

NAVIGATING KNOWLEDGE GAPS FOR WESTERN AUSTRALIA'S INLAND WATERS

RESEARCH PRIORITIES TO ENABLE
BIODIVERSITY RESILIENCE OF
INLAND AQUATIC ECOSYSTEMS





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Photo credits

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- Sonja Mennen
- Megan Hele
- Lisa Mazzella

Acknowledgement of Country

We acknowledge the Traditional Custodians throughout Western Australia and their continuing connection to, and deep knowledge of, the land and waters. We pay our respects to Elders both past and present.

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NAVIGATING KNOWLEDGE GAPS FOR WESTERN AUSTRALIA'S INLAND WATERS

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Foreword



This publication brings together expert insights to identify critical knowledge gaps and priorities for research and investment into inland waters. It is a timely and valuable resource for those working to protect and manage Western Australia's inland water ecosystems. WABSI is to be commended for leading this important initiative.

With annual potential evaporation exceeding annual rainfall throughout the state, areas of permanent open water are confined to areas where it accumulates, especially in aquifers which either discharge to the surface or support groundwater dependent ecosystems.

Agricultural clearing of the poorly flushed Yilgarn Craton has resulted in Western Australia having about three-quarters of secondary salt-affected land in the nation. Inland valleys were already affected by primary salinity which contain salt and dry climate adapted species and ecosystems with their own unique values.

Added to these stresses has been a reduction in the south-west region of winter rainfall which is one of the earliest examples of climate change reported anywhere in the world. Freshwater streams in the Darling Range have been greatly affected while coastal plain wetlands have been affected by both the drying climate and land use changes, some of which have increased recharge.

The poleward shift of climate systems has resulted in increased rainfall in northern Australia and an increase in the size and permanence of groundwater dependent ecosystems. The opposite is happening in the south. The rates of change throughout the state are often too rapid for natural systems to adapt.

In addition to extraction of fresh surface water and groundwater for public consumption and irrigation, iron ore and coal deposits are increasingly mined from beneath regional water tables. The rate of recovery of these aquifers is still uncertain but could take decades and mobilise heavy metals through acidification of exposed sulphides.

The high degree of flora and faunal endemism in WA makes extrapolating findings from other jurisdictions of less value than is ideal. Weeds, pests and diseases are especially difficult to manage in such a large state with a low regional population to identify, monitor and control outbreaks.

This review is a welcome summary of what we need to know more about rare and endangered ecosystems in Australia's largest state – its inland waters.

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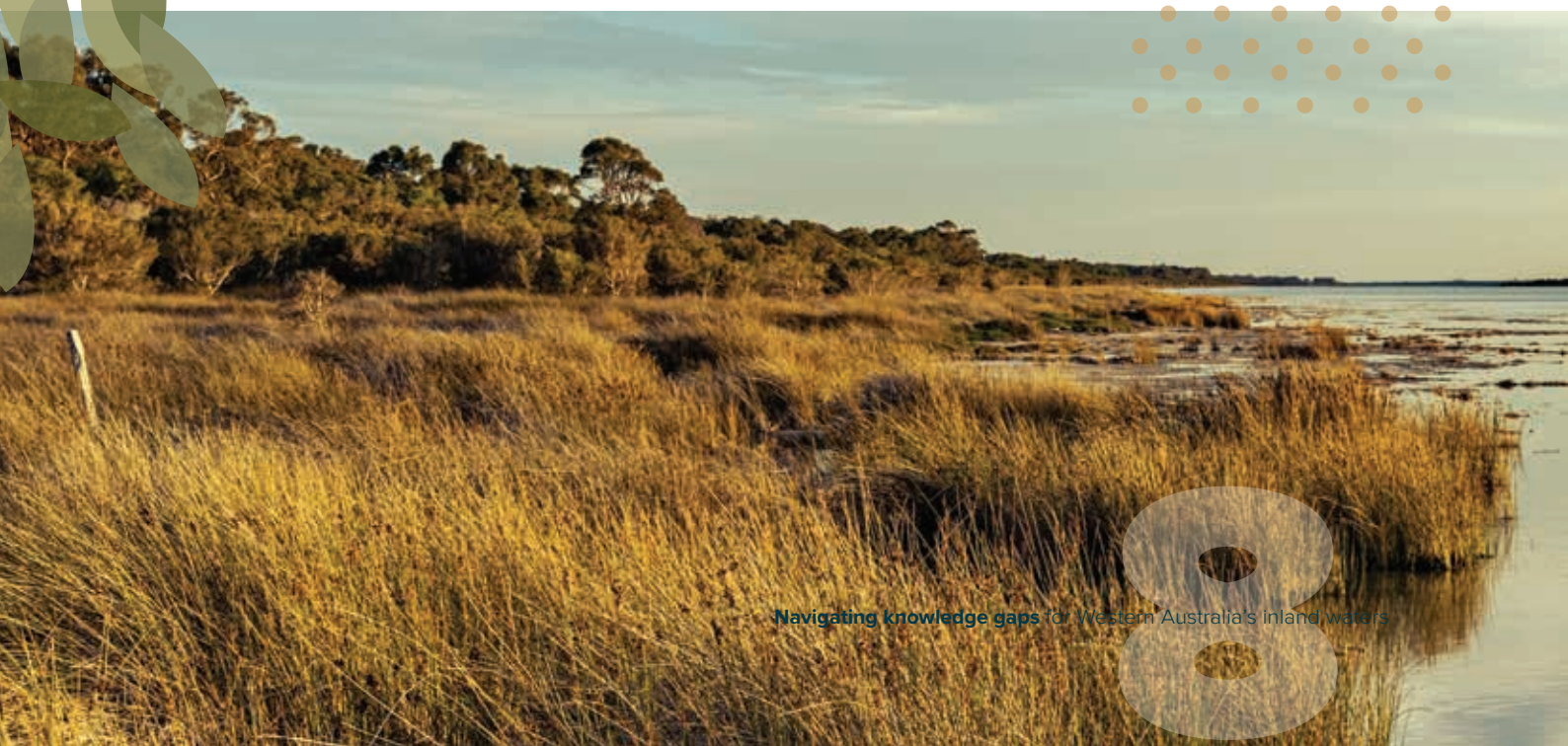
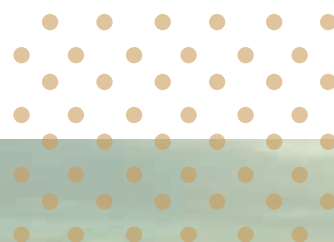
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Acronyms



ARC	Australian Research Council
BoM	Bureau of Meteorology
CISS	Centre for Invasive Species Solutions
CRCs	Cooperative Research Centres
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBCA	Department of Biodiversity, Conservation and Attractions
DCCEEW	Department of Climate Change, Energy, the Environment and Water
DoE	Department of Environment
PIRD	Department of Primary Industries and Regional Development
DSEWPC	Department of Sustainability, Environment, Water, Population and Communities
DWER	Department of Water and Environmental Regulation
eDNA	Environmental DNA
EIA	Environmental Impact Assessment
EMPs	Environmental Management Plans
EPA	Environment Protection Authority
ESVD	Ecosystem Service Valuation Database
FIP	Freshwater Information Platform
GDEs	Groundwater Dependent Ecosystems
GRCA	The Gunduwa Regional Conservation Association
HEPA	Heads of EPA Australia and New Zealand
IBRA	Interim Biogeographic Regionalisation for Australia
IPAs	Indigenous Protected Areas
IWRA	International Water Resources Association
LIWA	Living waters of Western Australia
MAR	Managed Aquifer Recharge
NACC	Northern Agricultural Catchments Council
NAWRA	Northern Australia Water Resource Assessment
NESP	National Environmental Science Program
NGOs	Non-government organisations
NRM	Natural Resource Management
PES	Payments for Ecosystem Services
PFAS	Per- and Poly-Fluoroalkyl Substances
PHCC	Peel-Harvey Catchment Council
SEAF	Shared Environmental Analytics Facility
SME	Small/Medium Business
TSFs	Tailings storage facilities
UWA	University of Western Australia
WABSI	The Western Australian Biodiversity Science Institute
WGCS	Wentworth Group of Concerned Scientists



1.

