	Perennial Horticulture	Cattle for Beef	Cattle for Dairy	Other Rural	Lifestyle	Urban	Fixation
Phosphorus											
Ludlow	2.9	6%	0%	3%	3%	**16%**	**38%**	**32%**	1%	0%	-
Abba	4.4	**24%**	0%	2%	0%	**21%**	**39%**	14%	0%	0%	-
Sabina	3.6	**8%**	0%	0%	0%	**29%**	**61%**	2%	0%	0%	-
Lower Vasse	4.7	**36%**	10%	1%	0%	**16%**	**13%**	10%	0%	14%	-
Nitrogen											
Ludlow	23	7%	0%	1%	1%	5%	**63%**	**9%**	0%	0%	**15%**
Abba	38	**17%**	0%	1%	1%	8%	**44%**	10%	0%	0%	**20%**
Sabina	40	**4%**	0%	0%	0%	**12%**	**81%**	1%	0%	0%	3%
Lower Vasse	34	**11%**	4%	0%	0%	**13%**	**60%**	3%	0%	4%	7%

Table 2: Load reduction targets and median concentrations in 2006 and 2012.

Sub-catchment		Current load (tonnes/y)	Interim reduction target (%)	Reduction target (%)	2006 median concentration* (mg/L)	2012 median concentration* (mg/L)
Ludlow	TN	23	34	55	1.1	1.6
	TP	2.9	-	21	0.08	0.14
Abba	TN	38	-	25	1.3	1.8
	TP	4.4	-	0	0.04	0.04
Sabina	TN	40	27	71	2.9	2.4
	TP	3.6	32	74	0.57	0.26
Lower Vasse	TN	34	27	70	1.7	2.2
	TP	4.7	38	67	0.21	0.17

* Target concentrations are 1.0 mg/L for TN and 0.1 mg/L for TP

The main features of the rivers entering the Vasse-Wonnerup Wetlands are shown in Figure 5 (Note: the Vasse Diversion Drain is discussed in Section 2.5).

Waterway values

As noted above, the current focus of management of the Geographe catchment is largely on water quality, and specifically on reducing the loads of nutrients entering the Vasse-Wonnerup Wetlands and Geographe Bay, but with some activity aimed at enhancing the biodiversity values of rivers (DoW, 2010a).

However, the catchment's waterways all retain important but limited aquatic values, including the presence of marron (in 2 waterways), freshwater fish (in 8 waterways) and freshwater mussels (in 3 waterways) (DoW, 2010a). The waterways with these aquatic fauna are all predominantly larger systems where deep pools provide important summer refuges. Allowing water quality to decline further may pose risks to the long-term survival of these species in the local area, since all are sensitive to poor water quality, especially low oxygen conditions.

Certainly, improvement of water quality will assist in improving the general ecological condition ('health') of these rivers, but this is not sufficient. A healthy river also needs good habitat and a sufficient environmental flow, as is recognised in the WQIP. GeoCatch have developed a broad Catchment Management Strategy for the Geographe catchment (GeoCatch, 2008), but it appears that, apart from the implementation of nutrient-reducing BMPs, other aspects of this strategy have been given lower priority, primarily because of limited funding opportunities for this type of work.

Implementation

Implementation of the WQIP is based largely on the voluntary adoption of Best Management Practices to reduce nutrient inputs from both agricultural and urban areas. A number of BMPs have been identified in the WQIP, which if fully implemented, would significantly reduce the nutrient losses from agricultural land and urban areas.

In agricultural areas, priority has been placed on BMPs for management of dairy sheds and feedlots, fertiliser management, implementing riparian management, and controlling of stock on waterways. However, there does not appear to be monitoring program in place to verify and quantify the effectiveness of these management practices. Soil amendments on sandy soils and perennial pastures, to reduce 'leakage' of phosphorus, have been trialled in other catchments (e.g. Peel Harvey), but not in the Geographe catchment. It seems unlikely that soil amendment would be suitable for the majority of the Geographe catchment because the phosphorus retention index is too high (Pers Comm, Dr Rob Summer, DAFWA, Feb 2014). DAFWA have shown that in most of the Geographe catchment the topsoil is saturated with phosphorus, which runs off when the soil is inundated, so that simply bringing the shallow subsoil to the surface through tillage would supply a suitable soil amendment.

In urban areas, priority has been placed on management of point sources (wastewater treatment plants, septic tanks), incorporating water sensitive urban design in new residential developments, and limiting fertiliser use in urban areas.

The WQIP recommended an annual capital cost of $1.6 million over 10-years to implement BMPs to achieve the interim targets (DoW, 2010a). But note that this did not include the major expenditure required in urban areas to address septic tank removal and infill sewerage.

Progress in implementing these BMPs is evaluated in Section 3.2 and Appendix B.

Comment: The Geographe Bay region is typical of many rural areas in Australia where the major land use in the catchment is productive agriculture, while downstream the growing urban population (Busselton) is focused on tourism and recreational use of aquatic assets (Geographe Bay and the Vasse-Wonnerup wetland in this case) that can be adversely impacted by upstream pollution. This dichotomy is not an easy one to manage and will require the community to accept some 'trade-offs'.

2.2.2 Issues

Excessive nutrients

The modeling undertaken as part of the WQIP development showed clearly that excessive amounts of nutrients are generated from the agricultural activities and urban areas in the Geographe catchment, and that these nutrients are significantly impacting on the condition of all water-related assets (DoW, 2009).

The main sources of nutrients have been clearly identified (agricultural and urban), as have the waterways contributing the highest concentrations and loads to the downstream assets (Vasse-Wonnerup Wetlands, Lower Vasse River). Additionally, the management actions (BMPs) to address these nutrient sources have also been identified, and these are (slowly) being implemented. There is a need to establish a robust monitoring program focused on the local implementation of various management practices on small subsections of the drainage system, to inform decisions about future options and expenditure.

Additionally, experience in other regions of Australia and overseas is that 'clean-up' of agricultural land is difficult, needs a long-term (decades) commitment and is costly. Reducing the downstream eutrophication problems (excessive aquatic plant growth) will not occur overnight, and there will be the need for 'symptom' management of the Vasse-Wonnerup Wetlands, and the Lower Vasse River, in the short to medium term.

However, despite the difficult and long-term nature of the 'clean-up' of agricultural land, this does not diminish the need to actively work to reduce the nutrient losses from agricultural activities and urban areas in the Geographe Catchment.

Waterway monitoring

DoW have a comprehensive water quality monitoring program currently in place, but it is concerning that this is totally dependent on external funds. Water samples are taken fortnightly in all major waterways (22 sites) in the catchment during winter when these streams are flowing (DoW, 2012 - Fig. 3.1). The samples are analysed for TN, TP, TSS, Filterable Reactive P, Nitrate + Nitrite-N, dissolved organic N, pH, temperature, dissolved oxygen (DO) and conductivity.

<u>Nutrient concentrations:</u> The TP and TN concentration data are used to calculate compliance with the relevant targets (TP <0.1 mg/L, TN <1.0 mg/L) using a binomial-type compliance method (DoW, 2009). For most of the major streams, there are adequate data available for the six year period 2006-2012 (DoW, 2012). Progress in meeting the targets is reviewed in Section 3.2.

The spatial and temporal coverage of this water quality sampling program are adequate. All major waterways are monitored mostly at a gauging station. However, it is noted that flow measurement in the Lower Vasse River is problematic. For the last year, flow has been measured at the point where water from the Vasse Diversion Drain can be diverted through a pipe (and valve) into the Lower Vasse River.

<u>Nutrient loads:</u> The measurement of nutrient loads is well known to be difficult, given that most of the nutrient transport occurs in a short period of time (in winter). Load estimation requires both nutrient concentrations and flow over major flow events.

The current fortnightly sampling data is used to calculate nutrient loads for catchments that are flow gauged. DoW indicate that they have undertaken considerable research on this matter and have found that use of fortnightly concentration data provides essentially the same load as that produced using daily concentration data (Pers Comm, Malcolm Robb, DoW, Jan 2014). In ungauged catchments, nutrient loads will need to be estimated using an appropriate model for calculating flows.

<u>Biological monitoring</u>: there is some monitoring of the aquatic biota (e.g. macroinvertebrates, fish, crayfish) in the Geographe catchment rivers as part of the DoW river health assessment scheme for south-west Western Australia (Storer et al., 2011). However, the sampling occurs at irregular times depending upon the availability of funds.

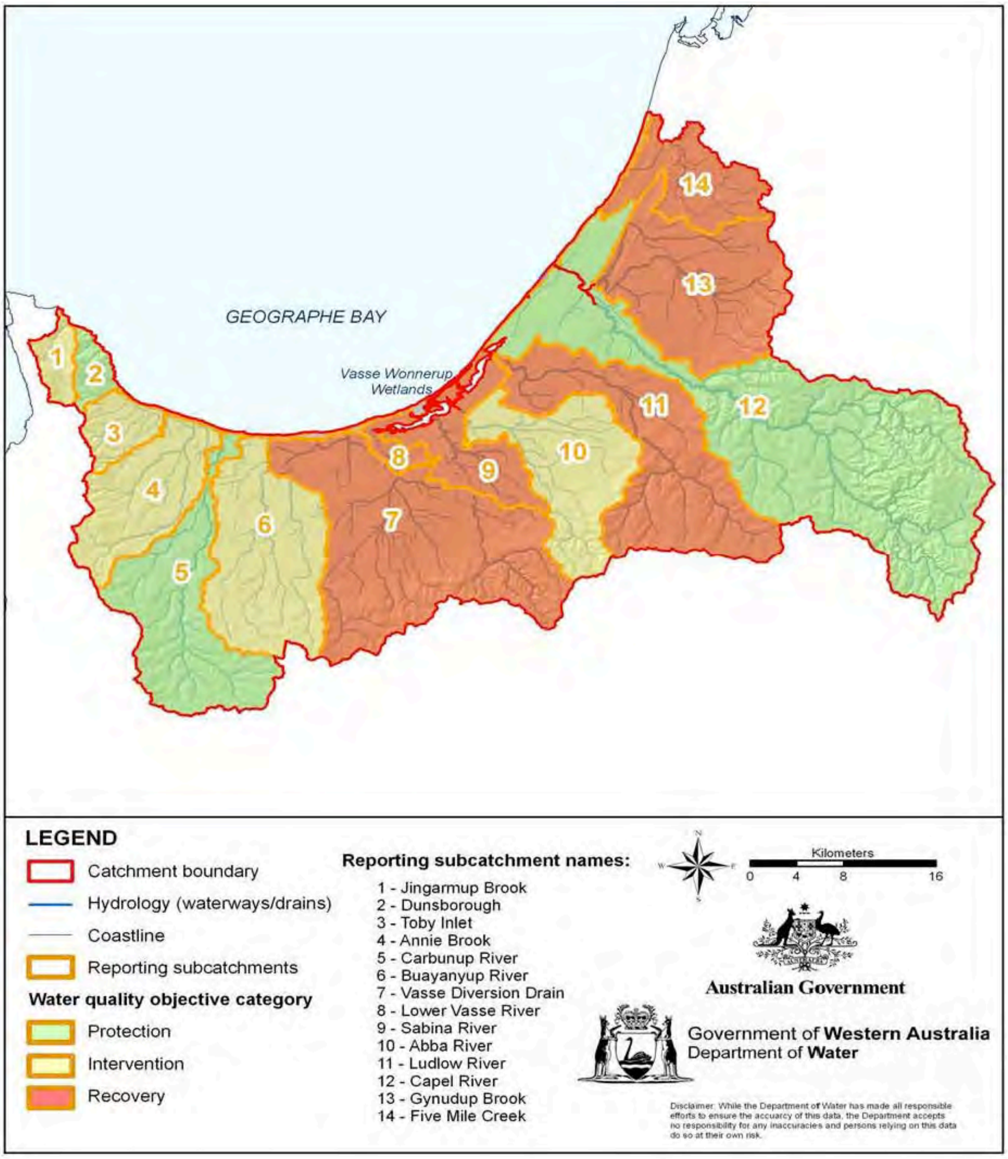


Figure 3: Map showing the catchments prioritised on the basis of their nutrient status (protection, intervention, recovery (priority))

Implementation of the BMPs

The success of the WQIP depends on the effectiveness and uptake of the BMPs identified. Both these aspects are evaluated in Section 2.2.3 below.

Drainage network

The drainage network in the Geographe catchment (known as the Busselton Drainage District) is extensive, covering over 1,000 km^2 in area with 530 km of drains and managed waterways (English, 1994). The network also includes a large number of assets including bridges, culverts, floodgates and other structures associated with the drains and waterways.

Much of the drainage network was designed and developed over the period between 1910 and 1970, a period of above average rainfall and considerably greater than today (English, 1994). This reduction in annual rainfall has likely made parts of this network less needed than in the past. The situation with the Vasse Diversion Drain is covered in Section 2.5.

Additionally, the drainage network is now old and poorly maintained, largely because farmers (the beneficiaries) are not required to pay a drainage levy.

Additionally, the drains are largely single purpose, to transport water from agricultural land to prevent flooding, and there is no requirement for these drains to achieve a certain water quality. It seems possible that at least part of the drainage network could be managed differently, such that the drains are ‘multi-purpose’, being managed to also remove nutrients.

There would be value in reviewing the Geographe catchment drainage network to assess its current and future relevance, and to assess what might be done to make this drainage network more effective at reducing nutrients, in addition to its flood protection and land drainage functions. This would require an assessment of the current effectiveness of the drainage system in removing nutrients (no matter how small) and the impact of current drainage maintenance and management practices on water quality, including the various forms that the nutrients are travelling in and which forms are impacted upon by the drainage system. This information could then be used to assess the effectiveness of proposed management practices.

2.2.3 Curent management

Roles and responsibilities

DoW, in partnership with GeoCatch, has been the lead agency since 2009 in implementing the WQIP. Other organisations involved in the implementation of the WQIP are DAFWA, CoB, SoC and SWCC.

The major WQIP activities in the Geographe catchment have been focused on the implementation of nutrient reduction BMPs in agricultural (e.g. dairy effluent management, rural fertiliser management, riparian management, stock control) and urban areas (e.g. reducing fertiliser use, ensuring new urban developments incorporate water sensitive urban design, strategic urban stormwater upgrades). Additionally, Geocatch and DoW have sourced funding for a number of research projects (e.g. Murdoch University research on ecological aspects of the Vasse-Wonnerup wetlands and annual seagrass monitoring of Geographe Bay since 2011). A summary of these activities, together with what has been achieved, is provided in Section 2.3.

In addition to implementing the WQIP, GeoCatch also undertakes other broader catchment management activities as described in its Geographe Catchment Management Strategy (GeoCatch, 2008).

DoW has a close relationship with GeoCatch, formalised under a Partnership Agreement signed in 2009, with DoW paying sitting fees, employing staff, and providing technical, strategic and managerial support. DoW have been integrally involved in the development and implementation of the WQIP. Additionally, they undertake fortnightly catchment water quality sampling since 2006, have developed nutrient and water balance models for the Geographe catchment, are developing catchment nutrient reports (currently in draft for release in 2014), and analyse water quality trends (DoW, 2012).

DoW are also the authorising agency for irrigation water licences and are involved in other aspects of resouce management in the Geographe catchment.

DAFWA work closely with GeoCatch and DoW in the implementatiion of rural fertiliser management program. They undertake whole farm nutrient mapping activities. Additionally, DAFWA have contributed considerable knowledge regarding many of the agricultural BMPs, with much of this new knowledge having been published after the WQIP development in 2009 (e.g. Weaver & Summers, 2013, 2014; Weaver & Wong, 2011; Summers & Weaver, 2014; Rivers et al., 2013).

DPaW is responsible for managing a number of Crown land tenures in the Geographe catchment (on behalf of the Conservation Commission of Western Australia). Within the five sub-catchments that flow directly into the Vasse-Wonnerup wetlands, DPaW actively manages 29,370ha (35%) of the catchment area comprising approximately 21,000 ha of State forest and Timber Reserves, 7,510 ha of national park, 676 ha of nature reserves and 190 ha of other crown reserves. The management includes fire, weed control, rehabilitation, recreation opportunities and management of inappropriate uses. DPaW has been undertaking restoration in the catchment, in particular on land adjoining the Vasse-Wonnerup wetlands. These actions collectively contribute towards protecting and improving the health of these wetlands. DPaW has been involved in the Vasse-Wonnerup wetlands for many years, undertaking a range of wildlife surveys and providing advice and support to DoW and the Water Corporation.

CoB is also a partner in the implementation of the WQIP, focusing primarily on strategic urban stormwater upgrades and ensuring the adoption of WSUD in new residential subdivisions.

SWCC are a partner in the implementation of the WQIP, through direct on-ground project implementation and through the provision of funds for dairy effluent upgrades, riparian management, urban stormwater upgrades and rehabilitation, wetland research and best management practice extension programs for farmers and landholders for water quality improvement. Additionally, they are involved in the region-wide urban fertiliser management and behaviour change program.

Implementation of BMPs

Effectiveness: The effectiveness the agricultural BMPs adopted in the WQIP, was based on the considerable amount of research undertaken by the DAFWA and the DoW, in particular into dairy shed management, fertiliser management, soil amendments and riparian buffers.

Since the development of the original WQIP, additional studies have been undertaken to better understand the BMPs and to assess their effectiveness (Gourley and Weaver, 2012; Rivers et al., 2013). This new knowledge should be used to update the BMPs and the cost benefit effectiveness modeling when the WQIP is reviewed in 2015, because some of the BMP's may not be operating as effectively as first thought.

Uptake: Currently, the uptake of BMPs by farmers is voluntary, although there is considerable range of advice and assistance provided by DAFWA and GeoCatch. Many of the incentive packages funded through natural resource management (NRM) programs have ceased, although DAFWA still have a fertiliser management incentive program running until the end of 2015.

A brief review of the implementation of 3 types of BMPs in the Geographe catchment over the past 4 years is provided in Appendix B. Note that DoW are currently undertaking a 5-year review of the implementation of the WQIP and this should be available during 2014.

Summary: GeoCatch and DoW, with significant contributions from SWCC, are the principal organisations implementing the Geographe WQIP. DAFWA are providing assisting in agricultural areas and CoB in the urban areas. Despite the fact that the WQIP identified priority catchment, it does not appear that GeoCatch has a documented strategic approach to target these catchments. Reasonable progress is being made in implementing three BMPs – riparian revegetation and fencing, dairy shed effluent management and fertiliser management.

Despite the fact that here has been Australian Government funding for more than a decade (e.g. Caring for our Country), the investment in implementing these (voluntary) BMPs has been relatively small given the scale of the problem, and it appears that current funding has almost ceased. There has been a large investment of people time in developing capacities, developing partnerships (e.g. with the dairy industry through DairyCatch) and in changing behaviours. Efforts in implementing fertilizer management best practice have been impressive, but this has yet to be translated into measurable reduction in fertiliser use. Surprisingly, there appears to be no regulation (or enforcement) that requires farmers to contain and treat polluted runoff from dairy sheds or to keep cattle out of waterways. Equally surprising is the lack of measurement of the effectiveness of these BMP's, especially at the small scale where their effectiveness can be measured in the short term.

There would be value in an independent review of the Geographe catchment drainage network.

2.3 Vasse-Wonnerup Wetlands

2.3.1 System

The Vasse-Wonnerup wetlands are located east of the township of Busselton in south-west Western Australia. They are now considerably altered from the original wetlands, which consisted of two estuarine lagoons, the Vasse and the Wonnerup, that discharged directly to Geographe Bay. Figure 4 shows the current Vasse-Wonnerup wetlands, and Figure 5 provides a summary of the main features of the rivers feeding to these wetlands.

Changes to hydrology

At the time of first settlement, the *Vasse Estuary* received direct flows from the Abba, Sabina and Vasse Rivers and indirect inflow from Iron Stone Gully, Buayanyup, Carbunup Rivers and other creeks to the west, which discharged into the Broadwater-New River system and then into the Vasse River and the wetlands. All rivers flowed seasonally. These western rivers were diverted to the ocean in around 1915.

Originally, the *Wonnerup Estuary* also received considerable freshwater via direct inflow from the Capel and Ludlow Rivers. The Capel River was diverted directly to the ocean via Higgins Cut some time in the 1880s.

During the 1920s extensive drainage networks were put in place throughout the catchment, increasing the river inflow to the system and resulting in more frequent flooding of low-lying coastal properties (including the Busselton township). In 1927 the Vasse Diversion drain was constructed to divert the upper Sabina River and virtually all the Vasse River to the ocean. Approximately 60% of flow from the Sabina and 90% of flow from the Vasse is diverted to the Vasse Diversion Drain, and the drain has effectively cut off the Broadwater-New River system from the Vasse-Wonnerup.

The Vasse-Wonnerup wetlands now receive around 20% of the pre-European freshwater inflows.

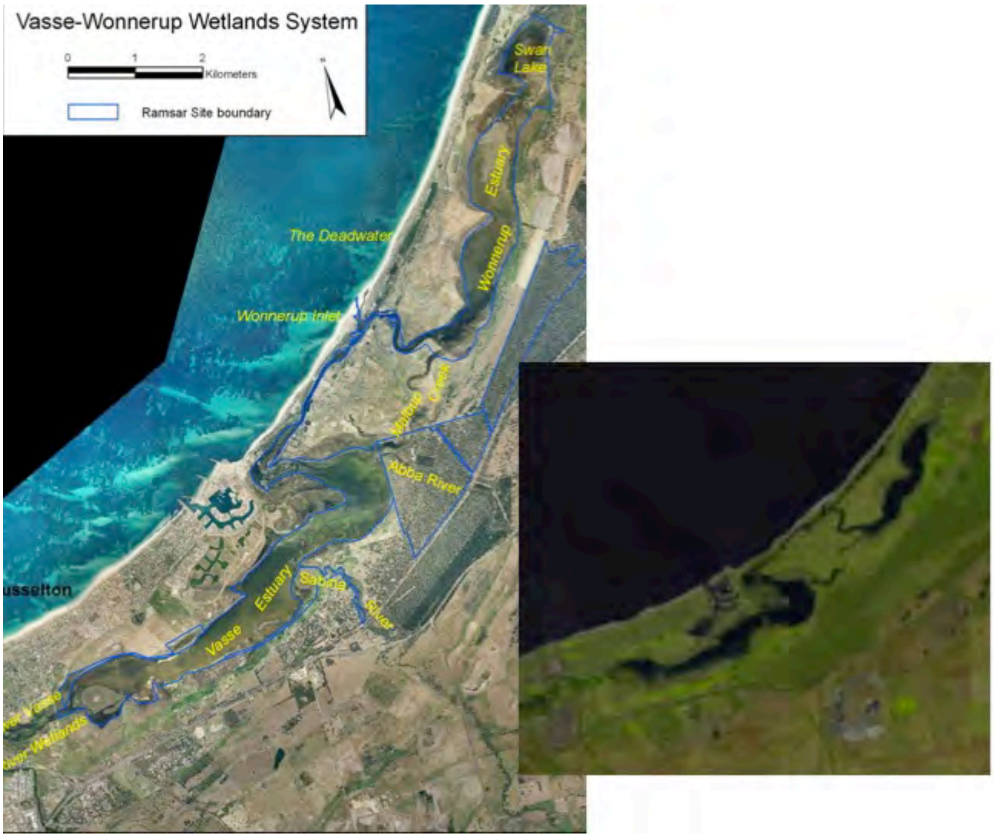


Figure 4: The Vasse-Wonnerup wetlands with Landsat image taken 17 Jan 2014

The wetlands are also now cutoff from the ocean. In the early 1900s, two sets of floodgates were built - one in the Vasse and the other in the Wonnerup. These were rebuilt in 2004. The primary function of the floodgates is to regulate water levels, exclude seawater and minimise flooding of the adjoining lands and Busselton township (Lane et al., 2011).

Ecological values

The Vasse-Wonnerup wetlands have experienced severe problems for many years caused by excessive amounts of nutrients entering them. These problems include: sudden mass fish deaths, blooms of macroalgae (e.g. *Ulva*, *Rhizoclonium*), toxic phytoplankton blooms (e.g. *Microcystis*), nuisance odours and mosquito problems (DoW, 2010a).

However, research undertaken over the past 6-7 years by Murdoch University has shown that these wetlands have high biodiversity and ecological values, despite their high nutrient status (Chambers et al., 2011, 2012; Tweedley et al., 2012, 2013). There is now considerable knowledge on the hydrological, ecological and water quality behaviour of both the Vasse and Wonnerup wetlands as a result of this and other research (McAlpine et al., 1989; Lane et al., 1997, 2007, 2011; WRM, 2007).

The following summary of the key ecological characteristics of the Vasse-Wonnerup Wetlands was provided by Dr Jane Chambers and Dr James Tweeley from Murdoch University and Dr Jim Lane from DPaW.

Despite the nutrient problems, the Vasse-Wonnerup Wetlands, support a great abundance and variety of waterbirds The area features tens of thousands of resident and migratory birds of a wide variety of species and the largest regular breeding colony of Black Swan in South-Western Australia and as such became listed under the Ramsar Convention in June 1990 (WRM, 2007).