EXECUTIVE SUMMARY

Western Australia (WA) has a wide variety of inland aquatic ecosystems with a huge diversity of habitats including rivers, permanent and ephemeral wetlands and groundwater-dependent ecosystems (GDEs). The expression of these different habitats range from open surface waters to subterranean water-filled cavities in limestone or fractured rock. A significant number of plants and animals depend on these aquatic ecosystems for survival. WA inland water biodiversity has a high proportion of regionally endemic species – species restricted in their geographic ranges. Flora and fauna are also highly adapted to uncertainty and infrequency of rainfall and presence of surface water.

Water is among the most highly sought after natural resources for life on Earth, for drinking, to sustain the environment and for development. Inland waters in WA face various threats and impacts due to both natural and human-induced factors. Significant research projects have been undertaken to date to enhance the resilience of inland waters, and while notable progress has been achieved, challenges remain.



Credit: Megan Hele (right)



Credit: Megan Hele

Based on end-user demand WABSI has developed the *Navigating knowledge gaps for Western Australia's inland waters* (Inland Waters) research program to help address current and future challenges including knowledge gaps, within the following focus:

Knowledge priorities associated with the health of inland waters to support Western Australia's biodiversity and provide ecosystem services.

Approach

A process to scope, define and prioritise research needs to inform project development that can be targeted for investment, was undertaken following the WABSI program development pathway. This approach followed an iterative process engaging both end users and researchers. These stakeholders helped scope, define and set research priorities. Engagement was undertaken through various platforms and strategies including one on one consultations, group meetings, workshops and online surveys.

Identification of knowledge gaps

Stakeholder engagement during program development helped to inform a framework for research priorities. Through initial scoping sessions 96 issues were identified. Further analysis of the scoping sessions outcomes led to a refinement of the issues raised and key research focus areas emerged which included:

1. Water quality
2. Water extraction and discharge
3. Ecosystem functioning
4. Climate change impacts
5. Data collection
6. Principles and guidance

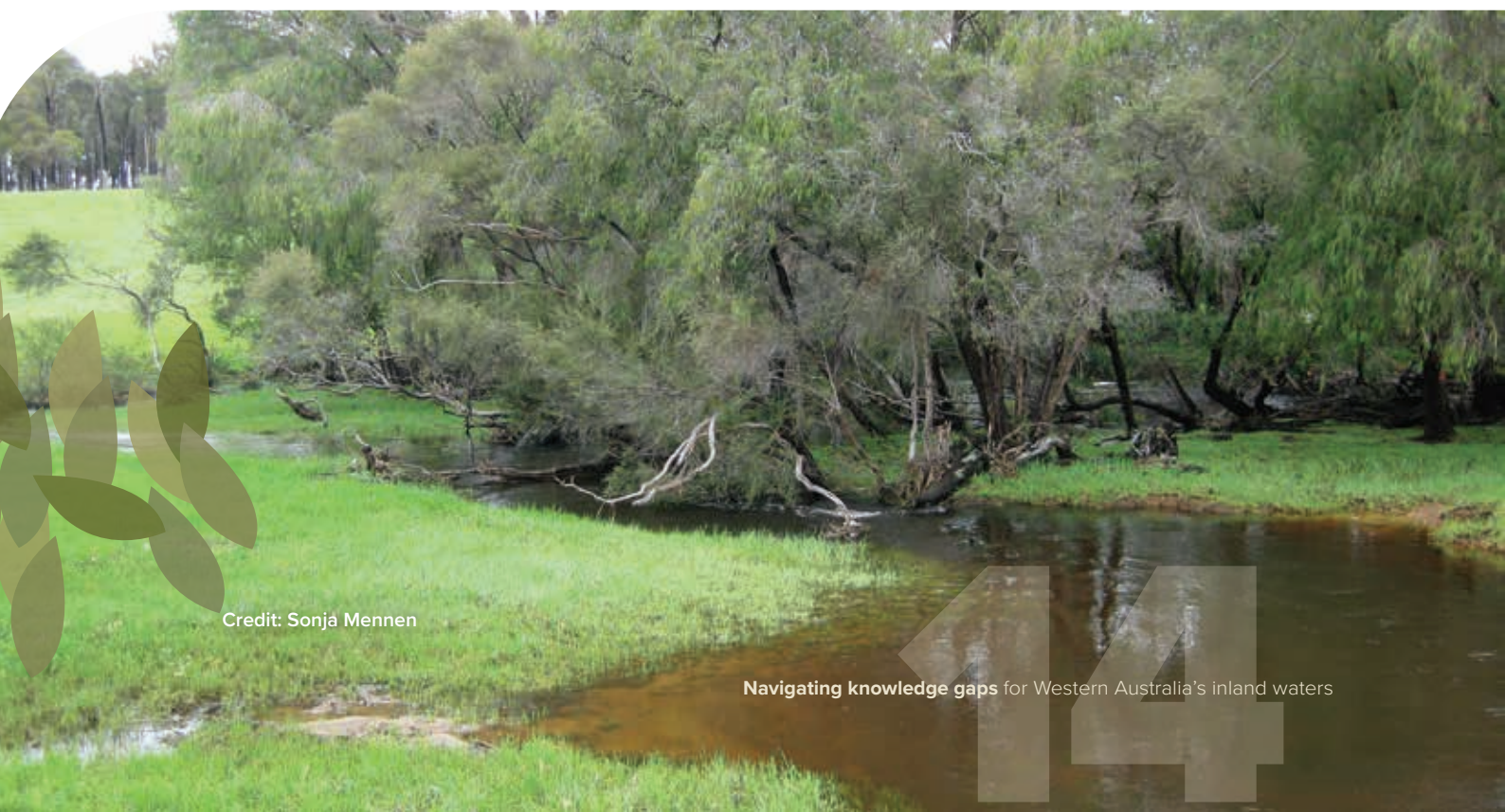


Credit: Sonja Mennen

The remaining issues were classified under each focus area with their associated research topic and regionally assigned (North/Mid WA, South WA and/or statewide). This information was further developed into a research program proposal.

Research prioritisation

The proposed research program was taken to two prioritisation workshops (one for North/Mid WA and one for South WA), where stakeholders were asked to prioritise research focus areas, determine which issues were identified as 'High', 'Medium' or 'Low' priority and identify a top three of urgent issues.



Credit: Sonja Mennen

Stakeholders identified the following five knowledge gaps as top priorities:



TOP 5 NORTH/MID WA

- 1** Develop more specific technical sampling guidance with the help of adequately qualified specialists
- 2** What are the impacts of water drawdown in groundwater dependent ecosystems (GDEs) to aquatic/freshwater fauna
- 3** Regional groundwater modelling to evaluate cumulative impacts across areas beyond mining and agriculture
- 4** Develop key ecohydrological principles which can be used to guide the assessment/understanding of ecohydrological functioning in riparian ecosystems
- 5** A Pilbara-wide freshwater pool inventory and wetland mapping to inform cumulative impact assessment



TOP 5 SOUTH WA

- 1** Improve knowledge on ecological water dependency to inform how much environmental flows are needed, plus timing, patterns and frequency
- 2** Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction
- 3** Minimal environmental flows to maintain waterway values, function and processes
- 4** Additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)
- 5** Regional groundwater modelling to evaluate cumulative impacts across areas beyond mining and agriculture



Development of a prioritised research framework

Informed by the prioritisation workshops and further stakeholder engagement with end users and researchers, this document sets out a plan for inland waters biodiversity resilience research in WA. Its objective is to address knowledge gaps identified through end user engagement underpinned by a prioritised research framework.

The Inland Waters biodiversity resilience research framework features two overarching themes and six high-level themes. Within each theme research focus areas, outcomes and objectives are identified to address critical knowledge gaps.

TABLE 1. The WABSI Inland Waters research framework in detail

Theme		Focus area	Outcome	Objectives	
Climate change	Traditional Owner knowledge	Mitigate	Impact reduction	Past, present and future anthropogenic harm to inland waters is actively reduced	Understand the specific drivers of degradation (e.g. altered flows, pollution, habitat fragmentation) in different catchments
			Climate change resilience	Reducing or preventing future climate change impacts on groundwater and surface waters	Identify and quantify climate-sensitive pressures on groundwater and surface water systems
					Prioritise water protection actions under projected climate impacts
		Restore	Adaptive management solutions	Past, present and future anthropogenic harm to inland waters is actively reduced	Develop adaptive restoration strategies that enhance the ecological function of inland waters under current and future climate and land use conditions
					Identify and prioritise restoration sites where interventions will maximise habitat quality, biodiversity support, and connectivity across the landscape
					Investigate nature-based and hybrid approaches for their ability to restore ecosystem services
			Novel Solutions	Novel solutions (both nature-based and human-engineered) contribute to restoring degraded ecosystem in the face of ongoing ecological transformation	Identify, test and implement innovative nature-based and human-engineered restoration approaches that enhance the ecological function, resilience, and connectivity of degraded inland waters, particularly in landscapes undergoing rapid environmental and climatic change
		Monitor	Land use impacts	High-quality monitoring over time protects the resilience of inland water systems	Collect consistent, long-term data
					Establish baseline conditions and tracking land use changes over time
		Threats to nature	High-quality monitoring over time protects water-dependent biodiversity	Collect consistent, long-term data	
Establish baseline conditions and tracking threats to nature over time					

TABLE 1. The WABSI Inland Waters research framework in detail (continued)

Theme		Focus area	Outcome	Objectives
Climate change	Traditional Owner knowledge	Forecast	Data-informed predictive modelling	Quantify cumulative impacts of multiple pressures
				Develop and refine predictive models that integrate historical, real-time, and spatial data
				Identify ecological tipping points and thresholds
		Equip	Enhanced data and information supply chain	Improve availability and accessibility of inland water data
				Streamline data collection, integration, and sharing
				Ensure data quality and relevance
				Create accessible analytical tools and communication products
		Clear and holistic guidance	Access to guidance that is informed by rigorous science, guides management and integrates both Western and Traditional Owner knowledge	Develop and promote ecohydrological principles
				Establish standardised terminology and technical guidance
				Integrate Traditional Owner knowledge and cultural values
		Value	Intrinsic value	Build understanding and documentation of the intrinsic and cultural value
				Demonstrate the ecological and societal importance of healthy inland water systems
				Develop frameworks and tools to integrate non-market values
			Instrumental value	Quantify the economic and ecosystem service benefits
				Assess the cost-effectiveness of management interventions
				Evaluate the role of aquatic ecosystems in delivering tangible environmental and economic benefits
				Develop tools and frameworks to integrate instrumental values

What next?

The implementation of this research program will require an effective governance structure and significant resources. A dedicated steering committee would provide the required oversight to facilitate the delivery of this program, a model that works successfully with WABSI research programs.

Strong alignment with research initiatives underway locally, nationally and in other states, and with relevant regulatory and policy bodies will enhance outcomes and reduce the risk of overlapping effort.

We encourage land managers and the research community, working in the field of inland waters biodiversity science in WA, to share and discuss their interests, challenges and opportunities with us and engage with the delivery of this program as we seek to transform this collaborative work into tangible on-ground impact.



2.

INTRODUCTION

Terrestrial aquatic ecosystems are expressions of the geophysical and ecological histories of the landscape through which water flows. The water present in any freshwater ecosystem forms part of the global water cycle—the movement of water throughout the Earth and its atmospheric system. Freshwater and terrestrial ecosystems are intimately linked by the water flowing through them. Consequently, every land-use decision is effectively a water-use decision (Pittock et al. 2015).

The 2021 State of the Environment for Australia reported that under a changing climate — in which severe droughts are projected to occur more frequently and last longer, extreme events to become more intense and cool-season rainfall to continue to decrease — Australia's hydrology will be impacted and this will have adverse effects on aquatic ecosystems and the flora and fauna that inhabit them (Green and Moggridge 2021).

Inland aquatic ecosystems provide numerous essential ecosystem services to humans, flora and fauna worldwide. WA hosts a diverse array of inland aquatic ecosystems that support a high proportion of regionally endemic flora and fauna species — species restricted in their geographic ranges and uniquely adapted to irregular rainfall and variable surface water availability.





Credit: Megan Hele

A considerable diversity of plants and animals rely on inland aquatic ecosystems, including fish, amphibians, waterbirds (including migratory shorebirds), epigeal and subterranean invertebrates, macroinvertebrates, and aquatic, riparian and floodplain vegetation. Moreover, they also support other terrestrial fauna by providing habitat and access to drinking water.

Inland waters are not only connected on the surface, but also in an invisible way, to groundwater. Surface water bodies can be connected along aquifers, whereas within the whole watershed, sub-surface and surface run-off connects both terrestrial influences to waterbodies and groundwater (Vári et al. 2022).

WA's inland water ecosystems include river ecosystems, extensive river floodplains that create a diversity of habitats, wetlands, and groundwater-dependent ecosystems (GDEs), that may be linked to surface waters or subterranean water-filled cavities in limestone or fractured rock.

For the context of this research program 'inland waters' includes both groundwater and surface water plus GDEs.