Surveys have revealed more than thirty thousand birds of sixty species inhabiting the wetlands each year. The total number of species recorded in all surveys to date is now almost 90. Waterbirds are present in greatest numbers during the hot, dry months of summer and early autumn, when both 'over-wintering' trans-equatorial migrants and many resident birds gather to feed on abundant plant and animal life that becomes more accessible as nutrient-rich waters recede. Several species - notably the Black Swan - also breed on and around Vasse-Wonnerup. At the peak of breeding, during spring, thousands of swans and cygnets may at times be seen spread out across the wetlands' shallow expanses.

Photo – Wonnerup floodgates (Nov 2013)

The diversity and abundance of waterbirds on which the Ramsar nomination for the Vasse-Wonnerup wetlands is based, is dependent on phytoplankton, macroalgal and macrophyte (charophytes and aquatic angiosperms) communities. As such it is crucial that the quality of this food source be maintained if waterbirds are to be conserved on the wetlands (Chambers et al., 2011).

Quite apart from its importance in supporting waterbirds, the diversity of plant life is unique in south–west. The shallow waters provide conditions suitable to benthic plants across the entire bed, while the water changes in salinity from 2 to 130 parts per thousand (4 times seawater) at different times of the year. Nowhere else is there such an ever changing mosaic of macroalgae and aquatic plants.

The lynchpin maintaining the swans and the ecological condition of wetlands is the seagrass, Ruppia megacarpa, which emerges from rhizomes each spring and tolerates a wide range of environmental conditions until late summer. In the clear waters and sandy substrates of the upper Vasse estuary the less tolerant Lepilaena cylindrocarpa thrives in years of good water quality and hangs on through the poorer ones. The saving grace of the Vasse Wonnerup wetlands is the charophyte, Lamprothamnium papulosum. This plant is actually an algae buts looks and acts like a flowering plant, binding the sediments and maintaining clear water. Its high tolerance of harsh conditions, particularly in the Wonnerup Estuary, maintains the dominance of aquatic plants when otherwise the system would be covered in algal blooms.

Each of these macrophytes maintains the good health of the Vasse Wonnerup wetlands, taking up nutrients providing a nursery for fish and a haven for a diverse suite of invertebrates, crucial to a diverse food web. Where macrophytes are present the invertebrate diversity is greater and the type of invertebrates is different – supporting damsel and dragonflies.

However, as the system is nutrient-enriched, particularly in summer, the estuary is often dominated by filamentous green algae, Cladophora vagabunda, Ulva flexuosa Ulva paradoxa and Rhizoclonium tortuosum. These algae form floating scums on the water, often browning under the sun and looking unsightly. Of these Ulva flexuosa*, while forming dense blooms, generally forms in clear water in the lower Vasse Estuary and is less offensive to the eye.*

Photo – Ulva bloom in Vasse wetland near floodgates (Nov 2013)

The sediment is usually covered in an algal mat comprised of a wide range of algae, most benign although occasionally dominated by cyanobacteria that are potentially toxic. So too the unicellular algae that float in the water column, the phytoplankton; these are generally benign species of green alga, prasinophytes, cryptophytes and diatoms, but in nutrient enriched sites (for example near the Vasse gates) can be dominated by quite a wide range of cyanobacterial species, many toxic.

The structure created by the macroalgae and marine plants provides habitat and a source of food for many invertebrate species, of which 62 have been found in the system to date. The vast majority of these are either small crustaceans, such as water fleas or copepods, or the larvae of aquatic insects. This latter group is particularly diverse containing beetles, dragonflies and water boatmen, as well as some nuisance taxa like midges and mosquitos. The sediments on the bottom of the estuary range from sand in the upper estuaries down to fine mud at the bottom near the floodgates. These sediments are home to a variety of worms, namely oligochaetes (aquatic earthworms) and roundworms (nematodes) in the upper estuaries and polychaetes (bristleworms) further downstream.

*The waters of the Vasse-Wonnerup Wetlands are home to over thirty species of fishes, some of which are of commercial and recreational importance. In particular, the areas downstream of the floodgates, i.e. the Deadwater and Wonnerup Inlet, provide a sheltered, food-rich environment for the juveniles of many key marine species caught in Geographe Bay, such as Mullets, Whiting, Tarwhine, Tailor and even the occasional Mulloway, while also supporting substantial numbers of the popular recreational species Black Bream (*Acanthopagrus butcheri*). The fish fauna of the Vasse and Wonnerup estuaries are dominated by small bodied fish species such as the hardyheads and gobies. These species are found throughout estuaries in south-western Australia and are tolerant of the wide range of environmental conditions, particularity salinity, which occur throughout the year. Sadly, two introduced freshwater fish species namely the Mosquitofish (*Gambusia affinis*) and the Goldfish (*Carassius auratus*) have been found in the wetlands during periods of low salinity following substantial rainfall.*

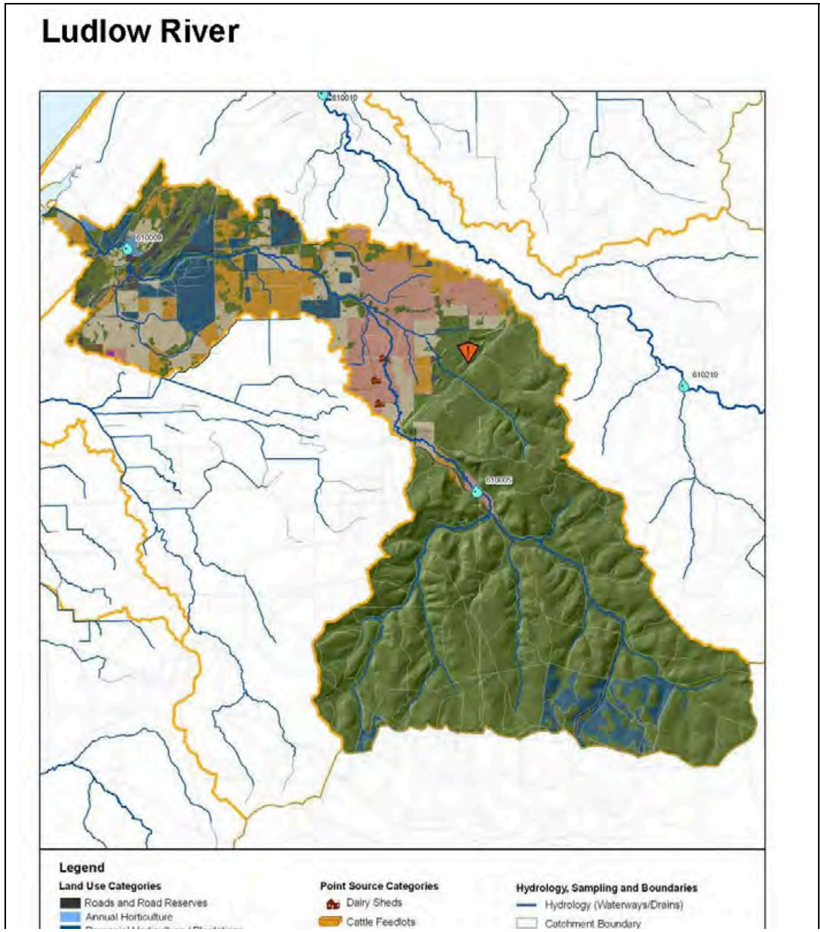
The conceptual models depicted in Figure 6 summarise the changes in water level, salinity, water quality and biology in both wetlands over the three seasons – summer-autumn, winter and spring.

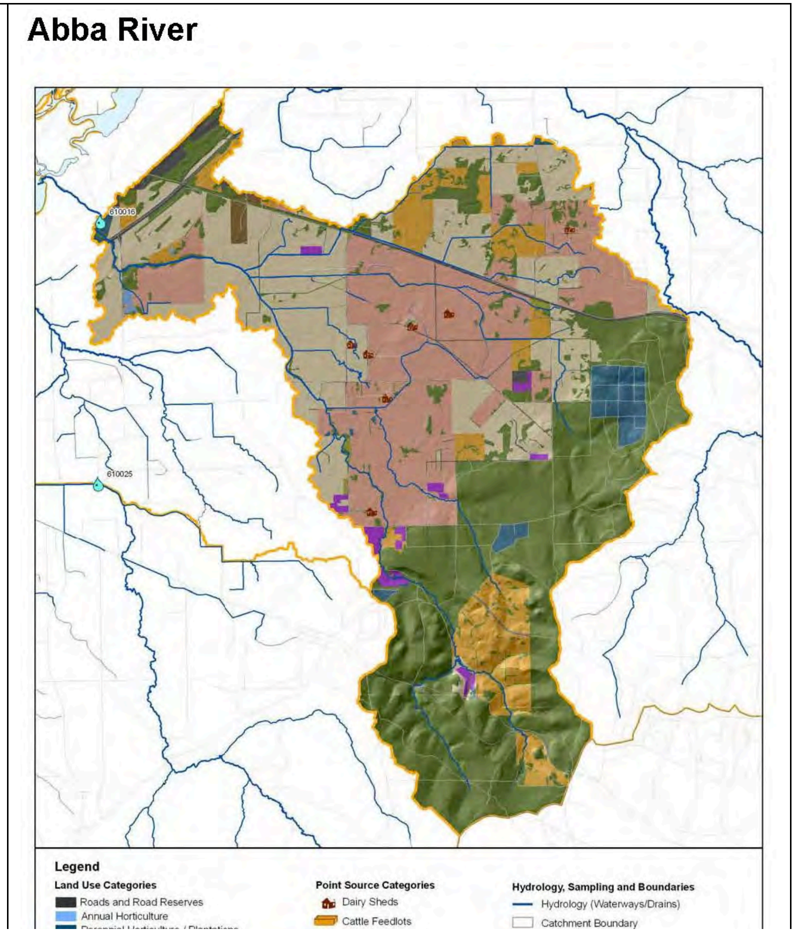
While these wetlands have high biodiversity and ecological values, the Murdoch University researchers warn that they are in a transition zone between macrophyte (good) and phytoplankton (bad) dominance, that is they are close to a tipping point (Chambers et al., 2013). However, this hypothesis is not shared by all aquatic ecologists.

Rather surprisingly, despite the fact that the Vasse-Wonnerup Wetlands are a Ramsar site, and contain high biodiversity and ecological values, the local community generally does not seem to know about them or to value them. But they do know and value Geographe Bay. The community seems focused more on the problems in these wetlands (e.g. fish kills, unsightly algal booms) than on the proper management of these wetland systems for their ecological and biodiversity values.

However, some work is being undertaken to increase the community's understanding of wetlands and to facilitate access to the Vasse-Wonnerup wetlands. The CoB established the Busselton Wetland Group in 2005 in response to the WA Planning Commission's *Busselton Wetlands Conservation Strategy* (WA Planning Comm, 2005). Both GeoCatch and DPaW are members of this group.

The Wetlands Group have developed a *Busselton Wetlands Ecotourism Strategy* that seeks to develop a series of trails, bird hides and eventually an interpretive centre. A demonstration wetland, located opposite the CoB offices, is almost completed and should be open to the community early in 2014. DPaW has also developed a bird hide and interpretive facility on the southern edge of the Vasse-Wonnerup wetlands and has involvement in another proposed facility on the northern edge of the wetlands.


Ludlow River
Legend
Land Use Categories
Roads and Road Reserves
Annual Horticulture
Point Source Categories
Dairy Sheds
Cattle Feedlots
Hydrology, Sampling and Boundaries
Hydrology (Waterways/Drains)
Catchment Boundary


Abba River
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Land Use Categories
Roads and Road Reserves
Annual Horticulture
Point Source Categories
Dairy Sheds
Cattle Feedlots
Hydrology, Sampling and Boundaries
Hydrology (Waterways/Drains)
Catchment Boundary

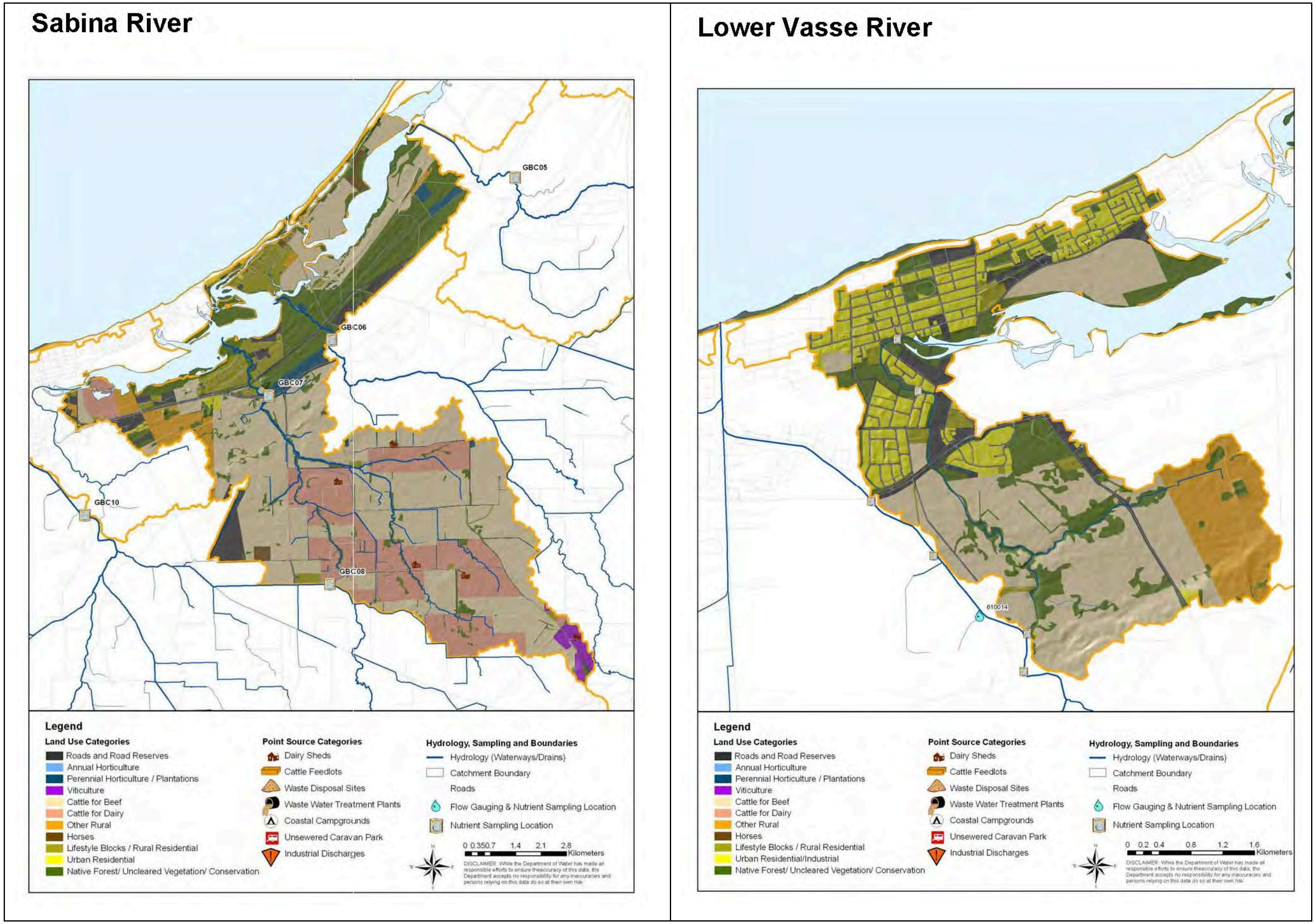

Figure 5: The main catchment features of the rivers entering the Vasse-Wonnerup Wetlands

2.3.2 Issues

Nutrient enrichment

The Vasse-Wonnerup wetlands are eutrophic with high nutrient concentrations. These nutrients come from the inflow of the Lower Vasse, Lower Sabina and Ludlow Rivers during winter, from the sediments and from cattle grazing in the immediate vicinity of the wetlands themselves.

These high nutrient concentrations are resulting in increased growth of macroalgae (e.g. *Ulva*) and at times toxic blue-green algae. These are unsightly and can cause additional problems (e.g. fish kills) when they die.

The wetlands are poorly flushed, with essentially no flow occurring during the summer period when most plant growth occurs.

The Vasse Wetland in particular has accumulated large amounts of organic sediment in the region close to the floodgates, which are a source of nutrients and may also assist in drawing down the dissolved oxygen concentration (Tweedley et al., 2013).

There have been fish kills (most near the floodgates) due to deoxygenation of water column caused by the accumulation of organic sediments and the death of macroalgal and phytoplankton blooms. In recent times, fish kills have occured in April 2013 and February 2014. It appears the cause of these fish kills may be different, with the April 2013 event due to low dissolved oxygen levels, and the February 2014 event due to an algal species *Prymnesium* spp., known to be toxic to fish (Pers Comm, Dr Kath Lynch, Feb 2014).

At times there are obnoxious odours from the wetlands that annoy local residents, and additionally all wetlands in the region are breeding grounds for mosquito's. There is a high incidence of Ross River virus, at least in Capel Shire.

Short-term solutions

Many 'solutions' have been suggested by community members to 'solve' the fish kill and other problems at least in the short-term. These include: dredging the sediments and 'resetting' the wetlands, operating the floodgates and the opening of the Wonnerup Estuary to the ocean such that oxygenated marine water enters the wetlands at times when dissolved oxygen levels are dropping, modifying the floodgates so that fish can move freely between the wetlands and the 'Deadwater' on the ocean side of the gates, adding a fish ladder to the floodgates, and establishing an oxygenation plant at the floodgates to oxygenate the water when levels are dropping[3].

Incident response plan

The community is also concerned that the agencies emergency response action plan to avert fish kills has been poorly coordinated, with no obvious lead agency. The community have noted that an earlier emergency response action plan MOU, developed by the Vasse Estuary Technical Working Group (VETWG) in 2004, was not signed by all organisations.

A new *Fish Kill Mitigation and Response Plan for 2013-14* has been developed by the responsible organisations, and is discussed below in Section 2.3.3.

Comprehensive management plan

The community have also noted that there is no comprehensive management plan for these wetlands, despite the fact that they are Ramsar-listed. Listing as a Ramsar sites does assume that a management plan will be developed for the site[4], but the Commonwealth Government does not provide and funds for either the development of a plan or the management of the wetland (Pers Comm, C Hepplewhite, Dept Environment, Feb 2014). A major issue is that there is neither a management plan nor any decision on what the main management objectives should be for this wetland system.

2.3.3 Current management

Incident response plan

A consortium of the responsible agencies, chaired by DPaW and including DoW, DPaW, DoF, CoB, Water Corp (known as VETWG), have been operating an emergency response plan to

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3 This already occurs in the Swan River estuary where DoW operates two oxygenation plants.

4 http://www.environment.gov.au/resource/wetlands-australia-—-roles-and-responsibilities

mitigate fish kills each summer period for well over a decade. Until the fish kills in April 2013 and February 2014, there had not been any fish kills in the Vasse or Wonnerup Wetlands over the previous 10 years. However, this appears to be largely due to the vigilant management of one individual, rather than the result of a well coordinated action plan.

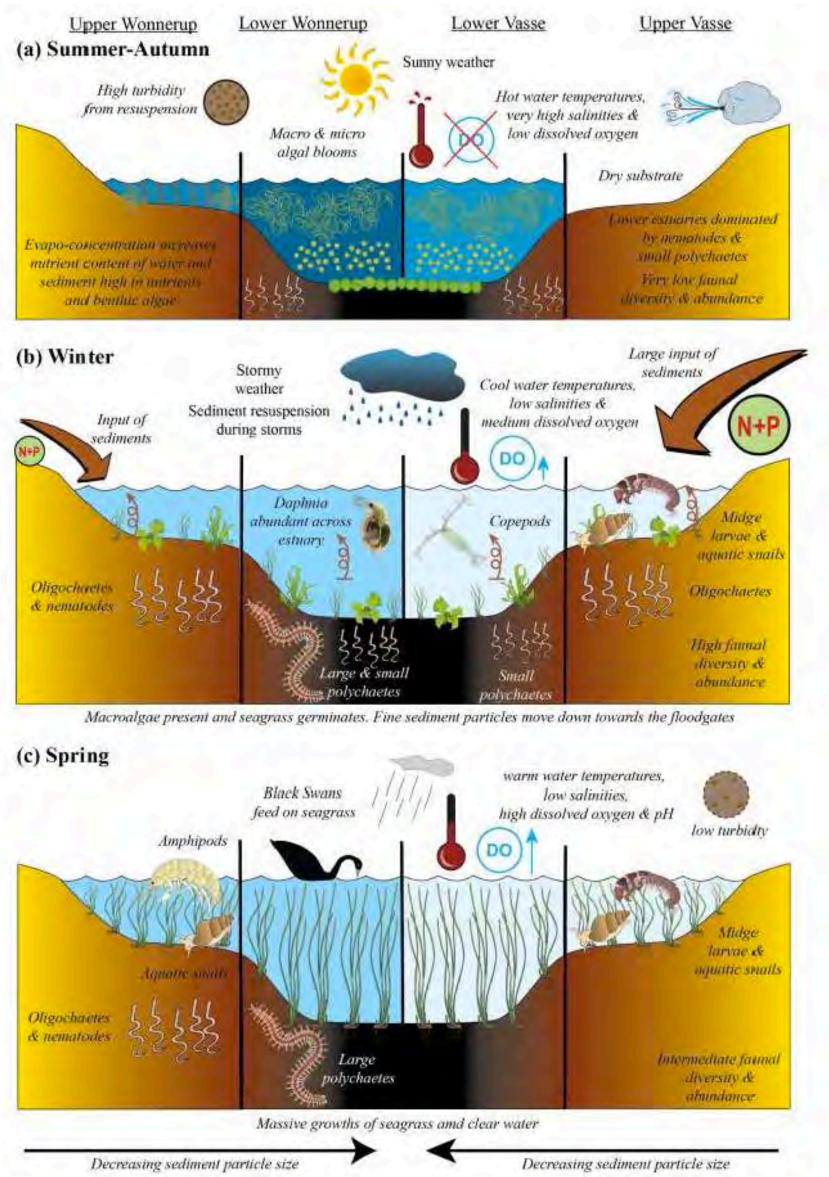

Figure 6: Conceptual model of ecological processes in the four regions of Vasse-Wonnerup during (a) summer-autumn, (b) winter and (c) spring (Note: in summer both the Upper Vasse and the Upper Wonnerup may be dry)

For this current summer period 2013-2014, a new *Fish Kill Mitigation and Response Plan* has been developed (VETWG, 2013). DoW has taken on additional responsibilities and will lead the response during 2013-14 until the outcomes of this independent review are completed.

This new plan seeks to monitor key indicators (e.g. water levels, dissolved oxygen levels, environmental conditions) that can indicate the likelihood of a fish kill occurring, and to then take appropriate action to reduce the risk of a major fish kill. Actions identified in this Plan include increased frequency of monitoring, opening the Wonnerup Inlet bar, opening the fish gate penstock in the floodgates, and installing pumps to circulate the water.

It appears that the agencies involved have agreed to provide the necessary resources for their component of the plan (DoW – Chair VETWG, coordinate emergency response, water quality monitoring; Water Corp – operate floodgates (fish gates, fish gate penstock, manage estuary water levels, open Wonnerup Inlet sand bar; CoB – coordinate fish kill clean up and disposal if needed, erect signage, hire pumps if needed; DPaW – provide information to DoW regarding optimum water levels; DoF – assist DoW with fish kill response, undertake fish pathology analysis if required).

However, despite this improved new Emergency Response Action Plan, a fish kill occurred in February 2014. Preliminary information suggests that this fish kill occurred because of a toxic alga, and not low dissolved oxygen levels (Pers Comm, Dr Kath Lynch, Feb 2014). If this proves to be the case, VETWG will need to modify the Emergency Response Action Plan to include monitoring of both dissolved oxygen and toxic algal levels, and to develop new action target levels for these.

Comprehensive management plan

As noted above, there is currently no comprehensive strategic management plan for the Vasse-Wonnerup wetlands, despite them being Ramsar-listed. Notably, it was DPaW and GeoCatch that undertook the preparation of the Ecological Character Description (WRM, 2007), a necessary part of Ramsar listing.

The need for such a management plan is obvious and is covered in Section 4.3.2. But before this management plan can be developed there needs to be agreement first on what values are to managed, and second who the lead organisation should be. Possible multiple management objectives could include the following: Ramsar values such as bird habitat and numbers, water quality, ecological biodiversity, recreation, aesthetics, flood protection, and to maximise floodplain grazing. There are also indigenous cultural values that need to be managed.

Currently, DPaW manage about 35% of the Vass-Wonnerup Ramsar site, but this does not include any of the waterbody, since this is not yet included in the conservation estate. DPaW are currently preparing a management plan for the southern Swan Coastal Plain[5], the draft of which should be released in March 2014 (Pers Comm, Laurina Bullen, DPaW, Jan 2014). This draft proposes inclusion of the majority of the Vasse-Wonnerup wetland area, but addition of this area to the conservation estate is dependent on a native title determination.

However, the long-term solution to the issues plaguing the Vasse-Wonnerup wetlands is to significantly reduce the loads of TP and TN entering from the catchment, a task we have noted that is difficult, costly and will probably take decades to achieve.

Because of this, it is likely that there will need to be an annual emergency response plan in place for many years. It would seem sensible if this annual emergency response plan was part of a more comprehensive Vasse-Wonnerup Wetland Management Plan (see also Section 4).

Ramsar reporting

The Vasse-Wonnerup wetlands were Ramsar listed in 1990 largely on the basis of the abundance and variety of waterbirds they support. Apparently, the only Ramsar reporting is on waterbird numbers, which is based on an annual waterbird count undertaken in early February each year as part of the Birdlife Australia Shorebirds 2020 project. The principle aim is to quantify shorebirds numbers and diversity, particularly in relation to JAMBA, CHAMBA and ROKAMBA species. The time of the survey does not necessarily coincide with the peak bird numbers (Pers Comm, Kim Williams, DPaW, Nov 2013).

A requirement of the Ramsar listing is that the Australian Government is obliged to maintain the ecological character of these Ramsar sites. An Ecological Character Description has been prepared for the Vasse-Wonnerup wetlands (WRM, 2007), but it appears that no monitoring is undertaken by DPaW to assess the 'limits of acceptable change' and ensure that the ecological character is being maintained. The Commonwealth Government provide no funds for monitoring of Ramsar wetlands (Pers Comm, C Hepplewhite, Dept Environment, Feb 2014).

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5 http://www.dpaw.wa.gov.au/parks/management-plans/draft-plans-in-preparation/102-swan-coastal-plain-south-draft-management-plan

Summary: The Ramsar-listed Vasse-Wonnerup wetlands are now very different to before European settlement. They now receive much less freshwater inflow as a result of the extensive catchment drainage network, are cut off from the ocean by floodgates, and receive excessive amounts of nutrients from the catchment (Lower Vasse, Lower Sabina, Abba and Ludlow Rivers), the sediments and cattle grazing in the immediate vicinity of the wetlands themselves. These high nutrient concentrations are resulting in increased growth of macroalgae, and at times toxic blue-green algae, that are unsightly and can cause additional problems (e.g. fish kills) when they die.

However, despite these changes the wetlands have high biodiversity and ecological values; they support a great abundance and variety of waterbirds, and have good populations of macrophytes (e.g. Ruppia megacarpa), fish and macroinvertebrates.

Currently, there is no comprehensive management plan for these wetlands despite the fact that they are Ramsar-listed. A new emergency 'Fish Kill Mitigation and Response Plan' has been developed and is in place for the 2013-14 summer.

2.4 Lower Vasse River

2.4.1 System

Most (approx 90%) of the Vasse River is intercepted by the Vasse Diversion Drain leaving a much smaller Lower Vasse River that flows through Busselton and then into the upper part of the Vasse Wetland (Figure 7). Currently, the Lower Vasse River receives flow from a small catchment, from local stormwater and groundwater, and from a small diversion culvert that can release water from the Vasse Diversion Drain. The Lower Vasse River only flows during winter (June to November), with little or no flow in summer. Even during winter the Lower Vasse River is poorly flushed because of its small flow and very low gradient.

In Busselton, the Lower Vasse River is maintained as a 'lake' for recreational and aesthetic purposes by a set of barriers located at the Butter Factory (Figure 8). This 'lake' is eutrophic and regularly experiences algal blooms (e.g. *Microcystis*) over most of summer, which reduce the recreational and amenity value of the 'lake' and cause offensive odours.

It should be noted that the water quality problems experienced in the Lower Vasse River have been increased because it is dammed up to form a 'lake' in the township region. If it were not artificially backed-up, the river would be dry during summer and there would be less, if any, algal problems.

2.4.2 Issues

Management plan

The need to better manage this system has been in the spotlight for over a decade, starting with the *Lower Vasse River Cleanup Program*, a partnership between GeoCatch, DoW and CoB. This Program successfully implemented a number of on-ground actions (Paice, 2005) in the period between 1998 and up to the introduction of the current WQIP, when it was largely superseded by the latter in 2009.

Members of the community are concerned that there is no comprehensive management plan for the Lower Vasse River, and particularly for the 'lake' section. The WQIP does of course provide a broad plan for the Lower Vasse River, but there is also need for an operational management plan for the 'lake', that ideally would address the dual objectives of achieving good water quality in the 'lake' section, while also preventing flooding in Busselton.

There also appears to be confusion over who is 'responsible' for management of this system. Currently, GeoCatch, DoW and CoB are involved. DoW and GeoCatch are focused on reducing nutrients from the broader Geographe catchment (and protecting Geographe Bay) in line with the recommendations of the WQIP. In contrast, CoB has more local objectives associated with improving the aesthetics of the river and maintaining an artifical 'lake' during summer. Finding a two tiered management approach may be appropriate in this situation.

Lack of flow

As noted, the Lower Vasse River now receives a relatively small flow because most of the catchment is cut off by the Vasse Diversion Drain. As a result there is little capacity for the system to be well flushed. Certainly during summer the system receives minimal if any flow.

There are community concerns about the proportion of flow that goes down the Lower Vasse River compared with that down the Vasse Diversion Drain, with suggestions that if there were greater flows in the river at critical times, the algal problems in Busselton may be less.

The relative flow is controlled via a diversion culvert that can let water into the Lower Vasse River. The culvert inlet is a 900 mm diameter pipe that is controlled by a valve. Currently, City of Busselton staff operate the valve, which is open in most years from June to February-March, although the summer (December to February) flow is very low. Flow generally ceases in late January to mid-February (Pers. Comm., Greg Simpson, CoB, January 2014). These operational 'rules' need to be reviewed.

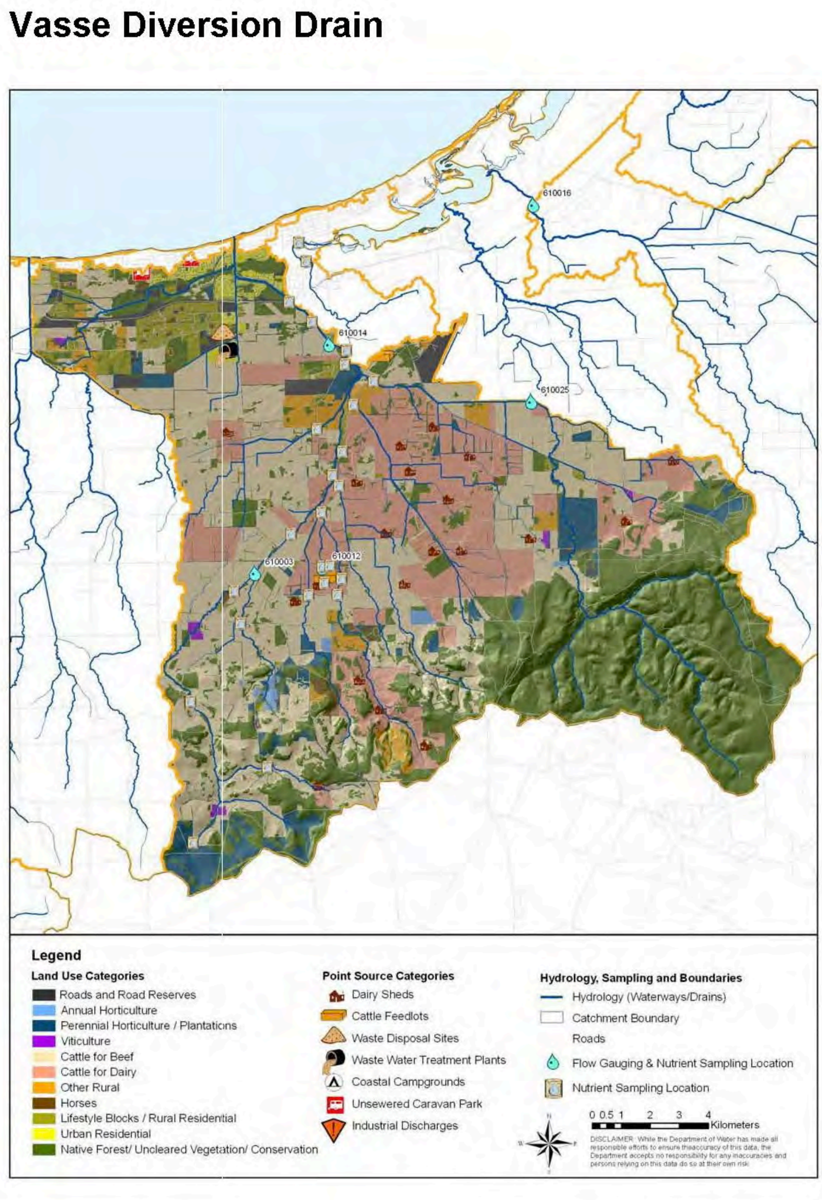

Figure 7: The main features of the catchment of the Vasse Diversion Drain

Additionally, the possibility for increasing the size of the culvert inlet pipe to increase the flow in the Lower Vasse River during summer should be investigated. In the development of the WQIP, DoW investigated the effects of changing the proportion of flow by increasing the size of the pipe (900 mm, 1050 mm and 1200 mm diameter pipes were modelled - DoW, 2009). They concluded that higher levels of flow were unlikely to alleviate the existing algal problems because flows during the critical period (summer) were not likely to be high enough and there would still be high nutrient concentrations.

Technical solutions

There have been a number of experiments over the past 10 years to find a technical solution to reduce the nutrient concentrations in the Lower Vasse River and thus reduce the frequency of algal blooms (Paice, 2005). For example, in 2001-2002 DoW ran an experiment using 'Phoslock' - a clay-like substance that adsorbs phosphorus. This was very effective in reducing the P concentration, but the effect only lasted until the next rain when high nutrient flows entered the Lower Vasse River (Robb et al., 2003).

Currently, the CoB is experimenting with three nutrient-reduction methods – floating islands of macrophytes, a clay adsorbent, and a bacterial water cleanse method. The effectiveness of these methods will be assessed over the 2013-2014 summer period.

Figure 8: The Lower Vasse River in Busselton

2.4.3 Current management

The current management of the Lower Vasse River, and particularly the 'lake' section in Busselton, is a major concern for the local Busselton community and is far from ideal. There is no comprehensive management plan, and no obvious lead agency.

Currently, CoB operate the boards at the Butter Factory that dam up the Lower Vasse River in Busselton, operate the valve that regulates flow into the Lower Vasse River from the Vasse Diversion Drain, manage crown land adjoining the river, and work with GeoCatch to implement water sensitive design features in urban areas. DoW monitor the Lower Vasse River (at Peel Terrace footbridge) for water quality and phytoplankton during the summer (Figure 8), and partner with GeoCatch in implementing nutrient BMPs in the Lower Vasse River catchment.

In the period 2000-2005, GeoCatch and DoW trialled a number of *in-situ* water quality improvement initiatives as part of the *Lower Vasse River Cleanup Program*. Although some of these initiatives resulted in visual improvements in water clarity, improvements were negated by rainfall and input of nutrients form the catchment. The key learning of that project was that *in-situ* actions were unlikely to improve water quality in the long term without significant reductions in catchment nutrients.

Since 2006, despite considerable management action undertaken in the Lower Vasse River catchment in an attempt to reduce the loads of nutrients entering the river (e.g. stormwater upgrades, urban fertiliser management), the concentrations of nutrients are still high enough to cause algal blooms in summer.

Not surprisingly, CoB and local Busselton community are still frustrated at the lack of visual improvement in water quality and are seeking support from State Government to actively undertake intervention strategies (e.g. dredging) to improve water quality in the short-term. There is considerable debate on who should lead and pay for those additional works. The question of who should lead the management of the 'lake' section of the Lower Vasse River and pay for additional works (CoB or DoW) needs to be resolved.

Summary: The Lower Vasse River now receives only a fraction of its original flow, since the major part of the catchment is cut off by the Vasse Diversion Drain. The river still receives and excessive nutrient load from agricultural and urban sources. In Busselton, the Lower Vasse River is maintained as an artificial lake for recreational and aesthetic purposes by a set of barriers located at the Butter Factory. This lake is highly eutrophic and regularly experiences algal blooms over most of summer, which reduce the recreational and amenity value of the lake and cause offensive odours.

The current management of the Lower Vasse River, and particularly the lake section in Busselton is far from ideal. Long-term nutrient reduction from the catchment is being addressed through the WQIP by GeoCatch and DoW. However, the question of who should lead the operational management of the lake section of the Lower Vasse River, and pay for additional works (CoB or DoW), needs to be resolved.

2.5 Vasse Diversion Drain

2.5.1 System

The Vasse Diversion Drain was originally constructed in the early 1920/30s to protect Busselton from flooding. It takes most of the Vasse River flow, approximately half the flow of the Sabina River, and also most of the flow of treated effluent from the Busselton wastewater treatment plant (Figure 7). The drain is designed to contain flows up to 140 m^3/s or 12,000 ML/d (approximately 1:100 year floods).

As noted the Vasse and Sabina Rivers are both diverted into the Vasse Diversion Drain; the diversion points are approximately 6.4 km and 14.4 km respectively upstream of where the drain enters the ocean.

Some water from the Vasse Diversion Drain can be directed to the Lower Vasse River at the Vasse Diversion Weir, where there is a compensating pipe with a valve that can be opened or closed. City of Busselton staff operate the compensation pipe valve, which is open in most years from June to February-March (Pers. Comm., Greg Simpson, CoB, January 2014), although the summer (December to February) flow is very low (< 0.5 m^3/s – ca. 40 ML/d) and generally ceases to flow in late January to mid-February.

Unfortunately, there is currently no capacity for additional flow to be diverted down the Lower Sabina River.

The treated effluent from the Busselton Wastewater Treatment Plant flows first into Queen Elizabeth Drain and then enters the Vasse Diversion Drain at the Queen Elizabeth Avenue Bridge, 1.3 km upstream of where the drain enters the ocean. Currently, the license allows for a discharge of approximately 4.5 ML/d, but flow is considerably less than this during summer and autumn. Licensed discharge to the Vasse Diversion Drain will increase to an average of 6.75 ML/d when the upgraded treatment plant is operational (likely early in 2014). Additionally, the upgraded plant will produce a high quality effluent (TN <8 mg/L, TP <1 mg/L) (Pers Comm, Robin Belford, Water Corp, December 2013).

2.5.2 Issues

Four issues were raised regarding the Vasse Diversion Drain.

The first relates to the size of the Drain where it goes through Busselton. It was suggested that given the changes that have occurred over the past two or three decades (e.g. reduction in rainfall since the drain was designed, recent construction of three upstream retention basins), it may be possible to reconfigure the Vasse Diversion Drain so it is a much less imposing structure particularly where it goes through Busselton (e.g. a pipe rather than open drain).

Unfortunately, this possibility will not be addressed in a review of the Vasse Diversion Drain currently being undertaken by the Water Corporation. The primary objectives of this review are to determine if the Vasse Diversion Drain is able to provide 1-in-100 flood protection, and to review upgrading options, if upgrading is required (Pers Comm, Anne Major, Water Corp, January 2014). A review of the hydrology of the Vasse Diversion Drain and its catchment has been completed (Water Corp, 2013) and the final review is scheduled for completion in June 2014.

The second concern relates to the lack of any water quality requirements on the Vasse Diversion Drain (apart from the licensed discharge of the Busselton Wastewater). The Water Corporation is not required to ensure the Vasse Diversion Drain (actually any drain) achieves a particular *water quality* target; the focus is entirely on water quantity. Increasingly around Australia, Environment Protection Agencies are tightening the controls on 'drains' to include consideration of water quality in addition to flow (e.g. Victorian EPA). The WQIP has implicitly specified a water quality condition on the water discharged from the Vasse Diversion Drain (Concentration - TP concentration <0.1 mg/L, TN <1.0 mg/L; Loads – TP <1.4 tonne/y, TN <38 tonne/y[6]). Currently, these targets are not being met (DoW, 2012).

Since the largest loads of TP and TN in the Vasse Diversion Drain are from beef and dairy cattle grazing in the Upper Vasse and Upper Sabina catchments, the water quality targets will only be met through the large-scale implementation of BMPs in these two agricultural activities. Currently, the Water Corporation has no legislative responsibility to assist with the implementation or monitoring of BMPs.

While on the matter of drains, it has also been suggested that the earlier reasons for the existence of many of these drains in the Geographe Catchment (and particularly those smaller drains on properties) are now less important given that average annual rainfall has diminished significantly, the road network has been substantially improved and the access difficulties that farmers and other non-urban landowners now face on and getting to/from their properties are less of a problem. There is an argument that many, if not most, of the small drains on rural properties serve no useful agricultural purposes and could be decommissioned. The predicted increase in intensity of summer rainfall events associated with climate change will also need to be factored into any hydraulic assessment prior to any possible modification of the system.

The third concern relates to the amount of water captured by the Vasse Diversion Drain. The CoB believes that the Drain captures too much of the Upper Vasse River flow, and deprives the Lower Vasse River of flow which contributes to the annual algal problems in Busselton where it is dammed up.

And fourth, there is concern that this open Drain, which transports effluent from the Busselton treatment plant, poses a potential health risk to the people known to fish and swim in the Drain.

2.5.3 Current management

The Vasse Diversion Drain is currently managed by the Water Corporation. Management of this asset is entirely focused on transporting water from the catchment to the ocean as efficiently as possible, so that Busselton is protected from flooding. There is no consideration of the quality of the water transported.

As noted above, the Water Corporation are currently conducting a review of the Vasse Diversion Drain, the primary objectives of which are to determine if the Drain is able to provide 1-in-100 flood protection to Busselton, and to review upgrading options that may be necessary. It does not appear that this review will consider the possibility of reconfiguring the Vasse Diversion Drain so that it contains some water quality treatment capacity (e.g. off-drain constructed wetlands) and is a much less imposing structure particularly where it goes through Busselton (e.g. a pipe structure rather than open drain).

[6] These load targets represent a reduction of 71% in the current TP load and 56% in the TN load (DoW, 2010a).

It should also be noted that in November 2013, the Busselton Water Board became a Corporation, which means they now have an opportunity to expand their business from water supply to also encompass wastewater treatment, drainage and floodplain management. There is now the potential for the Busselton Water Corporation to take over the Vasse Diversion Drain (and other drainage assets in the Geographe catchment) and include water quality and nutrient reduction as management objectives in addition to drainage and flood protection. The cost of this change would need to be considered.

Summary: The Vasse Diversion Drain is currently managed by the Water Corporation. It captures most of the Vasse River flow, approximately half the flow of the Sabina River, and most of the flow of treated effluent from the Busselton wastewater treatment plant. It is extremely important in providing 1-in-100 flood protection to Busselton. Currently, the Vasse Diversion Drain does not achieve the nutrient targets established by the WQIP, and is discharging excessive amounts of TP and TN to Geographe Bay. The Water Corporation has no legislative requirement to consider the water quality of the drain, except for the quality requirements of the wastewater discharged to the drain from the Busselton wastewater treatment plant.

It is possible that the newly formed Busselton Water Corporation could take over responsibility for the Vasse Diversion Drain (and other drainage assets in the Geographe catchment), and include water quality and nutrient reduction as management objectives in addition to drainage and flood protection.

2.6 Toby Inlet

2.6.1 System

Toby Inlet and its catchment are located at the western end of the Geographe catchment, close to Dunsborough. The Inlet is a narrow inter-barrier lagoon parallel to the shore, which is separated from the ocean by high beach ridges. It is approximately 4 km long and is highly valued for recreation and aesthetics.

The hydrology of Toby Inlet has been significantly modified by artificial drainage schemes within the catchment. The most recent was the construction of the Station Gully channel that drains much of the region and flow directly through the eastern end of Toby Inlet to the ocean (Figure 9).

Toby Inlet is largely managed by a community group, the Toby Inlet Catchment Group (TICG). This group has been in existence since the early 1990’s and are knowledgeable, enthusiastic and have achieved a considerable amount, particularly in terms of revegetation around the Inlet and its catchment.

The TICG have developed a *Management Plan for Toby Inlet Foreshore and Waters* (TICG, 2006), which has been accepted by the CoB. The CoB provides some funds to assist with the management of Toby Inlet, and DoW monitor water quality and phytoplankton levels fortnightly over summer.

2.6.2 Issues

The main issues with Toby Inlet are the regular occurrence of macroalgal and phytoplankton blooms in the inlet, and the occurrence of offensive odours when these algal blooms die. These issues are the result of (a) excessive nutrient inputs to the estuary, and (b) the lack of adequate flushing of the estuary.

Toby Inlet is still receiving too great a nutrient load from the catchment and from septic tanks associated with houses built directly around the Inlet. Additionally, there is evidence that the Inlet has received considerable amounts of sediment from the catchment, which has led to a decrease in water depth and contributed to the existing water quality problems.

But the largest changes to Toby Inlet are to the hydrology. There is now significantly less freshwater flow from the catchment, which has resulted in the regular breaching of the sand barrier between the Inlet and Geographe Bay no longer occurring. Breaching of the bar permits seawater to enter the Inlet, and to ‘refresh’ the Inlet, for a period of time until the channel again closes.

Additional to this, the construction of the Station Gully Drain now allows flows from this part of the catchment to pass through the eastern end of Toby Inlet via a channel that connects directly to the ocean (Figure 9). This in itself would not necessarily be a major problem except for the construction of a causeway built on the western side of the Station Gully channel. There is a small culvert connecting the two sections of this wetland, but this is too small and is restricting the interchange of water between the two sections of the Inlet (Figure 9).

It seems that when the Water Corp originally designed the drain, causeway and culvert, the impacts of the lack of flushing of the Inlet were not considered. The TICG would like to see the causeway removed since it appears to serve little purpose, or failing that, that the culvert be significantly enlarged.

Figure 9: Photo of Toby Inlet showing the Station Gully drain, the flow to the ocean and an insert of the causeway and culvert (Note: at this time there was a channel to the ocean from Toby Inlet on the western side of the causeway).

2.6.3 Current management

Current management of Toby Inlet is undertaken by a community group (Toby Inlet Catchment Group), with some assistance from the CoB and technical advice from DoW.

The is now insufficient freshwater flow entering the Inlet to breach the barrier between the Inlet and the ocean. This barrier needs to be artificially opened. There have been two recent occasions when CoB have opened a channel between the ocean and Toby Inlet on the western side of the Station Gully causeway, in 2006 and more recently in February 2014.

The Water Corporporation were requested to comment on the advantages and disadvantages of either removing the causeway or significantly enlarging the culvert, but no comment was received.

Summary: Toby Inlet is located at the western end of the Geographe catchment, close to Dunsborough, and is highly valued for recreation and aesthetics. It experiences regular blooms of macroalgae and phytoplankton, and offensive odours when these algal blooms die. These issues are the result of excessive nutrient inputs to the estuary, and a lack of adequate flushing. The reason for the lack of flushing seems to be a combination of the Station Gully Drain and associated causeway, that pass through the eastern end of the Inlet, and the lack of connection between the western section of the Inlet and the ocean. Currently, the only way adequate flushing can be achieved is for a channel between the Inlet and the ocean to be dredged from time to time.

3. Effectiveness of Current Management

3.1 General

This section contains an assessment of the effectiveness of the current management of the water-related assets in the Geographe Catchment. This initial assessment has focused on the three components of the study – the Geographe Catchment, the Vasse-Wonnerup Wetlands and the local waterways (including the Lower Vasse River, Vasse Diversion Drain and Toby Inlet).

A set of criteria have been established for this assessment these being:

- Are the roles and responsibilities of the key organisations clear?
- Is there an obvious lead agency for the water-related asset, and are they leading effectively?
- Is there a well-developed management plan for the water-related assets?
- Does the plan have clear targets and an adequate monitoring program to measure progress?
- Has the implementation of the plan over the past 5 years been satisfactory?
- Does the program have adequate funding?
- Has there been measurable progress in improved water quality and ecological condition of the asset?
- If progress has been less than satisfactory, what are the reasons for this?
- Are the community generally aware of the management arrangements and satisfied with progress?

The assessment of current management of Geographe catchment, Vaee-Wonnerup wetlands, Lower Vasse River, Vasse Diversion Drain and Toby Inlet is provided in the Tables below.