Surface water:

- Rivers and streams (permanent, intermittent, ephemeral)
- Wetlands (coastal, inland, floodplains, marshes, swamps, claypans)
- Lakes (freshwater, salt, seasonal)
- Dams and reservoirs (man-made lakes, farm dams)
- Other ephemeral water bodies (e.g. rockpools)

Groundwater:

- Aquifers (confined, unconfined)
- Groundwater basins (sedimentary basins, crystalline basement aquifers, karst aquifers)
- Artesian water
- Paleochannels
- Fractured rock aquifers
- Other groundwater systems (billabongs, soaks, springs, floodplains)



Credit: Lisa Mazzella (left), Sonja Mennen (right)

Groundwater-dependent ecosystems (GDEs):

- Aquatic (groundwater-fed rivers, streams, and wetlands)
- Terrestrial (vegetation dependent on shallow aquifers)
- Spring (groundwater-fed springs and mound springs)
- Estuarine (estuaries with groundwater inflow)



Credit: Megan Hele (top and bottom left), Lisa Mazzella (bottom right)

Navigating knowledge gaps for Western Australia's inland waters

Issues and challenges

Water is among the most highly sought after natural resources for life on Earth, for drinking, to sustain the environment and for development. Inland waters in WA face various threats and impacts due to both natural and human-induced factors. These threats affect the ecological health, biodiversity, and water quality of rivers, wetlands, and groundwater systems in the region. Biodiversity loss has profound effects on ecosystem function and productivity and consequently poses risks to ecosystem services vital for human wellbeing (Lintermans et al. 2024). Below is an overview of some of the key threats and their impacts.

Climate change

WA is already experiencing the impacts of climate change. All of WA has warmed since 1910, the average temperature has increased by 1.3°C (Australian Government 2021). The number of very hot days are projected to increase, leading to heatwave conditions. Heatwave events present a profound disruption to plants and ecosystems globally (Breshears et al. 2021). Drier and hotter conditions will lead to decreases in soil moisture and runoff because of increased water loss from plants and soils (evapotranspiration). This could further exacerbate drought conditions (DWER 2021).

Rainfall patterns across the state are changing. In the south-west of WA there has been a decrease of around 16 per cent in April to October rainfall since 1970. Across the same region, May to July rainfall has seen the largest reduction, by around 20 per cent since 1970, which will likely lead to more time in drought. Conversely, northern WA has been wetter than average over the last 30 years across all seasons, especially in the Kimberley and Pilbara during the northern wet season from October to April. Heavy, short-term rainfall events are becoming more intense (BoM & CSIRO 2024).

Urbanisation

Expanding urban areas increase land clearing, habitat fragmentation, and pollution. They are major causes of habitat modification and destruction and are predicted to continue to drastically alter the quantity and quality of freshwater habitats (Reid et al. 2019). Clearing of natural habitats contributes to reduced biodiversity and disrupted ecological processes. Urban pollution contaminates water bodies and brings harm to aquatic life. In Perth for example, the effect of urbanisation on water quality is considered to be one of the key environmental threats to the health of the Swan–Canning Estuary (Barron et al. 2013).

Credit: Sonja Mennen (below left)



Construction and impervious surfaces such as roads hinder the natural infiltration of rainwater into the ground, decreasing direct (soil) recharge and lowering groundwater levels. While direct recharge decreases, groundwater levels in urban areas and associated wetlands have been supported by indirect recharge from roofs and roads. Urbanisation generally increases surface runoff compared to natural landscapes due to the removal of vegetation and increase in impervious surface area (Schirmer et al. 2013). Increased runoff and the urban heat island effect would likely result in reduced recharge to underlying aquifers in most cities. However, in Perth it has been reported to result in increased recharge at point sources (McFarlane et al. 2025).

Mining and industrial activities

Mining activities in WA have led to environmental concerns, particularly regarding water contamination and ecosystem impacts. Open cut mining is necessarily highly destructive at a local scale and can also cause larger-scale damage due to changes to groundwater and surface water flows and quality, the disposal of tailings and waste, release of contaminants, air pollution and greenhouse gas emissions (Booth et al. 2022). Increasing critical mineral development, particularly for potash and lithium, can impact sensitive areas in remote regions where these minerals are found, such as inland salt lakes.

The mining industry dominates water use in the Pilbara region. To access mineral deposits, mining often involves pumping out groundwater when excavation is below the water table. Dewatering can destroy the habitat of stygofauna, dry up springs and perennial pools, and eliminate groundwater-dependent ecological communities. The disposal of dewater in rivers and creeks can change their ecology and destabilise and erode banks by changing their flow regime from seasonally intermittent to permanent (Booth et al. 2022).

Manufacturing processes often involve the use of a wide range of chemicals, such as solvents, heavy metals and acids. These chemicals can be released into the environment through accidental spills, leaks and wastewater discharges, and lead to pollution of groundwater and surface water, impact waterways and flora and fauna that depend on them. New wastes are emerging as a result of new industries, and new chemicals are emerging as contaminants. The most high-profile of these are PFAS (per- and poly-fluoroalkyl substances), a group of human-made chemicals that have been used since the 1950s in a variety of domestic products and in aqueous film-forming foam used in fighting liquid fuel fires. Increased environmental levels of PFAS have been found in certain areas around the State. PFAS is toxic and highly mobile in water, can travel long distances from their source, and do not fully break down naturally in the environment (Cresswell et al. 2021).

Credit: Megan Hele (below right)





Agriculture and livestock

In WA, agriculture and livestock farming significantly contribute to water pollution and habitat destruction in inland water bodies. Runoff containing chemicals, nutrients, and sediments from farming activities can enter rivers, streams, and wetlands, degrading water quality. Additionally, agriculture has also been identified as a source of pathogen contamination through livestock grazing near waterways (Alegbeleye and Sant'Ana 2020).

Unmanaged cattle can heavily impact wetlands, riparian zones, and surrounding vegetation, especially during the dry season. The cattle can damage cultural heritage sites and values, and contribute to the compaction and erosion of soil, and the loss of grazing-sensitive plant species. Indirect impacts of grazing include altered fire, nutrient and surface water flow regimes (DBCA 2024). Grazing that does not allow for adequate recovery can negatively affect plant communities, which can cascade to degraded soil and water resources (Burdick et al. 2021).

Invasive species

Non-native invasive plants in Australia are currently among the greatest threats to native biological diversity (Webber 2021). Invasive species, both flora and fauna, can outcompete native species, alter habitats, and disrupt ecological balance. This leads to significant impacts through degraded water quality and decreased biodiversity, particularly in sensitive freshwater systems. Furthermore, rising temperatures and falling water levels over summer encourage algae and aquatic weed growth in inland waters.