3.2 Geographe Catchment

Criteria	Assessment
Are roles and responsibilities of the key organisations clear?	No – there is currently no organisation charged, and appropriately funded, with the responsibility for the integrated management of the Geographe catchment. The current management focus is on water quality (nutrients) improvement through the implementation of the WQIP. Since 2009, the WQIP implenetaion has been lead by GeoCatch and DoW with support from DAFWA, CoB, SoC and SWCC.
Is there an obvious lead agency for the water-related asset, and are they leading effectively?	*Recognised lead agency* - Yes DoW in partnership with GeoCatch. *Effectiveness of this leadership* – over the period of almost 15 years, between the late 1990s and 2013, GeoCatch, DoW and partners have achieved much, commencing earlier with the Lower Vasse River Cleanup Program and the since 2009 with the WQIP. Particularly impressive has been GeoCatch's achievements in community engagement and awareness raising, and the development of partnerships with a range of organisations including industry groups. In the time available, it has not been possible to fully assess the effectiveness of GeoCatch's leadership in implementing the WQIP BMPs. This will be done more effectively in the 5-year review to be completed during 2014. However, from the information I have been presented with it seems GeoCatch have achieved reasonable progress in four areas: improving fertiliser management, improving effluent managent from dairy sheds and feedlots, implementing riparian management and stock control, and in reducing nutrient use and risk of export of these nutrients in urban areas. A more detailed summary of progress in these four area is provided in Appendix B. GeoCatch's capacity to implement the BMPs identified in the WQIP is highly dependent on funding, which has been both insufficient and difficult for them to obtain - see below.
Is there a well-developed management plan for the water-related assets?	Partially - the existing management plan (the WQIP) is, as noted in Section 2.2.1, quite good in what it seeks to achieve. But it is focused on one element of catchment management, namely reducing nutrient loads entering waterways and ultimately the downstream wetlands. In particular, the WQIP does not explicitly address the ecological 'health' of the catchment waterways, or indeed the Vasse-Wonnerup wetlands or Toby Inlet. In addition to river health many other aspects of catchment management are not covered by the WQIP, e.g. biodiversity, land management, invasive plants and animals, and erosion. Some of these aspects of broader catchment management are covered in more recent WQIPs (e.g. Leschenault Estuary WQIP, Hugues-dit-Ciles et al., 2012), and there is scope for the Geographe WQIP to be updated when it is reviewed later in 2014.
Does the plan have clear targets	*Nutrient targets* – Yes. The WQIP has identified nutrient load reduction targets for each sub-catchment and for the

	an integrated and targeting implementation program impossible to run, and further causes major problems with staff retention and stakeholder engagement. It is clear that the BMP implementation program needs to be more strategic, with a focus on the priority catchment being targetted each year and the BMPs to be implemented in that year; the information in Neville (2008) could help here. But to achieve this will require more stable funding. *WQ monitoring program* – DoW take water samples at 22 sites in the catchment each fortnight during the winter when these streams are flowing. These are analysed for TN, TP, TSS, Filterable Reactive P, Nitrate + Nitrite-N, dissolved organic N, pH, temperature DO and conductivity. The TP and TN data are then compared with the relevant targets (TP <0.1 mg/L, TN <1.0 mg/L). The spatial and temporal coverage of this WQ sampling program are adequate – all major waterways are monitored most at a gauging station. Nutrient loads will be estimated using concentrations and flows (flow either measured in gauged catchment or modelled in ungauged catchments) and the annual loads compared with the targets. There are no ecological 'river health' targets for the Geographe Catchment and very little monitoring. *Monitoring of BMP implementation* – this appears to be adequately done for changes/activities that are easily identified (e.g. dairy effluent upgrades, length of stream fenced and revegetated, number of properties with nutrient soil testing), although the information is difficult to obtain (see Appendix B). However, with activities that require behavioural change (e.g. fertiliser management) only qualitative (anecdotal) information is available. The difficulty in reporting on behavioural change in agricultural practice is not unique to this catchment. There is an urgent need to establish a robust monitoring program to verify and quantify the effectiveness of these management practices.
Has implementation of the plan over the past 5 years been satisfactory?	The success of the WQIP depends on the effectiveness and implementation of the identified BMPs. In agricultural areas, priority has been placed on BMPs for management of dairy sheds and feedlots, fertilizer management, implementing riparian management, and controlling of stock on waterways. In urban areas, priority has been placed on management of point sources (wastewater treatment plants, septic tanks), incorporating water sensitive urban design in new residential developments, and limiting fertiliser use in urban areas. Currently, the uptake of BMPs by farmers is voluntary, although there has been a considerable range of advice and assistance provided by GeoCatch, DoW and DAFWA, and a variety of incentive packages through natural resource management programs. A brief review of the implementation of 3 types of BMPs in the Geographe catchment over the past 4 years is provided in Appendix B.
Does the program have adequate funding?	No - The WQIP recommended that a capital cost of $16 million over 10-years was needed to implement the BMPs necessary to achieved the interim targets. Neville (2008) recommended a capital cost of almost $25 million over 20-years. These clean-up costs seem low, although they only reflect the capital costs of implementing the BMPs. The full cost would be much greater than this. As a comparison, in 2001 the Victorian Government allocated $22 million over a ten year period to improving the health of the Gippsland Lakes; considerably more than this was actually spent considering the investments the East and West Gippsland CMAs also made. DoW has indicated that they have an improved cost-benefit method for agricultural BMPs, and this will be applied to update the figures for the Geographe Catchment.

	It is disappointing that despite embracing the WQIP (e.g. by forming a Partnership between DoW and GeoCatch at the start of the implementation), the WA Government has not adequately funded this project. Over the period 2009-2013, GeoCatch has attracted $4.2 million from a range of sources. But only around $1.7 million was obtained from State NRM funding, mostly in three large grants totally $1.4 million. The bulk of the $4.2 million funding has been for rather small, project-based programs, which has made it difficult for GeoCatch to develop a strategic approach to the implementation and to retain high quality professional staff. I understand that the current program is essentially unfunded, except for some monitoring, and that the financial viability of GeoCatch is also at risk. A recent study used the INFFER method to assess the costs to achieve the TP reduction targets for the Gippsland Lakes in Victoria (Roberts et al., 2012). Using this analysis and scaling-down the Gippsland Lakes figures to the size of the Geographe Catchment (i.e by 10 for area 20,000 km^2 vs 2,000 km^2) suggests that a 40% P load reduction would need an investment of $100 million over 25 years, or $4 million per year. For the 20% P load reduction (close to the short-term target in the WQIP) the figure would be around $2 million per year
Has there been measurable progress in improved water quality and ecological condition of the asset?	*Improvement* in *WQ* – it is difficult to assess whether an improvement has been achieved as the program has only been in place for less than 5 years. However, water quality monitoring over the period 2006 to 2012 suggests variable results the annual median nutrient concentrations measured during winter (DoW, 2013a). For example, there has been a reduction in the TP concentration in the Lower Sabina River, a pleasing result for this catchment as it has been the target of considerable activity in introducing BMPs. In other catchments, the results are different, e.g. Vasse Diversion Drain TP concentration has remained essentially unchanged, while in the Ludlow River the median TP conc has increased. Unfortunately, there is insufficient data for Lower Vasse River to discern any trends (no water quality data for 2008, 2009, 2010) *Improvement* in *ecological condition* – the WQIP has no targets and no monitoring for ecological condition. However, even if these were available, it is probably still too early for there to be evidence that the catchment streams have improved ecologically. Assessment sites have been established on the Sabina and Abba Rivers to evaluate changes in ecological condition, especially in relation to riparian zone establishment.
If progress has been less than satisfactory, what are the reasons for this?	Progress in implementing the BMPs appears to have been rather slow. However, this is not surprising given that fact that the implementation of the BMPs is voluntary, and there has been insufficient core funding for the implementation. Given these difficulties, GeoCatch has done very well with the dedicated staff they have. However, it is crucial that in the future, GeoCatch develop a 5-year BMP implementation strategy (with targets) and a rolling annual work plan. But again this will only work if there is sufficient core funding for the program.
Are the community generally aware of the management arrangements and satisfied with progress?	The community appear generally well aware of GeoCatch's role in the management of nutrient loads in the Geographe catchment. I received no comments from the community regarding satisfaction or otherwise with progress. Neither the community or others have any information on the cost-effectiveness ($ expended for each kg of P removed) of the proposed management practices and those already carried out.
Summary	*Water quality management in the Geographe catchment is directed by an excellent WQIP plan developed in 2009,*

	which is underpinned by the need to introduce a range of (voluntary) BMPs to achieve the desired reduction in nutrient losses from agricultural land. This WQIP is largely single purpose (reduction of nutrient loads), and is not a catchment management plan. The WQIP is being implemented by GeoCatch in partnership with DoW and with useful assistance from DAFWA, some industry groups (Western Dairy, fertiliser industry) and SWCC (provide some funding). Sensibly, the focus of the BMP implementation has been in a small number of priority catchments (Upper Vasse/Vasse Diversion Drain, Lower Vasse, Sabina and Ludlow Rivers). *Some obvious improvements have been made over the past decade in the management of dairy shed effluent, streambank fencing and revegetation, and exclusion of stock from waterways; considerable efforts have also occurred in improving fertiliser management. The implementation of BMPs in the Geographe catchment has been difficult due to a lack of adequate funding, and in agricultural areas also to the fact that uptake of BMPs by farmers is voluntary.*

3.3 Vasse-Wonnerup wetlands

Criteria	Assessment
Are roles and responsibilities of the key organisations clear?	No - Currently, a number of agencies are involved in aspects of the management of Vasse-Wonnerup Wetlands, with this management largely focused on minimising the potential for fish kills (VETWG, 2013). The agencies involved include: DoW, DPaW, DoF, Water Corp and CoB. There is no overall strategic management plan for these wetlands
Is there an obvious lead agency for the water-related asset, and are they leading effectively?	No – Currently, there is an incident response plan for 2013-2014 that is primarily focused on minimising the potential for fish kills. There is no strategic management plan for these important wetlands. Up to 2013, when a massive fish kill occurred in April of that year, the Vasse Estuary Technical Working Group (VETWG) was chaired by DPaW (previously known as Department of Conservation). Currently, the VETWG is chaired by DoW, who have been responsible for developing a new fish kill mitigation strategy (VETWG, 2013). In the past, there has been indecision between agencies about the need for particular actions (e.g. opening the Wonnerup Inlet bar, opening the floodgates), who should undertake these actions (e.g. clean up of dead fish), and the urgency for undertaking actions. This has lead to community concern regarding the level of coordination between the agencies. The new strategy contains a sensible approach, with each of the agencies responsibilities well identified[7]. However, it remains to be seen if the organisations accept their responsibilities and act swiftly when called upon

[7] The new response plan is triggered when trigger criteria (DO, environmental, community concern, fish stress) are breached. During the period December to April, water quality is monitored weekly (note – soon to install continuous monitoring of DO, temp, pH and conductivity). There are three levels of response: (a) trigger criteria breached - green response – activate daily monitoring of water quality and fish, open fish gate pen stock, check Wonnerup Inlet bar, (b) if after 2 days DO is <4 mg/L or signs of fish stress – orange response – activate daily monitoring of water quality and fish, open fish gate pen stock, open Wonnerup Inlet bar, install pumps to circulate water, and (c) a fish kill occurs - red response – activates cleanup and communications (VETWG, 2013).

	should an incident occur in 2014. There is no long-term strategic management plan for the Vasse-Wonnerup wetlands – see below.
Is there a well-developed management plan for the water-related assets?	*Incident response plan* – Yes. There is a sensible incident response plan for the mitigation of fish kills that is implemented each year between December and April. The organisations involved acted swiftly in responding to the recent fish kill that occurred in February 2014. The response was well managed and well coordinated. *Long-term strategic management plan* – No. There is no long-term plan for the Vasse-Wonnerup Wetlands. The need for such a management plan is covered in Section 4.
Does the plan have clear targets and an adequate monitoring program to measure progress?	*Incident response plan* – Provisionally yes. There are clear trigger criteria, response actions and monitoring, but the new plan has yet to be tested in 2013-14 summer period. *Long-term strategic management plan* – No. There are no overall objectives or targets for the Vasse-Wonnerup Wetlands. Management objectives should include: water bird habitat, biodiversity, fish, recreation, aesthetics, mosquitos flood protection and operation of the floodgates. Regarding monitoring, Murdoch University has been funded over the past 5 years to undertake a range of monitoring and research projects that have substantially increased to knowledge-base for the wetlands. The funding has come from both GeoCatch and SWCC.
Has implementation of the plan over the past 5 years been satisfactory?	No – there is no strategic plan for the Vasse-Wonnerup wetlands. Equally, the Incident Response Plan, while being reasonably successful (until 2013) in preventing fish kills, has not addressed many of the community issues.
Does the program have adequate funding?	*Incident response plan* – No. The program is only funded for 2013-2014. For 2013-2014 the agencies involved have agreed to provide the necessary resources for their component of the plan (DoW – Chair VETWG, coordinate emergency response, WQ monitoring; Water Corp – operate floodgates (fish gates, fish gate penstock, manage estuary water levels, open Wonnerup Inlet sand bar; CoB – coordinate fish kill clean up and disposal is needed, erect signage, hire pumps if needed; DPaW – provide information to DoW regarding optimum water levels; DoF – assist DoW with fish kill response, undertake fish pathology analysis if required. Presumably, the program will need to be re-negotiated for 2014-2015. *Long-term strategic management plan* – No.
Has there been measurable progress in improved water quality and ecological condition of the asset?	*Improved water quality and ecological condition* – Murdoch University has been monitoring aspects of the ecological condition of these wetlands since 2006, and over that time has built up a considerably improved knowledge-base on this system. However, this monitoring has been in place for too short a time to unequivocally identify improved ecological condition. Additionally, DoW has implemented an ecological condition monitoring program on a trial basis, and have also progressed a water balance model for the wetlands to allow consideration of water level management options (Pers Comm, Malcolm Robb, Jan 2014).
If progress has been less than	*Incident response plan* – progress in ensuring major fish kills do not occur in the future should be assisted by the new

satisfactory, what are the reasons for this?	emergency response plan. This is more clear on the roles and responsibilities of the participating agencies, however still has to be successfully run in 2013-2014 summer. There is also an issue with future leadership since DoW have only agreed to coordinate the plan for 2013-2014 and not necessarily beyond that time. *Long-term strategic management plan* – no plan.
Are the community generally aware of the management arrangements and satisfied with progress?	The community are generally aware of the incident response plan and its focus on preventing fish kills. DoW and VETWG ran a community meeting in November 2013 to explain the new plan. Given that another fish kill occurred in early February 2014 (possibly due to the effects of a toxic algae), the community are still not satisfied with the performance of the organisations responsible for incident response. It is difficult to tell whether the community is satisfied with the overall management of the Vasse-Wonnerup wetlands, since my impression is that most people are unaware of the wetlands and their values.
Summary	*Currently, there is no comprehensive management plan for the Vasse-Wonnerup wetlands despite the fact that they are Ramsar-listed. A new emergency 'Fish Kill Mitigation and Response Plan' has been developed and is in place for the 2013-14 summer, with DoW as the coordinator. The new incident response plan has clear trigger criteria, monitoring requirements and agreed response actions. However, the fact that another fish kill occurred in February 2014 despite this new plan, suggests there is still more to be learned in managing this wetland system to minimise the potential for fish kills.* *A comprehensive long-term strategic management plan for the Vasse-Wonnerup Wetlands is needed, which sets realistic (and agreed) objectives, targets and expectations. The multiple management objectives for this plan should include: water bird habitat, biodiversity, recreation, aesthetics, flood protection and operation of the floodgates. This will require establishing a new water balance model and agreement on trade-offs. The overall goal should be to prevent further decline in ecological health of the system in the short-term, and improvement in system health in the long-term.*

3.4 Lower Vasse River

Criteria	**Assessment**
Are roles and responsibilities of the key organisations clear?	Clearly, GeoCatch, in partnership with DoW and CoB, are responsible for the implementation of BMPs in the Lower Vasse River catchment. Responsibility for operational management of the 'lake' section of the Lower Vasse River is not clear.
Is there an obvious lead agency for the water-related asset, and are they leading effectively?	See above.
Is there a well-developed management plan for the water-	Partially – The WQIP has clearly identified that the major issues associated with the Lower Vasse River are due to excessive loads of nutrients from agricultural and urban areas, and GeoCatch, DoW and CoB are working to

related assets?	implement BMPs to reduce these nutrient loads. This is the long-term solution to the algal problems in the 'lake' section of the Lower Vasse River. But, sufficient reduction in nutrient concentrations is not likely to be achieved in times less than a decade. In the interim, CoB should undertake a cost-benefit assessment of two options: (a) removal of the artificial lake and reverting to a dry river bed during summer, (b) continue with the artificial lake, with an 'emergency response management plan, possibly including a number of 'technical' solutions (e.g. reduce the P concentration (e.g. a new inexpensive P-adsorbing nanoclay that should be soon available), altering the physical conditions in the 'lake' to make it more difficult for algae to grow, or dredging the sediments in this 'lake').
Does the plan have clear targets and an adequate monitoring program to measure progress?	There are clear long-term targets for both concentrations and loads of TP and TN in the Lower Vasse River. There are no documented objectives or targets for the management of the 'lake' section of the river that is dammed up in the middle of the town.
Has implementation of the plan over the past 5 years been satisfactory?	Yes – the implementation of the WQIP has been satisfactory. The short-term management of the 'lake' section needs to be improved.
Does the program have adequate funding?	There does not appear to be any targetted funding for these wetlands. In recent years funding has been *ad hoc* and largely in response to algal bloom incidents.
Has there been measurable progress in improved water quality and ecological condition of the asset?	Significant water quality improvement is dependent on the reduction in nutrient concentrations contributed from the catchment (both agricultural and urban areas), and this will take considerable time. There is no evidence that this has occurred despite over a decade of activity with the implementation of BMPs. There is no evidence that the condition of the 'lake' section has improved.
If progress has been less than satisfactory, what are the reasons for this?	See above.
Are the community generally aware of the management arrangements and satisfied with progress?	The community generally are aware of the lack of management of the Lower Vasse 'lake', but seem not to be aware that damming of the lake in summer is contributing to the water quality problems.
Summary	*The WQIP provides a useful management plan for the overall Lower Vasse River, focused as it is on the long-term reduction of nutrients from agricultural and urban areas.* *However, management of the 'artificial lake' formed by damming the river at the Butter Factory is more problematic. The major algal blooms associated with this part of the river are due to excessive nutrients, a lack of adequate flow, particularly in summer, and the fact that the river is dammed. There is a lack of clarity between CoB and DoW as to*

	*who should be responsibility for managemen*t of the lake. *This review concludes that it should be CoB, and recommends that they undertake a cost-benefit assessment of two options: (a) removal of the artificial lake and reverting to a dry river bed during summer, and (b) continuation with the artificial lake including the on-going costs.*

3.5 Vasse Diversion Drain

Criteria	Assessment
Are roles and responsibilities of the key organisations clear?	Yes – the Water Corporation is the responsible organisation.
Is there an obvious lead agency for the water-related asset, and are they leading effectively?	Yes - the Water Corporation within the confines of its rural darinage responsibilities.
Is there a well-developed management plan for the water-related assets?	No detail provided.
Does the plan have clear targets and an adequate monitoring program to measure progress?	No detail provided.
Has implementation of the plan over the past 5 years been satisfactory?	No detail provided.
Does the program have adequate funding?	No detail provided.
Has there been measurable progress in improved water quality and ecological condition of the asset?	No improvement in water quality (nutrient concentrations) in the Drain. A recent isotope study by DAFWA was able to distinguish between nutrients from rural sources and from wastewater discharge, and to confirm that most of the nutrients transported by the Vasse Diversion Drain were fro agricultural activities in the catchment.
If progress has been less than satisfactory, what are the reasons for this?	
Are the community generally aware of the management arrangements and satisfied with progress?	No feedback was received.

Summary	*The Water Corporation manage the drainage and flood-protection functions of theVasse Diversion Drain. The review received no information on the operational management of this system. Management of this Drain does not consider the quality of the water transported. Currently, the Drain does not meet the nutrient targets established by the WQIP, and is discharging excessive amounts of TP and TN to Geographe Bay. The Water Corporation has no legislative requirement to consider the water quality of the drain. However, it is possible that the newly formed Busselton Water Corporation may take over responsibility for the Vasse Diversion Drain (and other drainage assets in the Geographe catchment), and include water quality and nutrient reduction as management objectives in addition to drainage and flood protection.*

3.6 Toby Inlet

Criteria	Assessment
Are roles and responsibilities of the key organisations clear?	It is not at all clear who is the responsible agency.
Is there an obvious lead agency for the water-related asset, and are they leading effectively?	No lead agency.
Is there a well-developed management plan for the water-related assets?	The community-based Toby Inlet Catchment Group have developed a *Management Plan for Toby Inlet Foreshore and Waters*, which they indicate has been accepted by the CoB. Just what this involves is unclear, although the CoB does provides some funds to assist with the management of Toby Inlet. DoW also monitors the water quality in Toby Inlet. While it is laudable that this community group have developed a management plan, the effectiveness of this plan will be limited unless better funded and supported by the professional expertise of the relevant agencies (DoW, CoB and probably DPaW).
Does the plan have clear targets and an adequate monitoring program to measure progress?	No
Has implementation of the plan over the past 5 years been satisfactory?	No – largely ad hoc.
Does the program have adequate funding?	No – most of the management is voluntary, with some assistance provided by the CoB and DoW.
Has there been measurable progress in improved water quality	Difficult to assess progress since there are no targets and no monitoring. However, anecdotel evidence from a number of residents suggests the condition of Toby Inlet has deteriorated over the past decade.

and ecological condition of the asset?	
If progress has been less than satisfactory, what are the reasons for this?	The general lack of progress is largely due to inadeqate funding. The Toby Inlet Catchment Group could probably do a serviceable job if they had more resources and greater backup from CoB and DoW.
Are the community generally aware of the management arrangements and satisfied with progress?	Yes - the Toby Inlet community group are well aware of the management arrangements, and are highly dissatisfied with the lack of progress.
Summary	*The management of Toby Inlet is minimalist at best. The Inlet experiences regular blooms of macroalgal and phytoplankton, and offensive odours when these algal blooms die. These issues are the result of excessive nutrient inputs to the estuary, and a lack of adequate flushing caused primarily by the Station Gully Drain and associated causeway, that pass through the eastern end of the Inlet. The condition of the Inlet would be improved if the causeway was removed or the small culvert in the causeway was enlarged. The community-based Toby Inlet Catchment Group have developed a 'Management Plan for Toby Inlet Foreshore and Waters', which they indicate has been accepted by the City of Busselton. Just what this involves is unclear, although the City does provides some funds to assist with the management of Toby Inlet. The Toby Inlet Catchment Group could probably do a serviceable job of managing the Inlet if they had more funding and greater backup from CoB and DoW.*

4. Possible Future Management Options

4.1 General

The assessment of the current management arrangement for the water-related assets in the Geographe catchment provided in Section 3 of this Final Report, has shown that there is considerable room for improvement. 'Business as usual' should not be considered as a viable option as this would inevitably lead to further deterioriation in the condition of the catchment's waterways, including the Vasse-Wonnerup wetlands.

In brief, the water quality in the catchment rivers is slowly being improved through the implementation of the WQIP, but this activity currently has little funding. The implementation of the WQIP is being led by DoW in partnership with GeoCatch, and with assistance from DAFWA, CoB, SoC, some industry groups and farmers. Some obvious improvements have been made over the past decade in the management of dairy shed effluent, streambank fencing and revegetation, and exclusion of stock from waterways; considerable efforts have also occurred in improving fertiliser management. While there is an emergency response plan for the Vasse-Wonnerup wetlands, focused on minimising the potential for fish kills, there is no overall strategic management plan and no obvious lead organisation. Also there is no management plan or designated lead organisation for the artificial lake section of the Lower Vasse River in Busselton. And finally, Toby Inlet has a management plan, but there are limited resources (funds and technical capacity) to implement this plan.

The sections below present first a summary of the roles and responsibilities of the key organisations (including responses they made to the Discussion Document), and then three possible options for the future management of the Geographe water-related assets. The main features of the three option are provide in Figure 10.

In considering future management options, I have taken the view that decisions about which organisation(s) takes a lead role in the management of a particular asset is less about legislation and more about the right fit of that organisation or grouping of organisations. The establishment of leadership and coordination does not require legislation. If a statutory approach is required then an appropriate piece of legislation can be used depending on the ambit of the management structure and organisations involved (e.g. the Water Agency Powers Act can be, and has been, invoked for a wide range of activities).

4.2 Roles and responsibilities of key organisations

This section summarises the current roles and responsibilities of the key organisation involved in management or control of water-related assets in the Geographe catchment. Also provided is a summary of the key points from their submissions to the review.

4.2.1 Department of Water

The Department of Water (DoW) is the lead organisation for the management of waterways in Western Australia. Waterways are defined very broadly to include: rivers, streams, creeks, lakes, estuaries, inlets and wetlands. They also include floodplain and wetland systems that overflow into rivers, as well as wetlands, lakes or swamps that are filled by streams rather than shallow groundwater (DoW web site[8]).

DoW derives its powers from three acts: the *Water Agency Powers Act (1984)*, *The Rights in Water and Irrigation Act (1914)* and the *Waterways Conservation Act 1976*.

The Waterways Conservation Act is potentially very powerful, and quite relevant to this review. Under this Act, DoW has the power to control and manage waterways, and to formulate and implement schemes for their conservation. Currently, five regions have been declared under this Act: Peel-Harvey Estuaries, Avon, Leschenault Estuary and associated rivers, Albany Harbour and associated rivers, and Wilson Inlet and associated rivers. Once a region is declared, DoW is then required to establish a management committee and management program. Such management programs can be discreet or broad in extent, and can also create regulations or by-laws to control particular activities.

The above Acts provide DoW with considerable powers as the water resources manager in

8 www.water.wa.gov.au/Managing+water/Rivers+and+estuaries/default.aspx

Western Australia. This includes the allocation and licensing of water for consumptive purposes, and managing the ecological 'health' and water quality of waterways (rivers, wetlands and estuaries). And given the linkage between catchment land use and water quality, DoW should also have a role in catchment management. No other agency has such a comprehensive role in water (quality and quantity) management.

DoW also has a key role in providing understanding and advice on water science, including the monitoring of water quality and quantity, catchment modeling, understand of estuarine and wetland processes, remediation options, and general integration of water-related activities.

However, despite the above comments, the role of DoW in the management and maintenance of water quality and ecological health of the state's waterways is far from clear. It is recommended that DoW provided a clear statement on their role in waterways and catchment management on their web-site.

In the Geographe region DoW has had an active role for many years. They led the development of the WQIP, and have partnered GeoCatch in implementing this plan since 2009. They also have the responsibility for monitoring water quality in the catchment waterways, and for reporting on water quality trends and success of the implementation program. Regarding the Vasse-Wonnerup wetlands, DoW has participated in the VETWG since 1997. They led the development of the new emergency response plan for 2013-2014, and are chairing VETWG for 2013-2014. They also monitor water quality and phytoplankton levels in the Vasse-Wonnerup wetlands and the Lower Vasse River during summer, and provide technical support and advice to TICG and CoB regarding Toby Inlet.

DoW are also a key partner in the WA Fertiliser Partnership 2012-2016[9], together with DAFWA, DER and the Swan River Trust.

DoW did not make a submission to the review, but DoW officers did provide comment on various drafts.

4.2.2 Geographe Catchment Council (GeoCatch)

GeoCatch is a community-based natural resource management body formed in 1997 as a result of growing concern about the health of the Geographe catchment. GeoCatch is an incorporated and advisory committee established under the *Water Agencies (Powers) Act 1984*, that works with DoW to coordinate catchment management of the Geographe Bay region. It has no statutory basis.

GeoCatch operates in partnership with local government, community, state governement agencies, regional NRM (SWCC) and industry to cooperatively manage land and water issues through an integrated catchment management approach. Since its inception, GeoCatch has had a Partnership Agreement with the Department of Water (DoW), which was formalised in 2009, with DoW paying member sitting fees, assisting in employing staff, and providing technical, strategic and managerial support. GeoCatch is dependent on external funding to pay staff and carry out activities, with funding sought from a range of sources, including the Federal and State Governments.

GeoCatch's mission is to work with the community and management agencies to manage the catchment of Geographe Bay and its marine environment, so that natural systems, people and their activities co-exist in a healthy, productive and sustainable way (GeoCatch, 2013c).

GeoCatch initially partnered with DoW in the development and implementation of the Lower Vasse River Cleanup Program, and more recently in the development and implementation of the WQIP. GeoCatch has participated in the VETWG since 2000. They have also sourced funds to contract Murdoch University to monitor macrophytes and other ecological aspects of the Vasse-Wonnerup wetlands.

In their submission to the review, GeoCatch supported the two options proposed in the Discussion Document subject to certain conditions being met. Regarding Option 1 (separate management structure), GeoCatch believe they are best placed to take on the coordinating role, but that in order to achieve this they would need adequate secure funding and resources (core staff salaries, administration and operating expenses) and a mandate (possibly Ministerial authority) to undertake the coordinating role. Regarding Option 2 (new catchment and wetland management authority),

[9] Note: the Fertiliser Partnership 2012-2016 superceded the 2007 Fertiliser Action Plan (FAP) (see http://fertiliserpartnership.agric.wa.gov.au/fertiliser-partnership-0).

GeoCatch believe this option is unlikely to be adopted by the Government since it would require significant changes and new legislation. However, if Option 2 was adopted, they believe it would take a considerable time to implement, and that GeoCatch could play an important role in the transition period.

4.2.3 South West Catchment Council (SWCC)

SWCC is the designated Natural Resource Management regional body for the South West of Western Australia, one of 55 bodies established nationally under the National Heritage Trust (including Caring for our Country) for the purposes of coordinating community-based NRM. In Western Australia, the NRM regions are community-based not-for-profit, non-government organisations, with no legislative or statutory basis, funded by the Federal Departments of Environment, and Agriculture ($5 mill p.a.) and the Western Australian Natural Resource Management Office ($0.25 mill p.a.).

The SWCC has a skill-based Board of Management and is responsible for six catchments: Peel-Harvey, Leschenault, Geographe, Cape to Cape, Warren and Blackwood (see web site http://swccnrm.org.au/). GeoCatch is a member organisation of SWCC with representation at various levels of SWCCs governance structures. SWCC have and continue to provide funds and implement projects in the Geographe catchment for a variety of NRM projects including for the implementation of BMPs and for research on the Vasse-Wonnerup wetlands.

In their submission to the review, SWCC noted that they favored Option 2 in the Discussion Document as the establishment of a dedicated Catchment and Wetland Management Authority would allow for a coordinated and integrated approach to management of the key assets within the Geographe Catchment, including the Vasse Wonnerup Wetland by a single organization. Regarding Option 1 in the Discussion Document they argued that this has the potential to continue the *status quo*, which was generally described in the recent Australia State of the Environment Report as *'the [WA] state agencies have established coordination mechanisms that might best be described as 'systems to avoid treading on each others' toes', but there is no formal or informal system that has the responsibility of maintaining the environmental values of the marine and coastal ecosystems of Western Australia or providing for systematic reporting on their condition'* (SoE Committee, 2011).

SWCC also strongly support the statement in the Discussion Document (p21) that '*It would seem sensible if this emergency response plan was part of a more comprehensive Vasse-Wonnerup Wetland Management Plan'*, suggesting that this move would contribute to a more integrated and holistic management plan.

Further, SWCC made the following suggestions:

- that it is critical that further funding is made available to the appropriate agencies with statutory responsibility for the Vasse-Wonnerup system to undertake appropriate monitoring and research to adequately manage the system and catchment,
- that information on the status of priority threatened flora and fauna in Geographe catchment, Vasse-Wonnerup wetland and Geographe Bay ecosystems and associated ecosystems services, are not readily available to the public. This information, packaged appropriately, will be essential if the community is to assist in the development of new management plans for these systems.
- that publically available 'report cards' should be regularly prepared to provide an overview of the health of Geographe catchment, the Vasse-Wonnerup wetlands and Geographe Bay.
- that there should be consideration of reinstating natural flow regimes of water-dependent ecosystems and redirecting water from drains (with treatment when applicable) back to natural systems.
- that all management plans should contain a costing for research (if required), monitoring and reporting back to the community.

4.2.4 Department of Parks and Wildlife (DPaW)

DPaW, established in July 2013 (previously Department of Environment and Conservation), operates under the Conservation and Land Management (CALM) Act. Their new Strategic Direction 2013-2014 document list four goals, two which have relevance to management in the GeoCatch region; goal 2 is to 'conserve, protect and manage the state's native fauna and flora based on best practice science', and goal 4 is to 'manage access to the lands and waters under our care and the state's biodiversity for sustainable uses including tourism and wood production.' (DPaW web site - www.dpaw.wa.gov.au).

DPaW have a major interest in the Vasse-Wonnerup wetlands given that they were responsible for nominating these wetlands for Ramsar listing, and in reporting to the Commonwealth Department of Environment on their ecological condition. These wetlands are recognised by DPaW as an important habitat for both migratory species and wildlife utilising the adjoining conservation reserves and other lands.

DPaW is not able to prepare a statutory area management plan for the wetlands since the area is not vested in or under the care, control or management of the Conservation Commission of Western Australia (CCWA)[10]. The CALM Act prevents DPaW from preparing a management plan in these cases. It appears the Vasse-Wonnerup wetlands will not vested until a Native Title claim over these waters is resolved.

However, this does not prevent DPaW or another organisation from preparing a strategic management plan (as opposed to a statutory plan). While such a non-statutory plan may be prepared to address the management issues, it will not be successfully implemented unless sufficient resources are made available.

The CALM Act also suggests that if the Conservation Commission were to have land placed with it (as opposed to vesting), and have the care, control and management, then a management plan could be prepared by DPaW (also in collaboration with others). For this to happen it would need support of the DPaW, CCWA and the Minister, and of course the resources to undertake the plan preparation and to implement it.

DPaW are also currently developing a high level Management Plan for the southern Swan Coastal Plain[11]. This plan is intended to guide management for over 80 existing DPaW managed reserves and over 20 proposed reserves in the southern portion of the Swan Coastal Plain. The Vasse-Wonnerup wetlands are one of the proposed new reserves. The management plan will be a strategic document, and provide direction for key issues that require resolution and/or action during the life of the plan.

It appears that the most recent Government position on the management of wetlands in Western Australia is contained in a 1997 document entitled 'Wetlands Conservation Policy for Western Australia' (Govt WA, 1997). However, I could not find a clear statement outlining DPaW's current position on its management responsibility in general for wetlands in Western Australia, and its resourcing for this activity.

DPaW were instrumental in establishing the VETWG in 1997 and chaired the group from that time until 2013. They also manage some land adjoining the Vasse-Wonnerup wetlands that is in the conservation estate.

In their submission to the review, DPaW indicated their agreement that an area management plan for the Vasse-Wonnerup wetlands is needed, but noted that the development of a plan alone does not ensure the required resources to implement it are guaranteed. They did not comment on either Option presented in the Discussion Document as they believe this is a decision at the Ministerial and Government level to determine how they wish to have the wetlands managed.

DPaW also believes that there is an ongoing role for the VETWG, perhaps with some consideration of supplementing the representation with relevant community interests.

DPaW also noted that the Discussion Paper does not clearly recognise aboriginal interests in the Vasse-Wonnerup wetlands, and suggest there should be some mention their cultural values.

4.2.5 Department of Agriculture and Food (DAFWA)

DAFWA administer the *Soil and Land Conservation Act 1945*. This Act is focused on land use impacts, and provides for the regulation of drainage, and soil and land degradation. Land degradation is defined as soil erosion, salinity, eutrophication and flooding and the removal or deterioration of natural or introduced vegetation that may be detrimental to the present or future

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[10] Some land around the Vasse-Wonnerup wetlands is vested in the CCWA and is being managed by DPaW.

[11] See www.dpaw.wa.gov.au/parks/management-plans/draft-plans-in-preparation/102-swan-coastal-plain-south-draft-management-plan

use of land.

DAFWA participated in the development of the WQIP, particularly through the provision of technical knowledge of BMPs, generated through their extensive research into nutrient losses from agricultural land on the sandy Swan coastal plains soils (e.g. Gourley and Weaver, 2012; Keipert et al., 2008; Rivers et al., 2013; Weaver and Wong, 2011; Weaver and Summers, 2013, 2014).

DAFWA are a key partner in the WA Fertiliser Partnership 2012-2016, and have a commitment to undertake a 5-year review of this Agreement.

Since 2009, they have been a partner with GeoCatch and DoW in implementing the rural fertiliser management BMP. In particular, they have been responsible for undertaking the whole farm soil testing and nutrient mapping for a considerable area of the Geographe catchment.

DAFWA did not make a submission to the review, but DAFWA officers did provide comment on various drafts.

4.2.6 Department of Fisheries (DoF)

DoF administer the *Fish Resources Management Act 1994,* and through this Act have a statutory role in the protection and management of fish, other aquatic resources and their habitats.

DoF has a role in the management of the Vasse-Wonnerup and Toby Inlet ecosystems. Currently, they contribute to the management of the Vasse-Wonnerup wetlands through their membership of VETWG, and play a key role in the response to any fish kills. They would obviously be a key agency in any future more strategic management plan for the Vasse-Wonnerup wetlands.

In their submission to the review, DoF supported Option 2 in the Discussion Document - the formation of a single Geographe Catchment and Wetland Management Authority. This option they believe would provide the opportunity to: (a) identify management priorities on a catchment-wide basis, (b) seek resources that align with management priorities in a transparent and holistic (catchment-wide) manner, and provide clear linkages with regional NRM groups (namely the South West Catchment Council) and thereby increase opportunities for alignment with, and effective delivery of, agreed management priorities.

Further, DoF argued that such an Authority should: (a) include community and local government representation, as well as wetland technical experts, with an independent chair, (b) provide the opportunity for ‘expert advice’ from relevant State Government agencies, and (c) have secure, long-term funding arrangements.

4.2.7 Water Corporation

The Water Corporation’s main role is in flood protection and drainage (urban and rural), and wastewater treatment. In the Geographe catchment they are responsible for the operation and maintenance of the Vasse Diversion Drain, the Vasse and Wonnerup floodgates, the regional sewerage infrastructure, operating the Busselton Wastewater Treatment Plant, and delivering scheme water suply to Capel, Dusborough and many other small towns.

The broad objectives of the floodgate operation are to control: (a) flooding from the Vasse River, (b) flooding from the ocean (surge control), (c) wetland water levels so that surrounding agricultural land is not inundated, (d) water quality conditions in the wetlands during summer and autumn to prevent fish kills.

The operational rules for the floodgates are largely related to water level[12], although in the event of fish stress the fish gates are opened to allow for fish movement. It does not appear that these rules are documented.

The Water Corp have been a member of VETWG since 1997. When the floodgates were upgraded they were instrumental in preparing an MoU on how the floodgates should be operated, but this was not signed by all parties.

During the 2013-2014 summer period they agreed in accordance with the new fish kill mitigation plan, to monitor water levels in the wetlands, operate the floodgates, open the Wonnerup Inlet bar at the start of summer and keep it open as necessary (VETWG, 2013).

The Water Corp did not make a submission to the review.

[12] The rules are: Winter – aim to keep water level <0.8m; Spring – aim to keep water level 0.4-0.8m; Summer – aim to keep water level > -0.1m, If <0.1m gates are opened.

4.2.8 City of Busselton (CoB)

The CoB is a local government area in the south-western region of Western Australia. The CoB covers an area of 1,455 km^2, almost three-quarters of the Geographe catchment. It has an estimated population of almost 32,000, mostly located in the two largest towns, Busselton and Dunsborough.

The CoB operate the boards at the Butter Factory that dam up the Lower Vasse River in Busselton, operate the valve that regulates flow into the Lower Vasse River from the Vasse Diversion Drain, and manage crown land adjoining the river.

They have been a partner in the WQIP implementation program since 2009, working with GeoCatch to implement water sensitive design features in urban areas and undertaking strategic stormwater upgrades.

The CoB have been a member of VETWG since 1997. During the 2013-2014 summer period they have agreed in accordance with the new fish kill mitigation plan, to coordinate fish kill clean up if needed, coordinate the hire of pumps if water circulation is needed, coordinate traffic and public management in the area of the floodgates and Wonnerup Inlet bar opening, and erect signage as needed (VETWG, 2013).

In their submission to the review, CoB was supportive of a management model that involves a clear, single, 'lead' agency, with overall responsibility for management of Geographe catchment waterways (i.e. Vasse-Wonnerup wetlands, Lower Vasse River, Vasse Diversion Drain, Toby Inlet, and the various other inland waterways that drain into Geographe Bay, plus the associated catchment area). They provided thought on the role of the 'lead' agency, including:

- that the 'lead' agency should have a strong, local on-ground presence, and be directly responsible for as many aspects of the management of Geographe catchment waterways as is reasonably possible,
- that while it may not be possible (practical) for the 'lead' agency to be directly responsible for all aspects of the management of Geographe catchment waterways, there should be clear means by which the lead agency can influence or direct actions of 'supporting' agencies, and draw on their expertise when necessary,
- that the 'lead' and 'supporting' agencies should work to an overall management plan, endorsed by Cabinet and/or of a statutory nature,
- that there needs to be a shift in the balance between the various, sometimes competing, management objectives for the waterways (i.e. amenity, water quality, biodiversity, rural drainage/protection of rural land, flood mitigation, mosquito management/disease control), with more emphasis on amenity and water quality, and less on rural drainage and protection of rural land,
- that there should be consistent funding available for the activities of the 'lead' agency and 'supporting' agencies, including both commitment from the State, as well as contributions from the local community, especially the urban community,
- that the 'lead' agency should be responsible for all of the public 'infrastructure' that influences the flow of water and nutrients into, out of and through the Geographe catchment waterways, except for urban and other road drainage (i.e. they must be responsible for rural drainage, flood mitigation, valves, floodgates and similar, as well as the sand bars at the mouths of the Vasse-Wonnerup wetlands and Toby Inlet), and water quality objectives should be set in relation to management of that infrastructure,
- that the 'lead' agency should be responsible for monitoring of water quality, levels and flows,
- that the 'lead' agency should have powers in relation to land management and regulation of land-use (i.e. encouraging and/or requiring landowners and land managers to reduce the amount of nutrients exported from their land), or there should be a 'supporting' agency with a clear mandate to do so in a much more pro-active way than is currently the case, in partnership with the 'lead agency' (and this should involve genuinely voluntary approaches, but also payments to landowners and regulation),
- that if the 'lead' agency is not the principal land-use regulator, then the Department of Environment Regulation (DER) may be the most appropriate 'supporting' agency to act as the principal land-use regulator (using the licensing powers provided to it in the Environmental

Protection Act).

- that GeoCatch should have a role as a key 'supporting' agency, responsible for working with landowners to achieve voluntary improvements in land management, and
- that DoF and DAFWA should also continue to be important 'supporting' agencies

CoB suggest that the agency that appears most willing and able to be an effective 'lead' agency is Busselton Water Corporation (BWC). BWC have expressed a clear willingness to play a lead role (see Section 4.2.10 below), have a substantial local presence and are a locally based organisation, have shown themselves to be very competent infrastructure managers over a long period of time (and infrastructure management is probably the most important of the various catchment management tasks), have significant financial capacity, their management and board have substantial relevant expertise and a keen interest in the issues, and they have an appropriate governance structure.

Further, CoB believe that much, if not most, of the above can be achieved without legislative change, but if legislative change is needed or desirable then it should occur, but it should also not be a reason to delay the making of changes that can occur without legislative change.

Three final points CoB make in their submission are:

- that an option to provide some funds would be an 'environmental levy' paid as part of water rates (which would be paid principally by water consumers in the Busselton-Vasse urban area, but not by most residents of rural areas),
- that if the 'lead' agency is not the manager of the key downstream water-bodies (i.e. Vasse-Wonnerup wetlands, Lower Vasse River and Toby Inlet), then the manager should be the DPaW, or in the case of the Lower Vasse River and Toby Inlet, either DPaW or the CoB,
- that the State should also ensure that infill sewer occurs in the Busselton LIA and that discharge of treated wastewater into the Vasse Diversion Drain ceases, as soon as possible (these are both currently Water Corporation responsibilities).

4.2.9 Shire of Capel (SoC)

The SoC is a local government area in the south-west region of Western Australia, located between the cities of Bunbury and Busselton. It has an area of around 558 km^2.

The Capel River flows through the Shire; this is the only river in the Geographe catchment which flows permanantly. This river originally flowed into the extensive wetland system which formed part of the upper portion of the Wonnerup estury and formed part of the extensive wetlands that ran from Bunbury south to Bussleton and Dunsborough. This system has been significantly modified by drainage and agriculture, so that now the Capel River discharges directly to the ocean through an artificial channel. The land in the lower Capel catchment is now mostly in private ownership.

The Shire of Capel is a member of GeoCatch and participates in the implementation of the WQIP in their region.

In their submission to the review, SoC supported Option 1 in the Discussion Document, with GeoCatch as the lead, coordinating organisation. SoC believes GeoCatch are well placed to undertake this role since they are well recognised as the lead organisation in catchment restoration with rural landholders, businesses and schools, have experience in developing successful applications to gain external funding, and have access to expertise to implement projects that cover the whole of the Geographe catchment.

However, for this to work, they believe GeoCatch must be adequately funded to do the job of coordinating the updating and implementation of a catchment management plan, including the WQIP. They mention the possibility of accessing corporate funding.

SoC also argue that the development of a new catchment drainage strategy should be undertaken, involving a review of current drainage network, and the possibility of reconnecting some of the natural waterways that have been degraded by drains.

4.2.10 Busselton Water Corporation (BWC)

BWC is not currently involved in waterways management in the Geographe catchment. However, the organisation became a Corporation in November 2013, which means they now have the opportunity to expand their business from water supply to also incorporate wastewater, drainage and floodplain management.

Through the review consultation process, BWC has expressed a willingness to consider a potential future role for them as the 'infrastructure manager' and 'supporting agency' in new management arrangements for the water-related assets of the Geographe catchment. To make these arrangements work would require appropriate structuring and resourcing, but could contribute to significantly improved water quality and ecological outcomes.

If there was sufficient Government will, and subject to evaluation and proving of the concept, BWC could be assigned responsibility to manage all infrastructure associated with the flow of water and nutrients in the Geographe catchment. This includes drains and associated structures, levees, flood retention basins, floodgates and sand bars. It would include all assets associated with flood protection and the rural drainage network within the Geographe catchment. Responsibility could also be assigned to manage water quality objectives in the drainage network in addition to the traditional water runoff and flow objectives.

Central to this model would be the transfer of the existing Rural Drainage Licence within the Geographe catchment from the Water Corp to BWC. Water quality objectives could be incorporated in the licence requirements with funding and resourcing to match such requirements.

4.2.11 Industry

Western Dairy/Dairy Australia

Western Dairy, one of eight Regional Development Programs that are spread through the nation's key dairy areas, operates under the auspices of Dairy Australia. Western Dairy has been operating since 1997 to guide the strategic direction and implementation of dairy research, education and promotion programs in the Western Australian region.

In their submission to the review, Western Dairy and Dairy Australia note that managing the nutrients (fertiliser and effluent) and water quality is one of the biggest challenges for the Australian dairy industry and is a top priority for industry research, development & extension (RD&E) using levy funds and leveraged funding.

Their submission also lists a number of activities Western Dairy have undertaken over the past decade to improve nutrient management and water quality particularly in south-west Western Australia, including publishing a Code of Practice for Dairy Shed Effluent Management, funded the preparation of effluent management plans, assisting in the Whole Farm Nutrient Mapping project, and involvement in the Fert$mart program aimed at improving fertiliser management.

They indicate that the dairy industry is keen to work with all partners to improve water quality in the Geographe catchment, and see the on-going support for technical expertise (e.g. NRM specialists who understand the complexities of managing effluent, nutrients, plant/soil interactions and water quality, on-farm technical expertise starting with service providers who sell and install effluent infrastructure, and soil scientists, farm advisors and fertiliser agronomists who provide advice to farmers around fertiliser management and plant/soil/water interactions) as important steps for continual improvement of water quality in the region.

WA Farmers Federation Dairy Council

In their submission to the review, the WA Farmers Dairy Council indicate that they exists to act as a voice on behalf of the states farmers and lobby for the best possible outcomes to ensure a sustainable and profitable future for the agricultural sector, and that they aim to support the long term sustainability of the dairy industry.

The WA Farmers Dairy Council believes the current arrangement of industry partnerships with Western Dairy and organisations such as GeoCatch, are the preferred method of using farmer funded levy payments to build research programs and focused best management practice solutions on-farm.

Dairy Council acknowledge the need for an increase in funding for catchment NRM, but noting the current financial pressures on WA dairy farmers, they believe any extra levy charges on the farmers within the Geographe catchment would be an undesirable outcome of this review.

The Dairy Council notes that the dairy industry within the catchment provides considerable economic benefit to the community in terms of jobs on farms and along the food supply chain, supporting local businesses, schools and community groups. They believe that the future management of the water assets in the Geographe catchment should include the agricultural community, recognising they are part of the long-term solution and the need to work collaboratively to ensure improvements on farm and throughout the wider catchment.

Fertiliser industry

The fertiliser industry did not make a submission to this review.

However, a representative of Summit Fertiliser (Ralph Papalia) provided useful information on the range of advice his company provides to farmers on fertiliser use, including subsidised soil testing. He noted that trust in the advice providers was a very important element in farmers accepting advice on fertiliser management.

The fertiliser industry is an active partner in the Fertiliser Partnership 2012-2016[13] established by DAFWA, DoW, DER and the Swan River Trust.

4.3 Future management options

This section presents and discusses three options for the future management of the Geographe water-related assets. The main features of the three option are shown diagramatically in Figure 10.

4.3.1 Option 1: Catchment and wetland management authority

This Option would permit the key assets within the Geographe catchment to be managed as an integrated system and by a single 'lead' organisation (Figure 10a).

The establishment of such an Authority would mirror the situation in other Australian states (e.g. Victoria[14], NSW[15], Qld and SA), where a range of slightly different types of catchment (or natural resource) management authorities have been formed. In general, these all have a common goal to provide for the integrated management of natural resources, using catchments as the administrative boundaries.

The Option below is built around the Victorian catchment management framework (see Appendix C), but with the two important wetlands – the Vasse-Wonnerup wetlands and Toby Inlet - also included. This is something the Victorian's have not been able to achieve, despite coming very close to merging CMAs and Coastal Boards in 2010.

Structure

A catchment and wetland management authority would be established, with an independent skill-based Board. The Board members would be appointed by the Minister for Water for a period of three years. The composition of the Board would include: an independent chair, 5-6 community members with requisite skills, with agency (DoW, DPaW, DAFWA, Water Corp, BWC) and local government (CoC, SoC) representation as observer status.

The Authority should be closely aligned with DoW, DPaW and DAFWA.