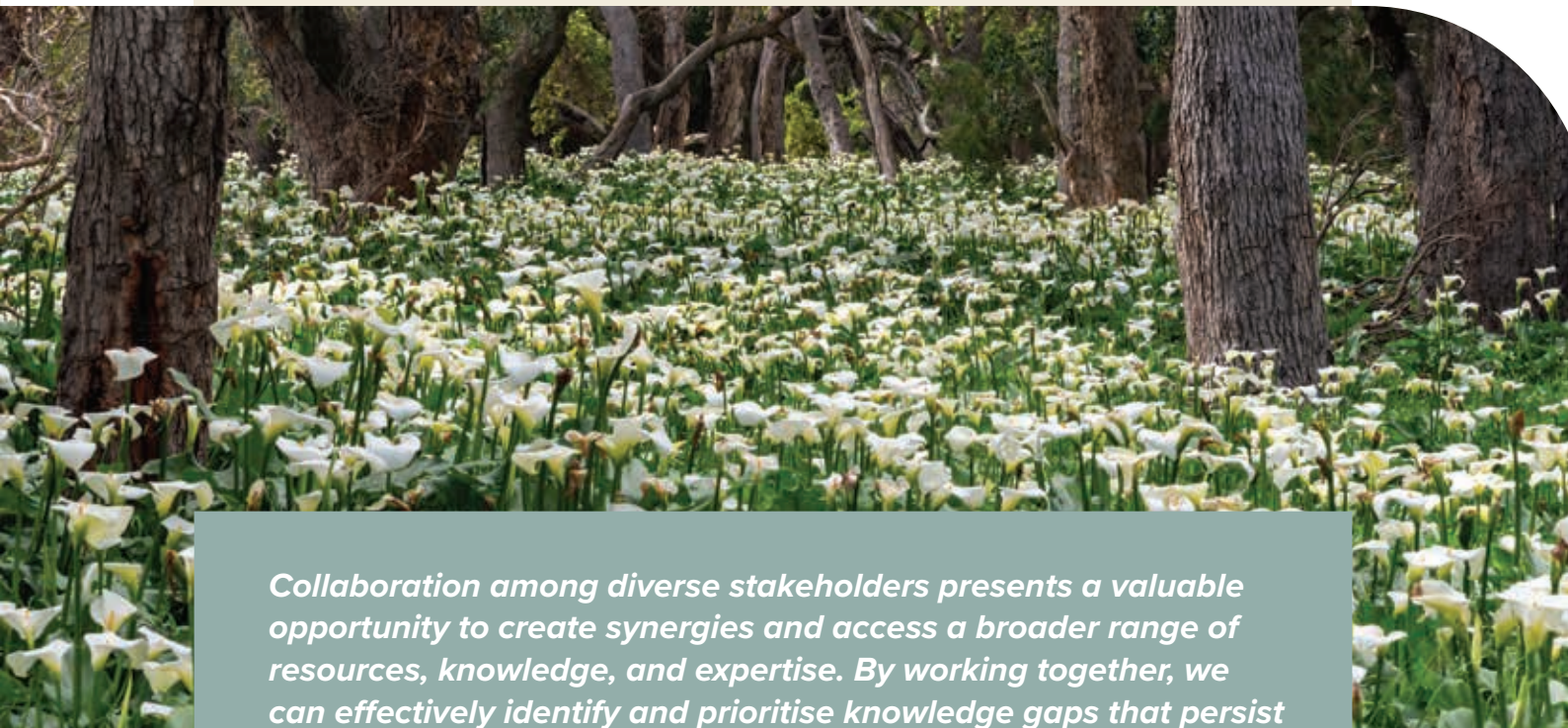
The introduction and distribution of non-native fish species have led to significant ecological challenges, particularly in freshwater ecosystems. These introduced species often outcompete native fish for resources, as they can tolerate degraded habitats, are highly adaptable and reproduce readily (Perth NRM 2017). For example, goldfish are now relatively widespread throughout WA, particularly near urban areas. They stir up sediment and deplete aquatic vegetation when they feed on the bottom of waterways.

Dryland salinity

Salinity levels in inland waters have changed due to the clearing of deep-rooted native vegetation to make way for agriculture, especially in regions like the Wheatbelt. This resulted in changes in the water balance from increased recharge and made groundwater levels rise – bringing stored salts to the surface.

Most of the WA's commercial broadacre farms are located in the dryland agricultural region of WA (farmland that receives less than 600 mm average annual rainfall). A direct consequence of clearing has been reduced evapotranspiration and increased contributions to shallow and deep groundwater. The replacement of deep-rooted native vegetation with predominately shallow-rooted annual crops and pastures has exacerbated the impact of clearing on relatively fragile landscapes of the Wheatbelt. The remobilisation of salts, stored within the regolith as a result of rising water tables and the development of localised perched systems, has resulted in extensive areas of the Wheatbelt being affected by seasonal waterlogging and secondary salinity (Ali and Coles 2001).

Credit: Sonja Mennen (bottom)



Collaboration among diverse stakeholders presents a valuable opportunity to create synergies and access a broader range of resources, knowledge, and expertise. By working together, we can effectively identify and prioritise knowledge gaps that persist in advancing the resilience of inland waters actions. Addressing these knowledge gaps through research prioritisation, planning and facilitation will assist with implementing best practices in land and water management.



3.

PROGRAM OUTLINE

This research program focuses on:

Knowledge priorities associated with the health of inland waters to support Western Australia's biodiversity and provide ecosystem services.

WABSI has responded to end user-led momentum, to initiate the development of this prioritised research program, to address knowledge gaps and deploy new knowledge generated through prioritised research projects. WABSI research programs bring together a diversity of stakeholders to achieve consensus on the most important factors limiting progress against challenges of great importance for biodiversity conservation.



Credit: Megan Hele (middle)



Credit: Lisa Mazzella

This program is written for a broad audience of stakeholders, including research providers, funding bodies, regulatory authorities, industry, utilities, the full range of land managers in the State, as well as members of the public with an interest in biodiversity threats and inland waters management. As such, the program needs to cover the interests of a very diverse stakeholder group, despite being end user led. This research program, when implemented via a steering committee (or equivalent), will provide a framework for identifying and implementing the highest priority research on inland waters resilience, and a pathway to maximise the adoption of that research to improve on-ground outcomes.

In developing this program on inland waters resilience, there was recognition of the following:

- Inland waters have been significantly altered in WA since British settlement in 1829.
- WA's inland waters have mostly been degraded due to rapid land-use change; however, the impacts of climate change are increasingly being felt. The cumulative impacts of development and vegetation clearing are further compounded by the challenges posed by a changing climate.
- There is a need to address knowledge gaps as a critical component of enhancing inland waters biodiversity resilience.
- It is essential to improve the value proposition for resourcing the mitigation of inland waters degradation, including understanding the consequences of delaying action or doing nothing.

The program has strong links to other research, especially in soil and land management, the resilience of marine ecosystems, and how losing biodiversity affects the social and cultural values of inland waters.

A targeted research program to address knowledge gaps in inland water biodiversity is very likely to benefit not only WA's plants, animals, and people but also the entire country and even the world.





Objective

The objective of this research program is to provide a prioritised framework for identifying knowledge gaps for increasing biodiversity resilience of inland waters in WA. It encourages collaboration, enabling a clear pathway from knowledge generation to on-ground uptake, to ensure improved outcomes for end users.

Vision

To address critical knowledge gaps in inland water biodiversity science, ensuring research directly translates into effective, on-the-ground action that improves the resilience of these vital ecosystems in WA.



Outcomes

This research program will deliver a transformative shift in our understanding and application of sustainable inland water management, driving conservation, restoration, and long-term resilience of inland aquatic ecosystems across WA.