The functions of the Authority would be to:

- develop a five-year Geographe Regional Catchment Strategy encompassing the Geographe catchment, the Vasse-Wonnerup wetlands, Toby Inlet and the Lower Vasse River,
- develop and implement appropriate Management Action Plans for priority assets (e.g. catchment waterways, Vasse-Wonnerup wetlands, Toby Inlet),
- develop and implement an adequate monitoring and reporting program,
- commission necessary research to increase the knowledge-base of the assets.

The Geographe Regional Catchment Strategy should have as its goal to contribute to maintaining (or achieving) the long-term productivity of agricultural land, to sustainable urban development, and to maintaining the health of the environment. The Strategy should include a focus on ensuring that:

- agricultural production and urban development is sustainable,
- the ecological condition of the catchment's waterways (rivers, wetlands, estuaries) are protected, maintained and enhanced,
- the catchment's biodiversity (animals, plants, ecosystems) is protected, maintained and enhanced,

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13 http://fertiliserpartnership.agric.wa.gov.au/fertiliser-partnership-0

14 www.vcmc.vic.gov.au/

15 www.cma.nsw.gov.au/

- the catchment's cultural values are protected, maintained and enhanced,
- the catchment's drainage systems are appropriate and effectively managed,
- adequate monitoring and assessment is undertaken and reported, so that the effectiveness of the management can be assessed.

Legislation

It would be preferable if a Geographe Catchment and Wetland Management Authority was established under new state-wide legislation, since the Geographe catchment is not the only one in Western Australia that would benefit from an integrated approach.

However, if the WA Government do not wish to establish the necessary new legislation, there are other options available, e.g. to establish a catchment and wetland management authority under the Water Conservation Act.

Resourcing

Obviously, the establishment of a new Authority will require additional quite substantial resources, and a commitment by Government that this commitment will be sustained for at least 10-years. An estimate of the quantum of the required commitment is around $3-5 million p.a for this period.

Assessment of the option

Pros – This option would provide a new integrated approach to the management of natural resources in the Geographe region (and perhaps also other regions of Western Australia). There would be a single authority with well defined roles and responsibilities that could develop over time a systems and coordinated approach management of the catchment's resources.

Cons – This option will require new arrangements, preferable also new legislation, to be established by government. It will also require the long-term commitment of a substantial investment portfolio. And it will take some time to establish the Geographe Catchment and Wetland Management Authority as a functioning entity with the necessary skills, expertise and know-how. There is also some possibility that existing agencies may feel that their role is being usurped.

4.3.2 Option 2: Overall lead agency coordinating the separate asset management arrangements

This Option would see the key water-related assets being managed as separate entities, but with an overall coordinating lead agency (Figure 10b). The separate water-related assets to be managed would be the Geographe catchment (including the drainage network), the Vasse-Wonnerup wetlands, the Lower Vasse River 'lake' in Busselton and Toby Inlet. A lead agency has been identified for each of the assets. It is anticipated that this governance structure would allow the management objectives, roles and responsibilities of the key agencies and the resources needed for each asset to be more focused and better defined, with the separate asset management arrangements better coordinated by the overall lead agency.

Overall Coordinating Body (Lead Agency)

Three options for the overall coordinating body are discussed:

- *Restructured Geographe Catchment Council* – In their submission to the review, GeoCatch indicated that they would be prepared to undertake the role of lead agency provided a number of changes were made to their present structure (see Section 4.2.2 above), the most important of these being adequate secure funding and resources (core staff salaries, administration and operating expenses) and a mandate (possibly Ministerial authority) to undertake the coordinating role. Apparently, a somewhat similar coordinating role to that suggested for the 'lead agency' was envisaged for GeoCatch when originally established in 1997. However, the capacity for GeoCatch to deliver on this overall coordinating role has been significantly reduced because of a lack of core funding and a lack of a legislative or Ministerial mandate.

  This option is somewhat similar to the management arrangements currently existing for the Peel-Harvey catchment. A restructured GeoCatch could certainly achieve the objective of a effective coordinating body, but only if adequately resourced with a stable and competent staff, and with a legislative or Ministerial authority to achieve the necessary coordination.

- *Busselton Water Corporation* – It was noted in Section 4.2.10 above, that BWC have expressed an interest in exploring the option of them becoming the 'infrastructure manager' of the rural drainage network, with water quality objectives included in their Operating Licence, and in time possibly assuming a broader 'waterways manager' role. If they took on this role they would be playing a critical and central part in the management of the Geographe catchment water assets, and would be potentially well placed to take a 'lead agency' role in the overall waterways management. BWC has not evaluated this concept but have indicated they are open to this possibility.

The option of BWC taking a 'lead agency' role in the overall waterways management in the Geographe region is attractive, as they have a proven 'corporate' structure with a skill-based board, a viable senior management structure, and considerable experience in on-ground infrastructure management. Also they are locally-based and should be more responsive to local needs. If BWC were to evolve to a 'lead agency' role, this would mirror the very successful Melbourne Water Corporation (MWC) model, where MWC has responsibility for bulk water supply, wastewater treatment and waterways management (rivers, wetlands, drainage) for the city of Melbourne.

- *Ministerial Task Force* – Government may feel that it is too early to consider BWC as lead agency since they have yet to take on the role of drainage network infrastructure manager, and therefore have yet to show they can do this effectively. To allow for a transition to BWC possibly becoming lead agency, Government consider the appoint of a Ministerial Task Force to perform the function of lead agency for a period of 3-5 years. A possible structure for this Task Force would be: an independent chair and representatives from the key organisations (e.g. DoW, DPaW, DAFWA, DoF, CoB, SoC, GeoCatch), served by an Executive Officer and an Administrative Officer.
- *Department of Water* – As noted above (Section 4.2.1), the role of DoW in the management of the State's waterways (rivers, wetlands and catchments) and catchments is unclear. However, a reasonable interpretation of the Acts they administer would suggest they have sufficient powers to play a significant role in the management of the State's waterways (quality and quantity) and their associated catchment should they wish. Certainly, no other agency has such a comprehensive role in these areas.

  DoW could assume the role of lead agency for the management of water-related assets in the Geographe catchment. In fact, they are currently undertaking this role in the catchment (implementation of the WQIP), and in the Vasse-Wonnerup wetlands (chairing the VETWG). However, to undertake the lead agency role envisage for this Option, would require the Minister for Water making a commitment that DoW assume the role of lead agency and providing the necessary resources for this to occur. Ministerial support would be vital to ensure the Department makes the necessary commitment of resources to ensure this option works.

However, whatever form of lead agency is decided by Government, it is suggested that such a model would need to include:

- The lead agency and supporting agencies to all have clear accountabilities,
- These accountabilities would need to be tied to a single overall Management Plan,
- Legislation and regulation must be available where required to compel compliance with water quality objectives,
- The lead and supporting agencies would need to be funded and resourced to levels that match the accountabilities and expected outcomes.

In considering the above options, this review concludes that the Minister for Water should consider in order the options for lead coordinating body as: (a) DoW, (b) a restructured GeoCatch, and (c) a Ministerial Task Force with transition to a corporate model involving BWC.

Geographe catchment

Currently, the management of this catchment is informed by the WQIP, with the lead organisations being GeoCatch and DoW. The management plan is largely focused on reducing the load of nutrients from this catchment through the introduction of best management practices in agricultural and urban areas.

The proposed future management arrangements would build upon this existing structure.

Lead organisation – This should be GeoCatch and DoW, with continuing assistance from DAFWA, Water Corp (BWC), CoB and SoC. The current GeoCatch structure (representatives of community, local government and agencies) seems adequate, but the size (15) should be reduced. The current partnership with DoW seems to be working well.

Management plan – A broader catchment management plan should be developed by building on the current WQIP, but with other elements of catchment management included. These could be: river health, biodiversity, soil & land management, pest plants & animals and drainage. GeoCatch has already developed a Catchment Management Plan (GeoCatch, 2008) that covers most of these elements. They have also developed a number of River Action Plans (e.g. see GeoCatch, 2010). This would also be a good opportunity to develop a catchment drainage strategy, with the capacity to rationalise the current drainage network and consider reconfiguring some of the drains to be multi-purpose, along the lines suggested by the Peel-Harvey Catchment Council (Del Marcos, 2007).

Implementation – The current focus on dairy shed effluent management, fertiliser management and riparian zone fencing and revegetation should be continued, as should the focus on the catchments of the river flowing into the Vasse-Wonnerup wetlands (i.e. Lower Sabina River, Lower Vasse River, Ludlow River and Abba River).

Resources – Both the number of professional staff and funds for BMP investment need to be increased for this Plan to have any chance of success. Funding in the order of $2.5 million p.a. over the next decade is required. While this funding should focus on the implementation of existing BMPs, these and other BMPs should be measured at the small scale to provide feedback on their success or otherwise.

Pros – This option builds on existing structure. It should be relatively easy to expand the current organisational structure and implementation program that has been in place for 5 years. If this option were accepted the community and government would have greater confidence that management of this important catchment would be improved and that within ten years, the nutrient loads entering the Vasse-Wonnerup wetlands and Geographe Bay would be significantly reduced.

Cons – The success of this option is highly dependent upon sufficient resources being found to fund GeoCatch's activities in implementing BMPs. It those cases where uptake of BMP's is not occurring, there may be a need for mandatory requirement to be introduced.

Vasse-Wonnerup wetlands

These wetlands now receive much less freshwater inflow as a result of the extensive catchment drainage network, are cut off from the ocean by floodgates, and receive excessive amounts of nutrients from the catchment. As a result, there is increased growth of unwanted algae. However, despite these changes the wetlands still have high biodiversity and ecological values; they support a great abundance and variety of waterbirds, and have good populations of macrophytes (e.g. *Ruppia megacarpa*), fish and macroinvertebrates.

Currently, there is no comprehensive strategic management plan for these wetlands despite the fact that they are Ramsar-listed. A new emergency 'Fish Kill Mitigation and Response Plan' has been developed and is in place for the 2013-14 summer.

Lead organisation – This should be DPaW. DPaW will have the statuatory responsibility for developing a strategic management plan for these wetlands once they become part of the WA Conservation Estate. And as noted in Section 2.3.3, DPaW already manage about one-third of the Vasse-Wonnerup Ramsar site, but this does not include any of the waterbody. Additionally, DPaW are currently preparing a draft management plan for the southern Swan Coastal Plain, which proposes inclusion of the majority of the Vasse-Wonnerup wetland area into the Conservation Estate. Although this inclusion is dependant on a native title determination, DPaW could lead the development and implementation of a non-statutory management plan for the wetlands in the interim.

Partner organisations should include: DoW, GeoCatch, DoF, Water Corp (BWC), CoB and SoC. The community input would occur via the involvement of GeoCatch.

Management plan – A 5-year comprehensive non-statutory strategic management plan should be developed for these wetlands, with multiple objectives (e.g. waterbird populations, water quality, ecological health, cultural values, recreation, aesthetics and flood protection). There will be many members of the community who will wish to have an input into the development of such a Plan. This Plan should also incorporate the main elements of the current emergency *Fish Kill Mitigation and Response Plan*, and be closely linked to the Catchment Management Plan since the long-term solution to many of the wetlands problems is ultimately dependent on reduction of nutrient inputs.

Given that a strategic management plan will take some time to prepare, the current VETWG and the Fish Kill Mitigation and Response Plan should be continued for a further 2-years (2014-2016), with DoW as the lead agency.

Implementation – The new Plan should commence as soon as possible.

Resources – This option will require DPaW committing adequate resources to wetland management in the Geographe region.

Pros – This option would see the development of a much needed management plan for a Ramsar-listed wetland system. It goes far beyond the current emergency response plans, and would address issues of great relevance to the community, including how best to minimise the possibility of fish kills, obnoxious odours and algal blooms. The Plan could also build on the extensive ecological knowledge obtained over last 5-6 years to protect and maintain water bird habitat and food sources. The establishment of an single lead organisation would also permit other management options to be investigated and perhaps adopted. These could include: redirecting part of the Capel River flow into the top of Wonnerup wetland to provide additional freshwater input at critical times, to redirect more flow into the Lower Sabina River (from the diversion channel taking Sabina River flow to the Vasse Diversion Drain) again providing more freshwater into the Vasse wetland, to modify the operation of the floodgates, to improve controls on cattle grazing on land surrounding the wetlands, and to dredge the Vasse wetland to remove nutrient-laden sediments.

Cons – This option is dependent upon DPaW (or the WA Government) agreeing to take the responsibility for managing this wetland system, and providing adequately resources to make this happen.

Lower Vasse River

The Lower Vasse River is maintained as an artificial lake (‘lake’) in Busselton for recreational and aesthetic purposes. This ‘lake’ is eutrophic and regularly experiences algal blooms over most of summer, which reduce its recreational and amenity value and causes offensive odours. The current management of the Lower Vasse River, and particularly the ‘lake’ section in Busselton is far from ideal; there is no comprehensive management plan and no obvious lead agency.

Lead organisation – This should be CoB, with continuing assistance from DoW. It seems appropriate that CoB manage this ‘lake’ asset, particularly since they are the organisation that wishes to artificially maintain the river as a ‘lake’ during the summer period, which provides the ideal condition for the annual algal blooms. There would be value in CoB developing a formal Partnership Agreement with DoW to define the roles and responsibilities of each organisation in managing this section of the Lower Vasse River.

Management plan – CoB should undertake a cost-benefit assessment of two options: (a) the removal of the artificial lake and reverting to a dry river bed during summer, and (b) the continuation of the artificial lake with an assessment of the on-going costs. If the latter option is chosen, an operational management plan needs to be developed for the ‘lake’ section of the river. This Plan should cover: operation of the water-retaining boards at the Butter Factory, operation of the valve allowing water to flow from the Vasse Diversion Drain to the Lower Vasse River, adequate monitoring of water quality and phytoplankton levels (should continue to be done by DoW), a set of responses dependant on predetermined triggers (e.g. based on DO and/or phytoplankton levels), and actions (e.g. warning notices, clean up) to be taken in the event of an algal bloom.

Implementation – The chosen option should commence as soon as possible.

Resources – If the agreed option is to retain the artificial lake, this will obviously result in increased resources being required by CoB to undertake the required management. There are several options for raising funds, including an increase in rates for Busselton residents or the setting of a special ‘environmental levy’ (see Section 4.2.8 above). The development of a Management Plan will take several months, and will require input from other organisations and the community. CoB will also need to decide whether they develop in-house skills to manage this asset or contract out the management.

Pros – CoB as the lead agency would make for a clearer line of management responsibility. The cost-benefit assessment of the two options would make it clear to the Busselton residents what is required (including additional resources) in retaining the artificial lake as the prefered option.

Cons - This option is dependent upon CoB agreeing to accept the extra responsibility and adequately resourcing it.

Vasse Diversion Drain

For this Option, the management of the rural drainage network (including the Vasse Diversion Drain) should be linked more closely with the management of the waterways system of the Geographe catchment, and involve new water quality requirements.

The Vasse Diversion Drain, currently managed by the Water Corporation, is an extremely important asset in providing flood protection for Busselton. There is a possibility that in the future the newly formed Busselton Water Corporation may take over responsibility for the Vasse Diversion Drain and other drainage assets in the Geographe catchment.

However, no matter what management arrangements transpire for the Geographe rural drainage network, there should be an independent review of the drainage network to assess (a) its current and future relevance and effectiveness, (b) the relevance of the current '72h rule', (c) what can be done to make this drainage network more effective at reducing nutrients in addition to its flood protection and land drainage functions, and (d) what can be done to reconnect some of the natural waterways that are influenced by drains.

Toby Inlet

Toby Inlet experiences regular blooms of macroalgae and phytoplankton, and offensive odours when these algal blooms die. These issues are the result of excessive nutrient inputs to the estuary, and a lack of adequate flushing.

Lead organisation – This should be the CoB, with close links to DoW, GeoCatch, DPaW, Water Corp and TICG. The CoB may wish to explore the establishment of an MoU between the key groups, similar to that for the Vasse-Wonnerup wetlands and VETWG.

Management plan – An operational management plan should to be developed, to address the key values of these wetlands (e.g. maintanence and protection of water birds, water quality, ecological health, recreation, aesthetics and flood protection). This should build on the existing *Management Plan for Toby Inlet Foreshore and Waters* (TICG, 2006). An initial component of this management plan should be to establish a solution to the lack of adequate flushing of the Inlet caused by the Station Gully Drain and associated causeway. The Water Corporation were requested to comment on the advantages and disadvantages of either removing the causeway or significantly enlarging the culvert; they did not respond. DoW should continue to monitor water quality in Toby Inlet.

Implementation – The new Plan should commence as soon as possible.

Resources – This option will require additional resources being made available to CoB and DoW. Again there are several options for raising funds, including an increase in rates for Busselton residents or the setting of a special 'environmental levy'. The Plan will take several months to develop with input from other organisations and the community. CoB will also need to decide whether they develop in-house skills to manage this asset or contract out the management.

Pros – This option would introduce a much strengthened management plan for this important asset. It builds upon an enthusiastic and knowledgeable community group who have been attempting to manage Toby Inlet for many years, but with minimal resources.

Cons - This option is dependent upon CoB agreeing the accept the extra responsibility and adequately resourcing it.

4.3.3 Option 3: Separate management arrangements

This Option is similar to Option 2 except that there is no overall lead agency with a coordination role (Figure 10c). This represents a minimal change to the existing governance structure, with the key water-related assets being managed as separate entities. However, there are some significant changes to that existing, including: (a) the water-related assets have been organised into three larger assets for management (the Geographe catchment and drainage network, the Vasse-Wonnerup wetlands, and the lower Vasse River and Toby Inlet), (b) a lead agency for each of these assets is clearly identified, and (c) the requirement that a management plan be developed that clearly identifies the management objectives, roles and responsibilities of the key agencies and the resources needed.

The details on each of the water-related assets are the same as in Section 4.3.2.

An advantage of this Option is that it would cost less since there is no overall coordinating lead agency. However, this lack of an overall coordinating body would represent a significant disadvantage manifesting in the potential poor communications between the separate management groups.

4.4 Investment needed

The desired improvement in the 'health' of the Geographe catchment and associated rivers and wetlands is unlikely to occur unless there is focused and effective management action plans, and a long term commitment to appropriately fund the core activities.

It is clear that which ever management option is selected, it will need to be adequately resourced for at least a decade in order to make a significant improvement in the condition of the key water-related assets. An initial estimate is that funding of the order of $3-5 million per year will be required over at least a decade.

The raising of these funds will be a challenge. Federal funding for NRM activities (e.g. Caring for Country) has been cut back and there is no guarantee that a new scheme with be introduced in the near future. Additionally, funding opportunities in Western Australia are limited, with traditional sources (e.g. State NRM funds) either cut or significantly reduced.

The following options should be considered to raise funds for these activities:

- A special grant by the Western Australian government to fund *Geographe catchment and Vasse-Wonnerup Wetlands Action Plan*,
- Making a bid to the 'Royalties for Regions' fund to provide resources for the improved management of the Geographe catchment and associated waterways and wetlands,
- Introduction of a 'catchment levy' on all ratepayers in the Geographe catchment,
- Introduction of a special 'environmental levy' on urban ratepayers by CoB to assist in managing the Lower Vasse River, the Vasse-Wonnerup wetlands and Toby Inlet,
- The introduction of a 'fertiliser levy' with the funds going to assist in the implementation of better fertiliser management in the Geographe catchment,
- Reintroduce a 'drainage levy' for rural properties to assist in the restructuring of the existing drainage network.

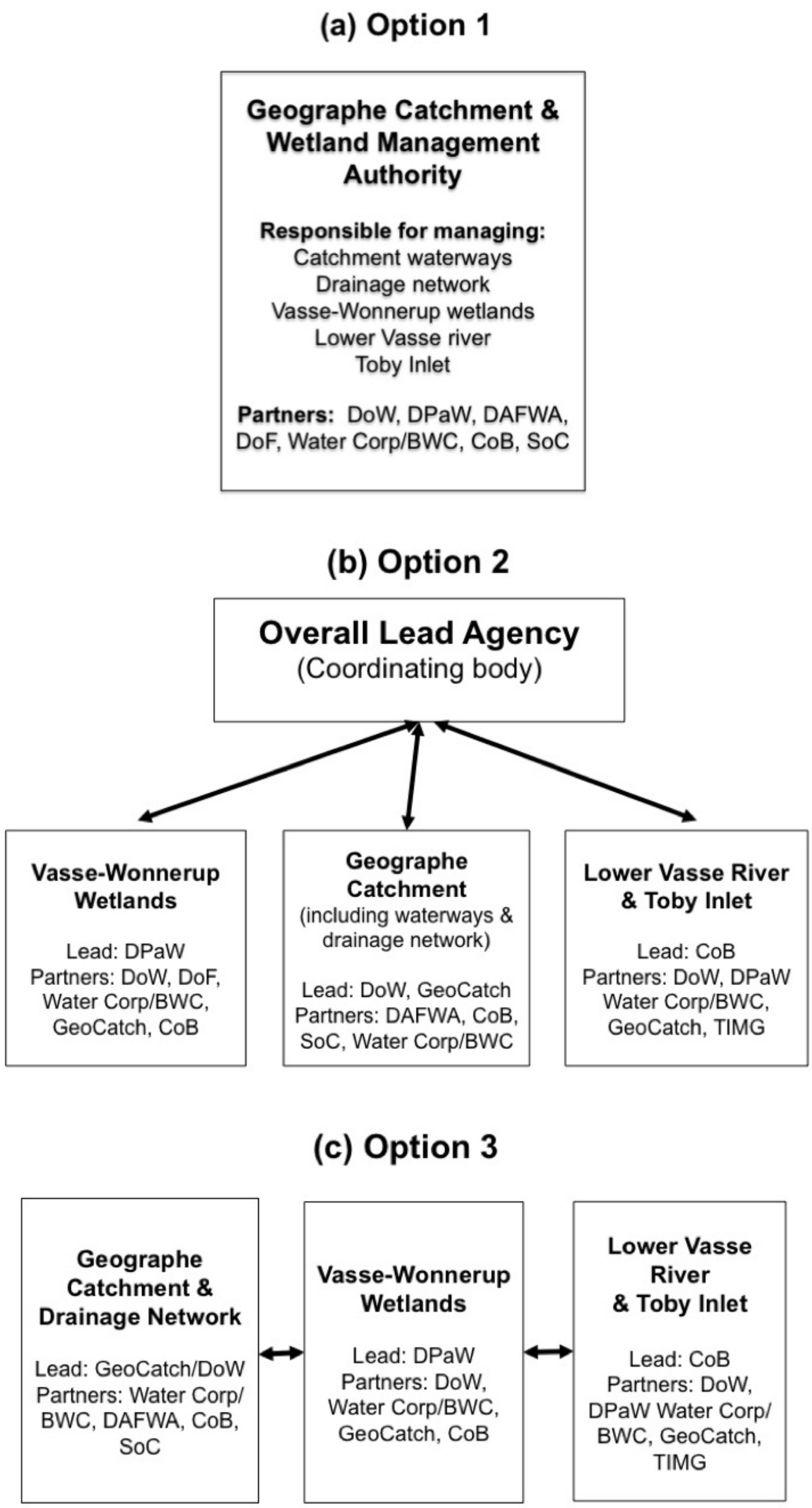

Figure 10: Diagram showing the main features of the three management options

5. Recommendations and priority actions

5.1 Management arrangements

This review has found that, while there are a number of very good aspects of the current management of the water-related assets of the Geographe catchment, there is generally a lack of a coordinated approach, lack of obvious lead agencies, lack of management plans (exception is the WQIP), and an overall lack of sufficient resources to make a difference. There is considerable room for improvement. 'Business as usual' should not be considered as a viable option as this would inevitably lead to further deterioriation in the condition of the catchment's waterways, including the Vasse-Wonnerup wetlands.

Three possible future management Options have been presented, these being:

- Option 1: the establishment of a Geographe Catchment and Wetlands Management Authority,
- Option 2: the establishment of an overall lead agency to coordinate the separate asset management arrangements,
- Option 3: the establishment of separate asset management without coordination.

Consideration of only the first two is recommended, since a major concern of the community has been the lack of coordination between the agencies and organisations involved in the management of the water-related assets in the Geographe region.

The recommendations from this review are:

Rec1: *That the Minister adopt management Option 1 (Figure 10a).*

Rec 2: *In the event that Rec 1 is not accepted, that the Minister adopt management Option 2 (Figure 10b). The Minister should consider in order the lead coordinating body being (a) DoW, (b) a restructured GeoCatch, and (c) a Ministerial Task Force with transition to a corporate model involving BWC (see Section 4.3.2 for details). Whatever form of lead coordinatng body is agreed, this body must have the necessary powers to be able to exercise its functions effectively. This could take the form of an authority from the Minister for Water, or all three Ministers involved (Water, Environment and Agriculture/Fisheries).*

Rec 3: *In the event that Rec 2 is accepted, that the arrangements outlined in Section 4.3.2 be established for the management of (a) the Geographe catchment (including waterways and rural drainage network), (b) the Vasse-Wonnerup wetlands, and (c) the Lower Vasse River and Toby Inlet.*

Rec 4: *That high priority be placed on the immediate development and implementation of a non-statutory management plan for the Vasse-Wonnerup wetlands, that incorportates both the VETWG and the emergency 'Fish Kill Mitigation and Response Plan'.*

Rec 5: *That until the Vasse-Wonnerup wetlands management plan is established, VETWG be retained (with DoW as chair) to implement the emergency 'Fish Kill Mitigation and Response Plan'.*

Rec 6: *That the lead agency for each of the water-related assets report annually to the community on both the asset condition (health) and effectiveness of management (perhaps using a simple Report Card format).*

Rec 7: *That an independent review of the Geographe catchment drainage network be commissioned to assess (a) its current and future relevance, including the current relevance of the '72 hour rule', (b) what might be done to make this drainage network more effective at reducing nutrients in addition to its flood protection and land drainage functions, and (c) the potential for reengineering the drainage system to reconnect natural waterways adversely affected by drains and to provide more freshwater inflow into the Vasse-Wonnerup wetlands and the Lower Vasse River.*

Rec 8: *That the current Geographe Water Quality Improvement Plan be reviewed with a view to updating it and expanding it into a broader Catchment and Wetland Management Plan, and that the implemetation of this new plan be empowered by the Minister for Water.*

Rec 9: *That DoW continue to provide the science to underpin the management of the Geographe catchment waterways, Vasse-Wonnerup wetlands and Toby Inlet, including the current water quality monitoring program, catchment modeling, and scientific investigations.*

Rec 10: That a research plan be developed for water-related assets in the Geographe catchment to identify the key knowledge needs, and the organisations able to conduct the necessary research (e.g. universities, CSIRO, DoW, DFAWA).

Rec 11: That DAFWA (in collaboration with DoW) undertake a program to better assess the effectiveness of the current agricultural BMPs.

Rec 12: That dairy sheds become a 'prescribed category' by amending Schedule 1 of the Environmental Protection Regulations 1987 *to ensure best management practices are adopted.*

5.2 Resourcing

The desired improvement in the 'health' of the Geographe catchment and associated rivers and wetlands is unlikely to occur unless there is focused and effective management action plans, and a long term commitment to appropriately fund the core activities. Which ever management option is adopted, it will need to be adequately resourced for at least a decade in order to make a significant improvement in the condition of the Geographe key water-related assets. An initial estimate is that funding of the order of $3-5 million per year will be required.

Rec 13: That the WA Government establish a fund of $30 million over 10-years to provide core funding for the enhanced management of the water-related assets of the Geographe catchment, including the Vasse-Wonnerup wetlands.

Rec 14: That as part of this fund, the WA Government consider the options listed in Section 4.4, namely a bid to the Royalties for Regions fund, introduction of a 'catchment levy' on all ratepayers in the Geographe catchment, introduction of a special 'environmental levy' on urban ratepayers by CoB, introduction of a fertiliser levy with the funds going to assist in the implementation of better fertiliser management in the Geographe catchment, and reintroduce a drainage levy for rural properties to assist in the restructuring of the existing drainage network.

5.3 Priorities actions

This independent review was commissioned largely because of the concern of the Busselton community at what they saw as the lack of an agreed lead agency, and a lack coordination and action by the agencies involved in the management of the Vasse-Wonnerup wetlands.

The review scope has been broader that just the Vasse-Wonnerup wetlands and the recommendations above reflect this broader scope. However, it will be important that the community are convinced that urgent action is being taken on those issues of concern to them.

This need is reflected in the priority actions listed below.

1. *Agree to develop and implement a non-statutory strategic management plan for the Vasse-Wonnerup wetlands, that incorporates both the VETWG and the emergency 'Fish Kill Mitigation and Response Plan' (Rec 4). This Plan must include consideration of the most appropriate operation of the floodgates and the desirability and feasibility of dredging the Vasse wetland.*
2. *Agree that, until the Vasse-Wonnerup wetlands management plan is operational, VETWG be retained (with DoW as chair) to implement the emergency 'Fish Kill Mitigation and Response Plan' (Rec 5).*
3. *Decide upon the future overall management structure, including its resourcing, and implement the necessary arrangements (Recs 1, 2, 3, 4, 5, 13, 14).*
4. *Review the existing WQIP with a view to broadening it into a catchment and wetland management plan (Rec 8).*
5. *Establish an independent review of the Geographe rural drainage network (Rec 7).*
6. *Introduce regulations to ensure BMPs for dairies are adopted (Rec 12).*

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Appendix A: Submissions on the Discussion Document

Submission	Address
Baldock, Michael	Dunsborough
Brain, Scott	Perth
Bussell, Vern	Busselton
Busselton & Districts Residents Association Inc.	Busselton
Busselton Dunsborough Environment Centre Inc.	Busselton
Busselton Water Corporation	Busselton
Busselton Wetlands Project Team	Busselton
Chapman, Gregory	Busselton
Chapman, Kieran	Kalgup
Chartres, Mike	Reinscourt
City of Busselton	Busselton
City of Busselton Environment Reference Group	Busselton
Clemenceau, Diane	Margaret River
Dale, David	South Perth
Department of Fisheries	Busselton
Dunsborough Coast and Land Care Inc.	Dunsborough
Elphick, Jocelyn	Busselton
Farquharson, Bill	Busselton
Farquharson, Margaret	Busselton
Fitzgerald, Peter	Bunbury
Geographe Catchment Council	Busselton
Grist, Rod	Quindalup
Hipplewhite, Christopher, Department of the Environment	Perth
Lynch, Dr Kath, Department of Water	Busselton
Maidment, Geoffrey	Cowaramup
Masters, Bernie	Busselton
Miles, Shane and Alan	Dunsborough
Norton & Sons	Capel
Paice, Robyn	Quindalup
Robb, Malcolm, Department of Water	Perth
Shire of Capel	Capel
Skitmore, Peter, Department of Environment Regulation	Perth
South West Catchment Council	Bunbury
Strong, Margaret	Busselton
Summers, Dr Robert, DAFWA	Busselton
WA Department of Fisheries	Perth
WA Farmers (Dairy Section)	Perth
Weaver, Dr Mike, DAFWA	Albany
Western Dairy and Dairy Australia	Mundijong, Melbourne
Winchcombe, Brian	Dunsborough

Appendix B: Assessment of the implementation of BMPs in the Geographe Catchment

Implementation of the WQIP is being led by GeoCatch and DoW, with assistance from DAFWA, CoB and CoC. The program is based largely on the voluntary adoption of Best Management Practices (BMP) to reduce nutrient inputs from both agricultural and urban areas. A number of BMPs were identified in the WQIP, which if fully implemented, would significantly reduce the nutrient losses from agricultural land and urban areas.

In agricultural areas, priority has been placed on BMPs for management of dairy sheds and feedlots, fertiliser management, implementing riparian management, and controlling of stock on waterways.

In urban areas, priority has been placed on management of point sources (wastewater treatment plants, septic tanks), incorporating water sensitive urban design in new residential developments, and limiting fertiliser use in urban areas.

Since 2009, priority has been given to activities to improve water quality in recovery catchment as required by the WQIP. Some projects are specific to priority catchments, for example riparian fencing projects to improve water quality[16]. Others, such as $mart Soils, used an eligibility matrix that prioritised farms in recovery catchments, but also included other sub‑catchments, depending on farm size and rates of land-holder participation (Pers Comm, D. Mussell, GeoCatch, January 2014).

A review of the progress of the implementation of the various BMPs in the Geographe Catchment is provided under the BMP headings below.

Fertiliser Management

Considerable headway in on-farm fertiliser management in the Geographe catchment has occurred, particularly in the 2011/2012 period, through the $mart Soils program. $mart Soils was coordinated by the GeoCtach, with the aim of reducing nutrient run-off from Geographe Catchment farms. The program had particular focus on phosphorus fertiliser application on grazing properties and how farmers can improve their efficiency of application, resulting in reduced runoff into nearby waterways. The program consisted of whole farm soil testing, nutrient mapping, and soil/pasture management workshops carried out for 80 farms, totaling around 18,000 ha of grazing land in the catchment (~25%) (GeoCatch, 2013a).

The priority catchments, Sabina and Ludlow, that flow into the Vasse-Wonnerup Wetlands, had a significant area tested and mapped (52% and 79% respectively) under the $mart Soils program (Table A1).

A survey of the program participants found that 89% of participants said $mart Soils influenced their decisions (64% saying it was the main influence) to apply fertiliser. Further, 58% of participants said that they reduced the amount of phosphorus that they applied in that year. A large majority of participants (81%) said that they used the $mart Soils maps to create a strategy of application. The number of participants who said that they would not apply P to the paddocks on their farm that was green (high P) was high (42%), while 33% said that they applied more to low P paddocks and less to high P paddocks (GeoCatch, 2013a).

Other programs that have been implemented in the past to improve fertiliser management in the Geographe catchment are the:

- Better Fertiliser Management Decision for Grazed Pasture in Australia (Dairy and Beef 2003- 2007),
- Accounting for Nutrients on Dairy Farms (Dairy) ,
- DairyCatch (Dairy) ,

[16] Some riparian zone fencing projects have also targeted ecological values/biodiversity in other (non-priority) catchments.

- Nutrient $mart (Dairy) ,
- Greener Pastures (Dairy),
- DAFWA Fertiliser Action Plan soil testing (Dairy and Beef).

GeoCatch identified that one of the key challenges for these types of programs is presenting a consistent message to land-owners regarding fertiliser management. This involves having consistent, agreed and fully integrated protocols from soil testing to application guidelines. Farmers need to have confidence in the methods, and this is currently limited in the farming community due to mixed messages from NRM groups, government agencies and private fertiliser company consultants (GeoCatch, 2013a).

Dairy Shed Effluent

Effluent management support for dairy sheds in the Geographe catchment has been on-going since 2003. There are approximately 46 dairy farms in operation in the Geographe catchment, with an average size herd of 300-400 cows. Of these, 15 dairy farms received effluent system funding through the 'Upgrading dairy effluent systems in Vasse WQIP' project in 2011-2012. DairyCatch, which ran from 2003 to 2005, also assisted ten farms with upgrades to their effluent systems (but many more south-west region) while the EII (Environmental Improvement Initiative, 2000-2004) project initiated through the Water Corporation funded 26 effluent system upgrades in the catchment (Water Corp, 2007). All but one farm in the WQIP upgrade program (and totaling over 80% of all dairy farmers in the catchment) have been involved in dairy effluent management (EII or DairyCatch) programs in the past (GeoCatch, 2013b, 2014).

Despite the high participation rates of effluent upgrade projects undertaken in the catchment, it is estimated that less than 20% of dairy sheds have an effluent system that is functioning to best management practice standards. Some farmers are working towards BMP systems, but due to financial constraints are having to complete their system upgrades in stages as funds become available (programs such as the WQIP effluent upgrade project supported 'staged' implementation of works). The remainder of farmers who have not recently been involved in effluent management projects are likely to perceive the system upgrades as too financially costly, not a priority (as unregulated), or not relevant to them or their business. There is also a perception that good system design for WA is not readily available and that many past projects have failed to improve effluent management over time due to unsuitable equipment choices, changes in herd size and high maintenance/labour requirements (GeoCatch, 2013b).

An evaluation revealed that effluent system upgrades require $50,000-$100,000 in materials and equipment, not including the farmer's in kind labour contributions to install items. The importance of incentive funds was acknowledged by the farmers with the majority making comment that they would not have undertaken their system upgrade if the incentive funds were not available. The project participants were generally motivated to participate in the project due to concern for the impact of effluent on water quality and/or their neighbours and/or to be able to utilise the value of the nutrients contained in effluent to improve pasture and reduce fertiliser costs (GeoCatch, 2013b).

The priority catchments that flow into the Vasse-Wonnerup Wetlands (Sabina and Ludlow), had a significant proportion of dairies upgraded in their catchments (75% and 50%) (Table A2).

Unlike in other states (e.g. Victoria), there are no mandatory requirements to collect and treat dairy shed runoff. However, GeoCatch, in partnership with Dairy Australia, Western Dairy and farmers, developed a Code of Practice for Dairy Shed Effluent Management in 2011 (Dairy Australia, 2012a,b). This code has been successful in setting the standard for effluent management in south-west WA, but it is voluntary and has no legislative backing.

Riparian zone management and stock control

Best practice riparian management is a high priority identified in the WQIP, as modelling shows that stock exclusion alone can contribute significant nutrient management benefits through prevention of direct fouling and erosion. GeoCatch has attracted significant funding to implement best practice riparian management on rural properties, focusing on recovery sub catchments (GeoCatch, 2013c, Table A3).

GeoCatch has facilitated over 362 km of fencing on private land since 1997 equating to over $4 million in funding incentives allocated to landholders.

Prior to the WQIP, considerable riparian zone management occurred from 1997-2009 through the development and implementation of River Action Plans. RAPs involved a riverbank condition assessment and rating of riparian areas, together with reach-by-reach recommendations to improve riverbank condition. RAPS were developed by GeoCatch for: Capel River in 1999, Vasse River in 2000, Carbunup River in 2000, Sabina, Abba and Ludlow Rivers in 2002, Gynudup Brook and Tren Creek in 2004, Cape Naturaliste Streams in 2005 and 2006, Buayanyup River in 2010, and the Upper Capel River in 2010 (completed by Shire of Capel).

Activity in this area has been significant over the period since 2009 (see Figure A1). Funding priority has been given to landholders in priority sub-catchments since 2010, however interest from landholders in these areas has slowed, indicating that 'saturation point' of voluntary uptake may have been reached with existing landholders. A different approach will be required to complete the required level of fencing in these sub-catchments. Interest in funding for riparian management remains high in other (intervention and protection) sub-catchments.

Urban BMPs

GeoCatch has successfully engaged with the community, as identified in the WQIP, to reduce diffuse urban nutrient inputs. GeoCatch developed the Bay OK program to raise awareness of the water assets in the catchment (waterways, wetlands and Geographe Bay) and link community actions (e.g. fertiliser use) with improving water quality and protecting Geographe Bay. Bay OK seminar series, workshops, information packs, website and facebook page have been coordinated to engage, inform and motive the local community. Bay OK also works with urban residents to become aware of their 'nutrient footprint' and improve their gardening practices (GeoCatch, 2013c).

Bay OK also has a 'recognition program' component, where businesses and schools can be recognised as 'Bay Friendly' if they meet certain criteria. GeoCatch has completed nutrient audits and management plans for 64 businesses and accredited 25 Bay Friendly Businesses and two Bay Friendly Schools.

Undertaking strategic retrofitting of water sensitive urban design in urban areas was also identified in the WQIP as a priority and has been a significant project for GeoCatch in partnership with local government and the Department of Water. GeoCatch has identified high risk large urban fertiliser users such as public open space and golf courses as a significant source of nutrients. GeoCatch has conducted 26 audits and provided management plans to improve water and fertiliser efficiencies. Fourteen urban drainage upgrades have been undertaken since 2007, reducing nutrients and pollutants leaving urban areas. The project has received two state awards in 2013 for its innovative approach and partnerships.

GeoCatch are now beginning to target new developers to engage new residents at the planning stages of their residential lots to ensure low nutrient options are given consideration. Nutrients from urban residential areas are predicted to increase faster than any other source as the Busselton population expands in the coming decades (GeoCatch, 2013c).

Urban point sources of nutrients include wastewater treatment plants and septic systems. The Busselton wastewater treatment plant discharges wastewater into the Vasse Diversion Drain. Water Corporation's proposed upgrade to the treatment plant has been designed to achieve no net increase in nutrient loads to Geographe Bay (GeoCatch, 2013c).

Table A1: Area of soil tested and mapped by sub-catchment (GeoCatch, 2014)

WQIP sub-catchment	Total area (beef + dairy) (ha)	Area (beef + dairy) tested and mapped (ha)	Area (beef + dairy) tested and mapped (%)
Sabina	4,653	2,410	52
Ludlow	2,977	2,340	79
Vasse Diversion Drain	14,307	5,783	40
Carbanup	6,172	1,245	20
Capel	12,695	250	2.0
Abba	6,165	1,738	28
Toby's Inlet	793	50	6.3
Buayanyup	8,113	570	7.0
Anniebrook	4,664	598	13
Gynudup	10,417	3,376	32
Five Mile Creek	3,568	540	15
Total	**74,525**	**18,900**	**25**

Table A2: Percentage completion of effluent management system upgrades for dairies by sub-catchment (GeoCatch, 2014).

Sub-Catchment	Effluent Management Plan Only	Effluent Management Plan and Upgrade Completed	Total no Dairies in Sub-Catchment	% upgrades completed through WQIP project*
Jingarmup			0	
Dunsborough			0	
Toby Inlet			0	
Lower Vasse			0	
Five Mile			0	
Carbunup	1	1	6	16
Vasse DD	2	1	11	9
Sabina		3	4	75
Abba	1	0	2	0
Buayanup	1	0	8	0
Gynudup		2	5	40
Capel		0	2	0
Annie Brook		1	1	100
Ludlow		2	4	50
Total	***5***	***10***	***43***	
Total upgrades				**23%**
Total upgrades & plans				**37%**

* does not include dairies that have been upgraded through other projects, or by landowner, however it is considered that these are unlikely to meet best practice

Table A3: Riparian zone fencing and revegetation efforts within the sub-catchments (GeoCatch, 2014)

WQIP Subcatchment	Riparian fencing (km)	Riparian revegetation (ha)
Jingarmup	0	0
Dunsborough	0	0.3
Toby Inlet	0	0
Abba	2.8	1.3
Annie Brook	5.8	1.5
Buayanyup	16	7.2
Capel	111	3.7
Carbunup	4.8	3.8
Gynudup	17	4.6
Lower Vasse	0.6	2.7
Ludlow	3.2	6.3
Sabina	3.3	19
Vasse Diversion	30	28
Five Mile	0	0
Total	**94**	**78**

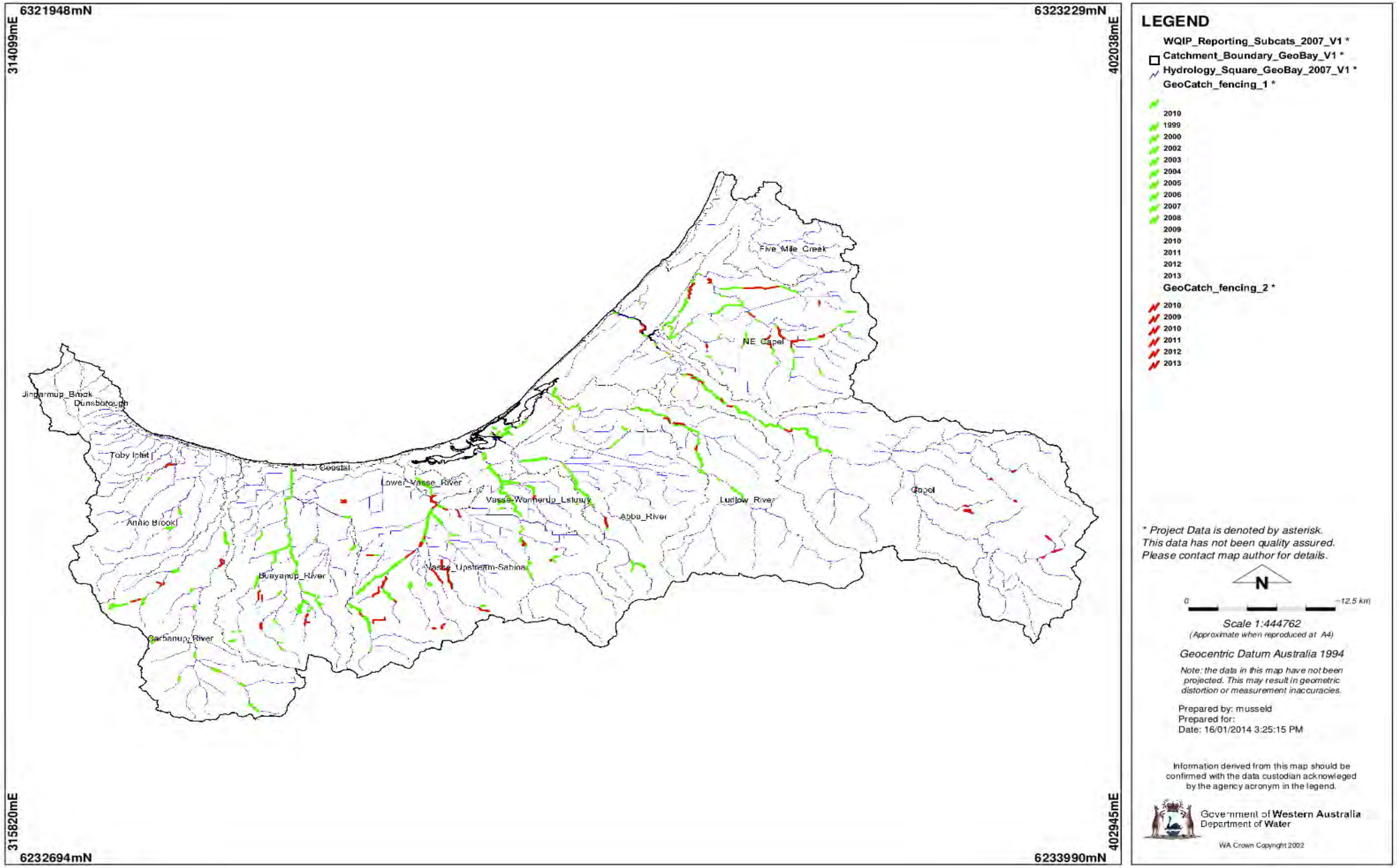

Figure A1: Map showing the length of fencing implemented by GeoCatch: pre-2009 and between 2009-2013

Appendix C: Victorian Catchment Management Framework

The Victorian Catchment Management Framework was established under the *Catchment and Land Protection Act (1994)* with the primary institutions being the Victorian Catchment Management Council (VCMC) and the ten Catchment Management Authorities (CMAs) (Figure A1). The CMAs also have regional waterway, floodplain, drainage and environmental water reserve management powers under the *Water Act 1989*. They are the caretakers of river health.

The major partner of the CMAs is the Department of Environment and Primary Industries (DEPI). They also partner at times with many other institutions and groups who contribute to catchment health, including: local governments, water authorities, educational and research agricultural and industry organisations, Indigenous communities and community groups.

The core objectives of the CaLP Act are to:

- maintain and enhance long term land productivity while also conserving the environment, and
- ensure that the quality of the State's land and water resources and their associated plant and animal life are maintained and enhanced.

The Victorian Catchment Management Council (VCMC) is the State's peak independent advisory body on catchment management. In order to determine if the objectives of the CaLP Act are being met, the Act requires Council to deliver an assessment of the condition and management of land and water resources in Victoria every five years (VCMC, 2012).

Every six years the CMAs are required to prepare a Regional Catchment Strategy (RCS) in accordance with guidelines established by the VCMC. An asset-based approach has been adopted (e.g. see WGCMA, 2013). The RCS is the overarching regional strategic planning framework, under which are found a range of sub-strategies and action plans for the region. The priorities established in the RCS are used to inform the development of future regional sub-strategies and action plans. RCS's aim to encourage an integrated collaborative approach to managing natural resources, to strengthen partnerships and to reduce duplication of effort.

The process of developing an RCS involves first defining the significant natural assets within the main thematic asset class (aquifers, biodiversity, coast, estuaries, marine, rivers, soil/land, and wetlands) according to a set of significance criteria, undertaking a risk assessment process and then grouping the significant assets according to their interaction as a system in the landscape.

The groups of significant natural assets have been named 'landscape priority areas'. This approach recognises the interaction between the various assets in the landscape, their interdependence as a system, and allows for an integrated management approach to be developed. The landscape priority areas represent groupings of significant natural assets at most immediate risk, which are a priority for attention during the life of the Strategy.

Importantly, action may also need to be taken in areas outside and in-between the landscape priority area boundaries in order to achieve an improvement in condition of those assets located within the landscape priority areas. For example, to gain an improvement in the Gippsland Lakes and Hinterland landscape priority area, the West Gippsland CMA identified on-ground action needed within the Macalister Irrigation District (which is adjacent to the landscape priority area) to ensure sediments and nutrients remain on-site to benefit both agricultural production within the district and improve river health and the quality of water entering the Gippsland Lakes system (WGCMA, 2013).

Progress towards implementation is monitored throughout the life of the RCS, generally with a mid-term review undertaken and reported.

Figure A1: Map of the Victorian Catchment Management Authority boundaries

7.2 Waterway Management Community and Stakeholder Engagement Plan

Strategic Theme:	Key Theme 1: Environment 1.3 Work with key partners to improve the health of the Vasse River and other waterways in the Geographe catchment.
Directorate:	Office of the CEO
Reporting Officer:	Community Engagement Officer - Eloisa Pickerill
Authorised By:	Chief Executive Officer - Tony Nottle
Nature of Decision:	Advocacy: to advocate on its own behalf or on behalf of its community to another level of government/body/agency.
Voting Requirements:	Simple Majority
Disclosures of Interest:	No officers preparing this item have an interest to declare.
Attachments:	1. City of Busselton Waterway Management Community and Stakeholder Engagement Plan [**7.2.1** - 10 pages]

OFFICER RECOMMENDATION

That the Committee receives and notes the proposed Waterway Management Community and Stakeholder Engagement Plan.