Through an integrated and collaborative approach, the program aims to optimise the use of available resources to achieve improved biodiversity outcomes. This will lead to inland water ecosystems that:

- Sustain critical ecosystem services that support both human wellbeing and ecological health.
- Nurture and protect a rich diversity of endemic flora and fauna.
- Are managed through the combined strengths of Traditional Owner and western knowledge systems, ensuring resilience in the face of climate change and rapid development.
- Flourish with robust and thriving biodiversity.

Credit: Lisa Mazzella

4.

BENEFITS TO STAKEHOLDERS

Stakeholders

A range of stakeholders will benefit from this research program. They include the industrial and agricultural sector, government, researchers, not-for-profit organisations, community groups and land and water managers.

Collaboration between various stakeholder groups provides an opportunity for scientists such as ecologists, hydrologists and hydrogeologists, Traditional Owners, environmental professionals, policy makers and other involved members of the community, to tackle the most pressing biodiversity challenges for inland waters.

In developing this program on inland waters resilience, there was recognition of the following stakeholders:

- The research community, in WA, nationally and internationally, whose members are working towards more effective, efficient and sustainable tools for enhancing inland waters biodiversity resilience.
- Government organisations (local, state and federal), some of whom are investing resources into the protection of natural environments such as inland waters and surroundings through ecological research, on-ground management, and education.
- Industry sectors, such as mining, oil and gas and manufacturing. Industry should strive to operate in a manner that minimises environmental disturbance and actively participate in the restoration of any degraded ecosystems.
- The agricultural, forestry and aquaculture industry sectors, whose ability to productively manage their land and waters may lead to biodiversity enhancement.





- Development and construction industry who are facilitating rapid growth and can advocate sustainable development.
- Utilities, e.g. providers of water who rely on groundwater and surface water as a source for drinking and non-drinking water.
- Indigenous landowners and managers (Traditional Owners), including Aboriginal Corporations and ranger groups with an interest in managing their country and water assets for biodiversity values (including areas where biodiversity loss is impacting on culturally significant assets).
- Natural Resource Management (NRM) organisations. These organisations work with land managers, communities and industries to manage the land, water, coast, plants and animals for biodiversity conservation and their work benefits the community, environment and the economy.
- Non-government conservation organisations (NGOs) who dedicate considerable time and resources towards biodiversity conservation and community education.
- The environmental consulting and contractor sector. Consultants can positively impact the many challenges around inland waters as they work with clients from a wide variety of sectors, including construction, water, waste, mining, energy, government and agriculture.
- The tourism sector, which relies on WA's natural environment including reserves and parks with inland water assets that provide significant habitat and refuge for native flora and fauna, for a significant component of their appeal to visitors.
- Community groups, including Landcare, Coastcare, Friends of and Naturalist groups that have a dedicated focus on specific wetlands, broader conservation efforts and water quality initiatives. They are advocating for issues relating to the conservation and protection of inland waters.
- The public, which has an interest in a healthy waterways, wetlands and groundwater and the conservation of native biodiversity.



Economic value

Healthy waterways, wetlands and other inland water systems are of significant economic importance across the world and people value water and water environments for a diverse range of reasons.

Water is essential for human life and wellbeing, is critical to food production, and is a part of many manufacturing and industrial processes. Healthy water environments support economic uses such as fisheries, tourism, and recreation. The direct economic value of water environments can be estimated from the commercial value of markets for tourism and other recreational activities. Ecosystem services provided by healthy inland waters also have indirect economic value, such as natural water quality improvement, which can reduce water treatment costs (Bark et al. 2011).

The economic valuation of inland wetlands highlights that 'values of both coastal and inland wetland ecosystem services are typically higher than for other ecosystem types' (Russi et al. 2013). This underscores the significant economic importance of wetlands compared to other ecosystems.

Aggregated data from 131 studies across 41 countries estimates that the average annual value per hectare of inland wetlands is approximately \$48,647 (2020 USD). This figure includes various ecosystem services, including flood mitigation, water purification, carbon sequestration, and biodiversity support (de Groot et al. 2020).

The Millennium Ecosystem Assessment says that estimates for the global economic importance of wetlands are highly variable, with an upper value of \$15 trillion (2005 USD) (over three times the value of global forest ecosystem services, which is \$4.7 trillion). Intact wetlands have a net present value of 1.6 times that of sustainable forests, 5.8 times that of mangroves and 4.5 times that of forests under traditional management. The value of intact wetlands is often greater than converted wetlands (Millennium Ecosystem Assessment 2005).

Closer to home, the WA Government says that healthy waterways provide clean water for drinking and domestic use, water appropriate for maintaining public spaces, and water for agriculture and industry to produce food and goods. They also contribute to maintaining soil fertility (DWER 2023).



Commercial enterprises such as transport, commercial fishing, aquaculture, and recreation industries (e.g., boating, water skiing) rely on healthy waterways. Furthermore, healthy waterways can lead to increased property values due to amenity and visual appeal (DWER 2023).

The Peel Development Commission and Peel Harvey Catchment Council undertook research to determine the economic value of the Peel Harvey waterways, a major estuarine system in WA. According to their research, it is estimated that the total economic asset value of the Peel Harvey Waterways is \$20.8 billion. The annual economic contribution of the waterways system is approximated at \$605.7 million, which supports over 2,000 full-time equivalent jobs within the WA economy. This annual contribution represents a considerable proportion (seven per cent) of the Peel region's Gross Regional Product. The drivers of this value include water sources, waterfront hospitality and accommodation, health and wellbeing, recreational boating and fishing, waterfront residential areas, nutrient run-off management, and science and research activities. The research emphasises that the ongoing health of the waterways is crucial for maintaining this significant economic role (Urbis 2023).

Research undertaken by Deakin University to gain insights into WA's blue (coastal and marine ecosystems) and teal (inland aquatic ecosystems) carbon stores provides valuations for the ecosystem services of two coastal and two freshwater wetlands in WA. Outcomes suggests that coastal blue carbon sites in the Pilbara region can provide over AU\$1.1 billion in ecosystem services annually, including coastal protection and carbon and nitrogen storage. Freshwater teal carbon sites in Perth, such as the Beeliar Regional Park, can provide over AU\$37 million annually. This highlights the economic value derived from natural functions of these inland water ecosystems (Costa et al. 2024).

Involvement of Traditional Owners in the management of inland waters, e.g. in Indigenous Protected Areas (IPAs), has the potential to generate a return on investment. The best estimates for the social returns on investment in IPAs and ranger groups are about 3:1 – meaning that every \$1 invested generates about \$3 in value (Booth et al. 2022).

Collectively research demonstrates the substantial and diverse economic contributions of these systems through various direct uses, ecosystem services, and their role in supporting key industries across WA.



Credit: Sonja Mennen



Environmental, health and social benefits

Environmental benefits

Healthy waterways have intrinsic ecological value and provide a wide range of ecosystem services. These services result from the functioning of a waterway's hydrology, landforms, vegetation, fauna, and micro-organisms (DWER 2023).

Inland waterways provide habitat for birds, frogs, reptiles, native fish, and macroinvertebrates and form important wildlife corridors between patches of remnant bush. Estuaries connect the land to the sea and have unique aquatic and terrestrial flora and fauna. Fringing native vegetation along healthy waterways plays numerous roles, including providing habitat, shade, holding banks to reduce erosion, filtering materials from the catchment, and slowing water flow. Aquatic plants within healthy waterways provide food and breeding habitat for native fish, waterbirds, and frogs (DoE 2004).

Surface waters contribute to aquifer recharge, which helps maintain water levels in groundwater-dependent ecosystems like wetlands. Depending on the quality of the recharge water compared to the quality of receiving aquifer water, aquifer recharge has the potential to either improve or degrade water quality (EPA 2018).

Additional inland waters ecosystem services include (FIP 2022):

- Water purification: maintaining sufficient water quality for drinking and domestic use. Freshwater plants and ecosystems can trap, breakdown, process and transform pollutants, toxins and heavy metals present in water.
- Decomposition and cycling of nutrients: e.g. by aquatic plants and algae.
- Carbon sequestration: carbon accumulates in living plant tissue and decomposed vegetation in waterlogged conditions. This 'locks up' carbon stores which helps regulate the amount of carbon dioxide in the atmosphere.
- Flood protection: controlling the frequency and magnitude of runoff and flooding through water interception and storage.
- Erosion prevention: bankside vegetation, reed beds, riparian zones and wetlands play an important role in soil retention and the prevention of erosion and landslides.
- Local climate regulation: evaporation over freshwaters and wetlands can cool the surrounding atmosphere and increase humidity, creating microclimates.
- Pollination: floodplain meadows provide habitat for pollinating insects such as bees.
- Fire breaks: bodies of water can act as breaks for regulating the spread of wildfires.





Health and social benefits

Recent literature increasingly identifies natural environments (e.g., parks, woodlands, waterways) as beneficial for population health and wellbeing.

Natural environments, such as inland waterways, have been identified as a potential means to increase physical activity and promote health and wellbeing (Afentou et al. 2022). Several studies have shown that living near inland water bodies is associated with better mental health (White et al. 2020). Healthy waterways provide opportunities for recreational activities such as swimming, boating, and fishing, which contribute to physical and improved mental health (DWER 2023).

Foreshore areas offer space for walking, cycling, and social gatherings, promoting physical activity, as well as offering opportunities for social interaction, both planned and unplanned, which is also linked to improved moods. Increased social interaction is particularly beneficial for the elderly, where increased social interactions improve community cohesiveness and has been associated with lower suicide rates, lower fear of crime and better physical health (Nutsford et al. 2016).

Connection to blue spaces like rivers and estuaries has been associated with lower rates of poor physical and mental health and a greater psychological connection to the natural world. This connection, in turn, is associated with more pro-environmental behaviours (White et al. 2020).

The health of the waterway is crucial for people to safely swim and enjoy a pleasant environment, which supports recreational and social activities. Poor ecological health can lead to waterway closures, directly impacting recreation and socialisation (Urbis 2023).

Waterways have significant cultural and spiritual significance for Aboriginal people. They are important for customs and spiritual beliefs (DWER 2023). Traditional values of water are complex and are at the centre of Indigenous identity. It is imperative that water policy makers and managers recognise the value of Indigenous land management practices and the application of Traditional Knowledge in adaptive water management (Leonard 2011).

Indigenous peoples regard the inland waters, rivers, wetlands, sea, islands, reefs, sandbars and sea grass beds as an inseparable part of their estates. As well as underpinning social and economic well-being, the relationship Indigenous peoples have with waters, lands and its resources is crucial to cultural vitality and resilience (Jackson and Altman 2009).

Waterways provided important food resources, trade routes, and camping sites for Traditional Owners, and foreshores often contain artefacts. They are significant places for spiritual and ceremonial reasons (DoE 2008). Stories of serpent-like creatures like Waugal creating rivers and wetlands are of special significance (Leonard 2011).

Maintaining healthy waterways for future generations is a significant social value, reflected in community efforts and investments in their protection. This 'bequest value' is an important aspect of the overall value of these natural assets (Urbis 2023).

The cost of inaction

The cost of inaction regarding inland waters poses significant threats to ecological, social, and economic systems. Globally, biodiversity is in decline with freshwater ecosystems being particularly affected. Based on monitored natural inland wetlands (including peatlands, marshes, swamps, lakes, rivers and pools, among others), 35 per cent of wetland area was lost between 1970 and 2015, at a rate three times faster than that of forests. Of the remaining wetland habitats, 65 per cent are under moderate-to-high levels of threat. Declines are continuing, generally out of sight and out of mind, despite the importance of the freshwater realm (Sayer et al. 2025).

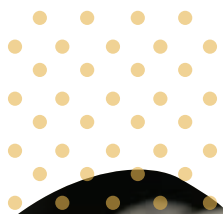
In Australia, the 2021 State of the Environment report highlights climate change, habitat loss and degradation, and invasive species as the key threats to biodiversity (Cresswell et al. 2021). These pressures have intensified over the past five years, leading to persistent and sometimes irreversible impacts on biodiversity across the country (Murphy and van Leeuwen 2021).

If we do nothing, the important ecosystem services provided by inland water biodiversity will rapidly deteriorate, leading to increasing constraints for further development. Investing just US\$1 in ecosystem restoration of inland water ecosystems can generate significant economic benefits, with some studies showing returns of up to US\$30. Data on these broader societal returns are becoming increasingly available, as highlighted in a report by The Economics of Ecosystems and Biodiversity (Russi et al. 2023).

For Indigenous peoples in Australia, water is central to their identity and connection to Country. Inaction on protecting water resources can disproportionately affect Indigenous communities, impacting their cultural and social well-being, and hindering their ability to achieve economic and social aspirations related to water (Leonard 2011).

The Wentworth Group of Concerned Scientists demonstrate how repairing Australia's landscapes is achievable and affordable. Using the best available science and expert advice, they identify 24 actions valued at A\$7.3 billion each year over 30 years, which could repair much of the past two centuries of degradation (WGCS 2024). Research has found improving riparian vegetation on less than two per cent of Australia's landmass could not only lead to a healthier environment and stronger communities but would sequester enough carbon over the next 30 years to offset 37 per cent of Australia's net emissions (Capon et al. 2025).

Protecting and restoring inland water systems in WA is not only an environmental imperative but also an economic necessity. The costs associated with inaction—ranging from increased infrastructure damage to public health risks—underscore the importance of proactive investment in ecological restoration.





Credit: Megan Hele

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5.

INLAND WATERS RESEARCH IN WESTERN AUSTRALIA

Research on inland waters and biodiversity in WA has a long history, with a broad range of research focusing on ecological understanding, conservation and management. An overview of past and current research as it applies to WA includes, but is not limited to, research from the following organisations.

Department of Biodiversity, Conservation and Attractions (DBCA)

WA's State Government agency DBCA and its predecessors have a long history of undertaking research to conserve, discover and protect biodiversity and to engage with the community to inspire a passion for nature. The organisation consolidates conservation science under one department to build and share knowledge of the state's biodiversity.