EXECUTIVE SUMMARY

This report outlines the City's proposed community engagement approach from November 2024 to January 2025 relating to the management of local waterways, including the Lower Vasse River and Toby Inlet.

STRATEGIC CONTEXT

The Waterway Management Committee will provide oversight and direction for the City's work with key partners to improve the health of the Lower Vasse River and other waterways in the Geographe catchment. Community and stakeholder engagement forms a key element of this work and was one of the drivers behind establishment of the Committee.

BACKGROUND

The City of Busselton is the interim asset manager for both the Lower Vasse River and Toby Inlet. Both waterways face complex long-term water quality issues. Due to this complexity, it is important that the community is provided with opportunities to fully understand the City's management strategies for and be kept regularly informed on the progress of the work being undertaken to manage these water bodies.

In May 2023, the Council made a resolution on 17 items (C2305/093) with regard to the City's role as Interim Asset Manager of the Lower Vasse River and Toby Inlet. Item number 13 of this resolution endorsed a broad community and stakeholder engagement model. The engagement plan in attachment 1 is an updated version of the plan prepared in response to the Council's decision and has been prepared to show the activity plan for the period from November 2024 to January 2025. This updated engagement plan outlines the key goals and actions for engaging with the community on waterways management matters.

At the Ordinary Council Meeting in January 2024, the Council resolved to establish the Waterways Management Committee, which has been formed following the disbandment of the previous Lower Vasse River Management Advisory Group. This will be the first engagement approach presented to the Waterways Management Committee.

The previous engagement strategy outlined several opportunities to engage and inform the community, including holding biannual Open Days. The first Open Day occurred in November 2023 and was held at the City of Busselton's Administration Building. The event was held in partnership with key waterway management stakeholders, including Department of Water and Environmental Regulation (DWER) and GeoCatch. There was low community attendance on the day (14 people). A proposed second open day was also scheduled for 2024, however, this did not end up going ahead due to key partners being unable to attend. The Council was informed at the time of the need to cancel, and a commitment was made to bring a new engagement plan to the new Waterways Management Committee to refocus and refresh the City's engagement efforts with its partners into the future.

Lower Vasse River project updates were provided on the City's website and Your Say page in April, May and June 2024 to ensure the most recent information was openly available to the wider community.

Community updates online over the course of 2024 have been provided on topics such as the completion of Stage 2 sediment removal process and the advertisement of the tender for Stage 3. Additional updates include information about the City's trial pit established to enable testing of approximately 4 tonnes of sediment removed from the Lower Vasse River, and an update about tree planting which was undertaken by City staff along the banks of the Lower Vasse River.

OFFICER COMMENT

The previous Waterway Stakeholder and Community Engagement Plan is out of date and has been updated for the period November 2024 to January 2025, while firmer commitments can be negotiated with project partners. The proposed plan reflects the commitment to keep the community informed on updates and projects affecting the Lower Vasse River and Toby Inlet through the uploading of information to the City's website and providing communications via social media and the Bay-to-Bay e-newsletter, as required. It is also proposed that the City will collaborate with DWER and GeoCatch to provide opportunities throughout the year to partner on events and ensure transparent and aligned information sharing.

Upon reviewing the previous engagement approach, officers have removed the use of Your Say for providing community updates, instead directing information to the City's official website. This enables a wider audience reach, is easily searchable and reflects the City's approach of having all available information on the main website where it is easy to find. From January 2025, it is proposed that monthly updates or frequently asked questions will be uploaded to the website, providing a consistent channel of information to the community.

The City and DWER had a meeting in October 2024 to discuss opportunities for collaboration on community programs and events in 2025. All agencies note that the current perception within the community is that not enough is being done to improve the river. It is anticipated that through more regular communication of the work currently being conducted, and alignment of messages and information from all agencies involved, the ability to conduct valuable in-person engagements in the future will be possible. These activities are proposed to start in 2025, through City officer attendance at DWER programs and events. An update on this can be provided in January 2025.

The key messages relating to communications for the waterways are as follows:

- That the Lower Vasse River and Toby Inlet have been impacted by the cumulative effects of approximately 100 years of agriculture, urban development, flood management, and more recently impacted by climate change.
- Water quality issues in both waterways are complex, long-term problems, very similar to those seen globally, and effective management requires long-term solutions.
- The long-term solutions to manage nutrient inputs in the catchments and waters should be complemented by ongoing short-term solutions for more immediate improvements in water quality and amenity.

Understanding that the waterways are of very high importance to the community, officers recognise the need to keep the public informed about management approaches and outcomes.

Statutory Environment

The Lower Vasse River is an asset owned by the WA State Government. The City is the current Interim Asset Manager.

Relevant Plans and Policies

The officer recommendation aligns to the following adopted plan or policy:

Plan:
City of Busselton Local Environmental Planning Strategy 2011
Lower Vasse River Waterway Management Plan 2019
Toby Inlet Waterway Management Plan 2019.

Policy:
Not applicable.

Financial Implications

Engagement activities will be managed within existing budgets and resources.

External Stakeholder Consultation

The City has commenced discussions with DWER and GeoCatch and will continue to liaise with these partner agencies as work progresses.

The 2024 MARKYT Community Scorecard was a wide-reaching community perceptions survey, through which it was clear the health of the Lower Vasse River (and other waterways) was a top priority for the City to continue to address.

Risk Assessment

An assessment of the potential implications of implementing the officer recommendation has been undertaken using the City's risk management framework, with risks assessed considering any controls already in place. No risks of a medium or greater level have been identified.

Options

Not applicable.

CONCLUSION

In summary, the proposed Waterway Management Community and Stakeholder Engagement Plan aims to provide effective communication to the community on the Lower Vasse River and Toby Inlet. This will be conducted through website updates, Bay-to-Bay e-newsletters and social media content, as required. Collaboration with DWER on future events and opportunities will be explored to provide in-person engagement with the community.

TIMELINE FOR IMPLEMENTATION OF OFFICER RECOMMENDATION

The officer recommendation will be implemented in stages as per the following table:

Milestone	Completion Date
Deliver the attached 3-month Waterway Management Community and Stakeholder Engagement Plan	January 2025
Continue to work with partner agencies to review opportunities for more active community engagement throughout 2025	December 2025

City of Busselton Waterway Management Community and Stakeholder Engagement Plan

Project Title:	City of Busselton Waterway Management Community and Stakeholder Engagement Plan
Project Manager:	**Danielle Halliday – Senior Sustainability/Environment Officer**

Project Summary:

The City of Busselton is the interim asset manager for both the Lower Vasse River and Toby Inlet. Both face complex long-term water quality issues. Long and short term management strategies are detailed in both the Lower Vasse River and Toby Inlet management plans and the City is currently implementing these. The City practices waterway management under Revitalising Geographe Waterways, a collaborative local and state government structure. Considering the complex and ongoing nature of waterway management it is important that the community is provided with opportunities to understand these management strategies and the progress made towards outcomes.

This engagement plan is an updated version of the plan prepared in response to Council's decision at the May 2023 Ordinary Council Meeting. This decision was to dissolve the Lower Vasse River Management Advisory Group and move towards a broader community engagement model for waterway management engagement.

At its meeting on 31 January 2024, Council resolved to establish the Waterways Management Committee (the Committee). The Committee will act for and on behalf of Council in accordance with the provisions of the Local Government Act 1995, local laws, policies of the City of Busselton, and in accordance with the Terms of Reference (ToR).The Committee consists of four Elected Members, one deputy Elected Member, and two independent external members. The Committee sits within the internal structure of the City of Busselton and has regard to both the Lower Vasse River and Toby Inlet.

City of Busselton Waterway Management Community and Stakeholder Engagement Plan

Strategic Alignment:

Lower Vasse River Waterway Management Plan:

WQ1.6 Support educational campaigns that aim to reduce nutrients in runoff through individual and community actions (e.g. Bay OK).

ARE1.3 Develop online and printed resources with interesting and important information on ecology, water quality, history and management of the Lower Vasse River.

G1.4 Maintain and develop partnerships with research organisations to improve knowledge and management of the Lower Vasse River.

Toby Inlet Waterway Management Plan:

- Develop an education approach to reducing sediments inputs from the catchment.
- Support educational campaigns that aim to reduce nutrients in runoff through individual and community actions (e.g. Bay OK) and investigate options to improve nutrient management in public open space.
- Prepare and distribute fact sheets and educational material for key management focus areas, relevant to schools, community members and natural resource managers.

Strategic Community Plan:

1.2 Work with the community to manage and enhance natural areas and reserves and their biodiversity.

1.3 Work with key partners to improve the health of the Vasse River and other waterways in the Geographe catchment.

1.6 Promote and facilitate environmentally responsible practices

Environment Strategy:

1.3 Work in partnership with other agencies and organisations to identify opportunities for implementation of recovery plans for protection of endangered species.

2.5 In partnership with other water agencies continue to raise awareness about water quality and wetland values and strategies to reduce nutrients entering waterways and wetlands through the Busselton Wetlands Initiative

3.4 Create a Strategic communication plan for undertaking environmental awareness with community in partnership with other agencies.

3.6 Develop community programs to raise awareness and facilitate behaviour change in all areas of environmental sustainability.

3.7 Support, coordinate and promote environmental initiatives and projects to the community.

City of Busselton Waterway Management Community and Stakeholder Engagement Plan

Project Budget:	To be managed within existing City of Busselton budgets
Budget for Engagement:	To be managed within existing City of Busselton budgets

Community Engagement Officer Review?	**Y / N** (please circle one)	**Date: 4/10/2024**

Context

Trends	- Management of waterway health and water quality is a complex and widespread issue globally. - Nuisance algal blooms are a common occurrence globally, and are exacerbated by climate change, and the intensification of rural and urban land uses. Locally, algal blooms are triggered by excessive nutrient loads in surface water, ground water and nutrient rich sediment. - Growing number of emerging algal bloom management technologies on the market, with limited supporting research or testing.
Community	- Concerns around the health of the Lower Vasse River and Toby Inlet have existed in the community for many years. - There are perceptions in a sector of the community that the City is not effectively addressing the health of the Lower Vasse River and Toby Inlet. - Potential for misinformation and limited understanding in community around research and waterway management projects that the City and its partners carry out in the Lower Vasse River, Toby Inlet and catchments.
Organisational	- Waterway Management Plans were developed for both the Lower Vasse River and Toby Inlet in 2019. - Management of water quality issues and public amenity in the Lower Vasse River and Toby Inlet have been a focus since the 1990's. - The City is currently the interim asset manager for both waterways. - Waterway management has been an issue of contention with the riverside community for many years.

	- Desire of Council to find a positive, broad-reaching community engagement model evidenced through May 2023 Ordinary Council Meeting. - The City undertakes waterway management under the collaborative structure of Revitalising Geographe Waterways, and the overarching governance of the Vasse Taskforce (Ministerial). - The City is able to report to the Waterway Management Committee on matters pertaining to the Lower Vasse River and Toby Inlet, and the Committee can report to Council as needed.
Key Personnel	- While the City is the interim asset manager for the Lower Vasse River and Toby Inlet, Officers will require support from other partners and State Government bodies to provide robust community engagement and information. - The Senior Sustainability/Environment Officer will lead this project with support from the Stakeholder Relations Team, but there is opportunity to incorporate other environmental and sustainability programs into the engagement activities. This would be reliant of support from other City staff.

Key Messages

- Water quality in the Lower Vasse River and Toby Inlet is impacted by the cumulative effects of approximately 100 years of agriculture, urban development, flood management, and more recently impacted by climate change.
- Water quality issues in both waterways are complex, long-term problems, very similar to those seen globally.
- Effective management requires long-term solutions, managing nutrient inputs in the catchments and waterways, which should be complimented by ongoing short-term solutions for more immediate improvements in water quality and amenity.

What is Negotiable and not Negotiable?

NEGOTIABLE	NOT NEGOTIABLE
What aspects of the project are non-negotiable and what aspects can the community influence? This may include safety, budget and technical or legislative requirements.	
Suggest how and when face to face community engagement sessions are run.	Collaborate with partner agencies on community engagement sessions.

City of Busselton Waterway Management Community and Stakeholder Engagement Plan

How communications and updates are delivered to community on waterway management projects.	Program for Lower Vasse River has largely been set and is detailed in the Lower Vasse River Management Plan (2019), the current focus priorities are the sediment removal project in the Lower Vasse River, and bar management and foreshore revegetation at Toby Inlet.
Suggesting how community can be involved in managing waterways – i.e. planting days, school involvement, friends of groups etc.	Council supports the current management of Toby Inlet, which is carried out according to the Toby Inlet Management Plan (2019). Council supports revegetation of adjacent foreshore reserves in partnership with Toby Inlet Catchment Group. As part of the Green Taskforce, City staff are involved in rehabilitation of riparian vegetation along the Lower Vasse River.
Suggestion of future research/waterways management projects.	Any suggested research or project ideas will be subject to technical scrutiny. While community can suggest ideas, ultimately the City's decision making in regards to waterways management projects will be at the advice of experts, largely the Department of Water and Environmental Regulation (DWER). Priorities on the support of waterway management works and trials are established through the Vasse Taskforce, using the Decision Support Framework.

What are the Potential Engagement Risks?

RISK	**MITIGATION**	**RISK LEVEL (Refer to Risk Matrix)**
Identify risks and mitigation strategies for your engagement.		
Misinformation is spread about waterways management.	Consistent messaging, particularly by providing ongoing and updated digital media.	M12
Limited attendance at face to face engagement opportunities.	Identify and prioritise opportunities for interagency collaboration on engagement opportunities. Prioritise City digital media content. Adequate advertising ahead of events using a range of formats to ensure a broad spectrum of community is reached. Reviews after each face-to-face	L4

City of Busselton Waterway Management Community and Stakeholder Engagement Plan

	engagement opportunity, and changes to format made in response to attendance as required.	

Stakeholder Mapping

Stakeholder Group	Role/Connection	Benefits of Involvement	Level of Interest	Level of Impact	Level of Influence (Refer to IAP2 Spectrum)
Council	Council have stipulated engagement expectations through the May 2023 Council meeting. Ultimate decision makers in regards to waterway management funding, projects etc.	Providing updates to Council regarding engagement strategies ensures that Officers are meeting Council's expectations, and that Council is aware of any potential reputational risks. Council can promote engagement opportunities to residents/ratepayers.	HIGH	MEDIUM/ HIGH	EMPOWER
Waterways Management Committee	Can provide input on waterway management regarding Toby Inlet and Lower Vasse River.	May enable streamlined Council decisions.	HIGH	MEDIUM/ HIGH	EMPOWER
Executive Leadership Team (ELT)	Responsible for strategic decisions in regards to waterway management.	Review engagement strategies and provide approvals and advice. Providing updates to ELT regarding engagement strategies ensures they are across any potential reputational risks.	HIGH	MEDIUM/ HIGH	EMPOWER

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City staff	May facilitate projects that overlap with waterways management.	Events may provide other City staff an opportunity to promote their projects.	LOW/ MEDIUM	LOW	CONSULT
Waterway management stakeholders; - DWER - DBCA - DoH - Water Corp - GeoCatch	Partners in waterway management and responsible for water assets in the City of Busselton.	Can support engagement strategies through providing information for community/attendance at events.	MEDIUM/HIGH	MEDIUM	INVOLVE
Vasse Taskforce	Oversight on waterbody management in Geographe area. Sits under Revitalising Geographe Waterways. Ministerial leadership.	Coordinated, supported programs. Ministerial influence. Science-backed work.	HIGH	MEDIUM/ HIGH	COLLABORATE / EMPOWER
Vasse Wonnerup Wetlands Partnership	Collaborative technical group for waterbody management in Geographe area. Sits under Revitalising Geographe Waterways.	Coordinated, supported programs. Science-backed work. Builds productive relationships for delivery of regional water management.	HIGH	MEDIUM/ HIGH	COLLABORATE
Toby Inlet Catchment Group	Not-for-profit that supports the City with managing Toby Inlet.	Can support engagement strategies through providing information for community/attendance at open days. Contributes significant labor and planning in delivering foreshore rehabilitation.	HIGH	MEDIUM	INVOLVE
Karri Karrak Aboriginal Corporation	Local native title body.	May have connections to local waterways/could provide advice around waterways management.	LOW	LOW	INFORM

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		May enable more rapid progression of Aboriginal Cultural Heritage approvals.			
Undalup Association	Organisation representative of local Aboriginal families.	May have connections to local waterways/could provide advice around waterways management. May enable more rapid progression of Aboriginal Cultural Heritage approvals.	LOW	LOW	INFORM
Local schools	May have some links to waterway management in curriculum.	Opportunity to involve young people in engagement on waterway management. May be able to assist TIC Group.	LOW	LOW	INFORM
Residents/ratepayers	Place high value on local waterways; recreational users of waterways; historical connection to waterways; reside near waterways.	Understand community views; educate generally on the science behind waterway management; dispel myths and misinformation.	HIGH	LOW	INFORM/CONSULT

Purpose of Engagement

Goal	Success Criteria
Better understand community concerns and dispel misinformation in community.	Review responses to Council Plan Community Scorecard, provide updates on website to address areas of concern. Share partner agency communications on waterway management programs.

Goal	Success Criteria

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Improve City communication on waterway management programs to inform the community.	Updates on waterway management, particularly regarding Toby Inlet and the Lower Vasse River, is provided to the City website regularly as work progresses. Share partner agency communications on waterway management programs.

Activity Plan

Timing	Engagement Purpose	Stakeholders	Influence	Engagement Method/s	Responsible Officer
October 2024	Provide community update on Environmental Consultant appointment	ALL	INFORM	• Website	Stakeholder Relations
October 2024	To provide community with an update on Tender decision for Stage 3 of the Sediment Removal Trial.	ALL	INFORM	• Website update	Stakeholder Relations
October 2024	Provide update to Waterways Management Committee	Committee	INFORM / INVOLVE	• Committee Report	Senior Sustainability/ Environment Officer
TBA 2024	To engage with community and provide education on waterway management through a collaborative event with waterway management partners.	ALL	INFORM	• Liaise with DWER and GeoCatch to organise collaborative event • Anticipating mid-2025 execution	Stakeholder Relations
November 2024	Provide update on the bar opening at Toby Inlet.	ALL	INFORM	• Website update • Social media	Stakeholder Relations
December 2024	Provide update to Waterways Management Committee	Committee	INFORM / INVOLVE	• Committee Report	Senior Sustainability/ Environment Officer
January 2025- Summer/Autumn	To provide an update on the sediment removal project (Stage 3 potentially complete).	ALL	INFORM	• Bay to Bay e-newsletter • Website	Stakeholder Relations
January 2025	Provide FAQs on City website to assist community.	ALL	INFORM	• Website update	Senior Sustainability/ Environment Officer

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January 2025	To provide resources in the community that direct to the website updates.	ALL	INFORM	• DL flyers printed and distributed	Community Engagement Officer
February 2025	To provide Committee with an overview of 2025 engagement activities.	Committee	INFORM	• Committee meeting	Senior Sustainability/ Environment Officer

	Updates at Waterways Management Committee meetings

7.3 Aeration Trial

Strategic Theme:	Key Theme 1: Environment 1.3 Work with key partners to improve the health of the Vasse River and other waterways in the Geographe catchment.
Directorate:	Infrastructure and Environment
Reporting Officer:	Director Infrastructure and Environment - Oliver Darby
Authorised By:	Director Infrastructure and Environment - Oliver Darby
Nature of Decision:	Executive: Substantial direction setting, including adopting budgets, strategies, plans and policies (excluding local planning policies); funding, donations and sponsorships; reviewing committee recommendations.
Voting Requirements:	Simple Majority
Disclosures of Interest:	No officers preparing this item have an interest to declare.
Attachments:	Nil There are no confidential attachments

OFFICER RECOMMENDATION

That the Council requests the CEO to proceed with a subsurface aeration trial (subject to attaining the appropriate approvals) on a section of the Lower Vasse River to determine feasibility for the method to improve water quality and reduce the occurrence of algal blooms in the Lower Vasse River.

EXECUTIVE SUMMARY

This report seeks Council endorsement to proceed with a subsurface aeration trial on a section of the Lower Vasse River to determine whether this methodology would be suitable for the long-term improvement of water quality and reduction of algal blooms in the Lower Vasse River (LVR). The trial would be subject to attaining approvals from the Vasse Taskforce and relevant government agencies.

STRATEGIC CONTEXT

The officer recommendation aligns with Strategic Priority 1.3: Work with key partners to improve the health of the Vasse River and other waterways in the Geographe catchment, and (less directly) to Strategic Priority 1.2: Work with the community to manage and enhance natural areas and reserves and their biodiversity.

BACKGROUND

The City of Busselton is currently the Interim Asset Manager for the LVR, working as part of the Revitalising Geographe Waterways program and the Vasse Taskforce to improve the water quality of the LVR (and Toby Inlet). Water quality issues have caused considerable community concern, with local rivers, inlets and waterways, one of the highest priorities cited by the community in the recent MARKYT Community Scorecard Survey.

The City continues to implement strategies to improve the LVR (and Toby Inlet), in accordance with adopted waterway management plans. Item 7.1 provides an update of previous and current works.

Further to these works, there has been significant community and officer interest in the potential of subsurface aeration, oxygenation and mixing of water within the LVR to reduce cyanobacterial blooms, by using fine air bubble diffuser systems. Oxygenation is not currently necessary in the LVR due to existing appropriate levels of dissolved oxygen, aeration and water mixing. However, companies supplying subsurface aeration systems have advised these systems have been used successfully in conditions similar (although not identical) to that experienced in the LVR, where algal blooms are present. Note, at present there have been no identified identical circumstances to the LVR. Systems have however, been used with reported success in water treatment systems, lakes, and dams.

This report recommends that the City progresses a trial of an aeration system subject to the appropriate approvals being obtained.

OFFICER COMMENT

Officers are seeking the opportunity to work with appropriately experienced contractors/suppliers to trial sub surface aeration, oxygenation and/or water mixing systems, that may have the potential of improving water quality in the long term for the length of the LVR. These systems consist of weighted pipes that, when connected to a compressed air pump, produce bubbles that agitate the water and introduce air into the water body. Companies supplying these systems have advised they have been successful in various situations where water quality has been problematic on an ongoing basis.

While there are many factors that influence water quality in the LVR (as detailed in agenda item 7.1), officers recommend a trial of these systems in a section of the LVR that can be hydrologically separated (using floating curtains) so that the water quality can be monitored to assess trial outcomes. This trial would be additional to the ongoing work of current management strategies as per the LVR Waterway Management Plan.

It is essential that the trial is not detrimental to the already existing sensitive water quality issues, flora, and fauna. The method may have the potential to introduce detrimental effects to the waterway. Any risks will need to be adequately mitigated, and it is not yet clear whether this water treatment method will be a viable long turn solution. Should the Committee and subsequently Council agree to proceed with the trial, officers will work with the Vasse Taskforce and various agencies to determine the most appropriate way to proceed, and to seek the appropriate approvals and environmental management consultant.

The exact approvals, control and testing requirements however are currently unknown and will be further understood (and communicated to the Council as required) through the approvals process and development of trial management plan. As the infrastructure associated with the trial is not considered to be significant, we would expect the main conditions to be associated with ensuring there is no deterioration of water quality associated with the trial, including to downstream environments.

Officers would also need to work with regulators and waterway management stakeholders to ensure that the information received from the trial is relevant to make ongoing decisions with regards to the feasibility of this water treatment method.

While it is unknown how long these processes will take, officers hope to be able to commence a trial in February 2025 or appropriate timeline as suggested by Environmental experts and Agencies.

Statutory Environment

To proceed state and federal government approvals will be required. Additionally, endorsement will be required from the Vasse Taskforce and associated Government agencies, in particular the Department of Water and Environmental Regulation (DWER).

Relevant Plans and Policies

The officer recommendation aligns to the following adopted plan or policy:

Plan:
Lower Vasse River Waterway Management Plan

Policy:
Environment

Financial Implications

Costs associated with the potential trial are estimated to be in the region of $50,000 which includes, the provision of curtains, power supply, compressed air pumps, water quality monitoring, approvals, and management plans which will be covered by existing budgets.

External Stakeholder Consultation

Initial discussions with DWER have indicated that the most appropriate method to progress the trial is assessment under the *Vasse Taskforce Water Quality Decision Support Framework,* for review by the Taskforce.

Risk Assessment

No risks of a medium or greater level have been identified, with progression of the trial subject to approval requirements.

Options

As an alternative to the proposed recommendation the Council could determine not to proceed with the trial, and to continue with its current management strategies.

CONCLUSION

Subject to obtaining approvals from the Vasse Taskforce and appropriate government agencies, officers recommend proceeding with a subsurface aeration trial on a section of the LVR to determine whether this methodology would be suitable for the long-term improvement of water quality and reduction of algal blooms for the length of the LVR.

TIMELINE FOR IMPLEMENTATION OF OFFICER RECOMMENDATION

Officers will commence seeking the various agency approvals as soon as Council decides to proceed with the trial. However, no timeline can be provided for this approval process.

8 CONFIDENTIAL MATTERS

Nil

9 NEXT MEETING DATE

Wednesday 11 December 2024.

10 CLOSURE