Credit: Megan Hele (middle and right)

Navigating knowledge gaps for Western Australia's inland waters



With regards to inland waters research, some of the programs that align are:

- The Rivers and Estuaries Science Program undertakes and supports research across a wide range of disciplines to address knowledge gaps and inform management of the Swan Canning Riverpark.
- The Ecosystem Science Program undertakes applied research to understand the environmental, ecological, and biogeographical processes that determine the conservation values, health and productivity of the lands and inland waters managed by the department.
- The Species and Communities Program provides leadership for biodiversity conservation programs and provides expert advice on conservation, policy, and management focussed on threatened species, threatened ecological communities, wetlands, and other matters of conservation significance.
- Research and monitoring program for Ramsar wetlands across WA.

Department of Water and Environmental Regulation (DWER)

DWER is responsible for managing and regulating WA's groundwater and surface water resources in proclaimed areas. This is done by allocating and licensing water use. DWER assumes responsibility for all water and environmental regulation. Some of their programs that align with inland waters research are:

- Development and maintenance of data and geospatial datasets and interactive mapping tools, used to enable vital science and planning capabilities that lead strategic policy development about future water and environmental resource protection outcomes.
- Interactive water science monitoring and data, critical for scientists to assess and advise how best to manage and protect WA's water resources. Information is collected on surface water and groundwater levels, flows and quality, in addition to meteorological data.
- The Climate Science Initiative and the Climate Adaptation Strategy to understand how climate change will affect ecosystems in future, and take this into account in environmental planning, management and restoration to maximise the health and resilience of waterways.
- The Bindjareb Djlba (Peel-Harvey estuary) Protection Plan is a whole-of-government approach to protecting the Peel-Harvey estuary and its internationally recognised values.
- Healthy Estuaries WA focuses on improving the health of Peel-Harvey estuary, Leschenault Estuary, Vasse-Geographe waterways, Hardy Inlet, Wilson Inlet, Torbay Inlet and Oyster Harbour.
- Through the Healthy Rivers Program data on South West rivers and their catchments are collected and interpreted, and the knowledge gained is used to support development of strategies to best protect the environment.
- Kep Katitjin – Gabi Kaadadjan Waterwise action plans set out action and collaboration, helping to conserve Perth and Peel's water resources, support urban greening, biodiversity, the tree canopy and urban cooling to create climate-resilient communities.

Department of Primary Industries and Regional Development (DPIRD)

DPIRD's inland waters research focuses on sustainable water management to support agriculture and regional development in WA. DPIRD conducts research and provides guidance on best practices for water management in both dryland and irrigated farming systems, including rainfall-runoff capture, storage, and use, as well as management systems to prevent land degradation. The Department also supports initiatives like WaterSmart Farms, which aim to improve water security and climate resilience in agricultural regions through collaborative projects involving desalination and groundwater studies. DPIRD also develops interactive tools, such as the Hydro Guide and groundwater and salinity maps, to assist landholders in making informed decisions about water management and salinity risk.

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

CSIRO plays a pivotal role in advancing inland waters research in WA, particularly through comprehensive assessments like the Pilbara Water Resource Assessment. This project, conducted in partnership with BHP and the Government of Western Australia, provided an in-depth understanding of water systems in the Pilbara region, covering approximately 11 per cent of the State (CSIRO 2020).



Another example of inland waters research in Australia is the Northern Australia Water Resource Assessment (NAWRA), led by CSIRO. This large-scale study focused on three key regions—Darwin catchments (NT), the Fitzroy catchment (WA), and the Mitchell catchment (QLD)—to evaluate the potential for sustainable agricultural development through better use of water resources. The research assessed surface water and groundwater availability, soil suitability, ecological impacts, Indigenous cultural values, and economic viability (CSIRO 2021).

Geoscience Australia

The Australian Government is undertaking the Resourcing Australia's Prosperity initiative, led by Geoscience Australia. The initiative will help support the resources sector into the future by mapping onshore resource potential for critical minerals and strategic materials. As part of this initiative, an effort will be made to map all of Australia's groundwater systems, to help support climate resilience, agricultural output and water security for communities, industries and the environment, with the aim to enhance the responsible management of natural resources. Over the next ten years, groundwater assessments will be undertaken in priority regions throughout Australia, in consultation with stakeholders.

Other Western Australian organisations

Non-government organisations (NGOs) in WA play an integral role in the community to conserve inland waters and their biodiversity, such as:

- Natural Resource Management (NRM) organisations. There are seven NRMs within WA that work from the paddock to the regional scale to address issues that require a landscape perspective. The NRM approach enables the community to better address long term strategic issues of national importance through land care initiatives. A recent initiative from the South West NRM is the project: *Addressing the threat of climate change for endangered amphibians and reptiles* in the South West region, an initiative to conserve species in the South West Global Biodiversity Hotspot (South West NRM 2025).
- The Conservation Council of Western Australia, WA's peak body for conservation and climate action is working to educate the public about the importance of conservation and lobbies on environmental issues including water related advocacy to create legislative change. The Council's Citizen Science Program generates engagement at a community level to fill knowledge gaps and contribute to the ecological research and monitoring.
- Catchment Councils, such as Peel-Harvey Catchment Council (PHCC), Torbay catchment Group and the Wilson Inlet Catchment Committee. The PHCC is undertaking research and actions to improve a section of the Serpentine River by creating refuge pools and riparian habitat to benefit the Carter's Freshwater Mussel, Rakali, and improve connectivity with Threatened Ecological Communities including Banksia Woodlands and Clay Pans of the Swan Coastal Plain (PHCC 2025).

Universities in WA have a long history of undertaking biodiversity research in the areas of restoration, fire management, water management and species conservation.

Curtin University's Water Quality Research Centre, Edith Cowan University Centre for Ecosystem Management and Murdoch's Harry Butler Institute and Centre for Water, Energy and Waste and the University of Western Australia's Centre for Water and Spatial Science are prime examples of how universities are working to protect and enhance inland waters research.



Community groups are active in undertaking research in the form of trials, restoration, monitoring and analysis of inland waters. The Wetlands Conservation Society is involved in wetland conservation throughout WA. It supports long-term studies of wetland hydrology and ecology (e.g., Lake Mealup, Forrestdale Lake) and involves volunteers and researchers in water quality and species monitoring. Trillion Trees Australia works on ecological restoration with attention to catchment hydrology and wetland buffering. Its members collaborate on research into revegetation effects on soil and water, and support field trials for groundwater recharge and saline land restoration. These groups work to ensure their experiential knowledge reaches the broader community through regular engagement with research organisations, reports in the grey literature, departmental papers and workshops.

Environmental consulting companies are also undertaking hydrological and hydrogeological research, particularly in relation to clearing for development and sustainable resource management. However, confidentiality clauses and data intellectual property issues prevent much of this knowledge from being shared in the public domain.

Cooperative Research Centres and collaborative research initiatives

Federally funded Cooperative Research Centres (CRCs) have provided the resources for inland waters biodiversity research in WA of relevance to this program. They are an Australian Government initiative that was established in 1990 and funds industry-led collaborations between industry, researchers and end users.

The Future Food Systems CRC investigates sustainable water use for inland food production, irrigation innovation, and water recycling. Its relevance to inland waters includes inland aquifer use and groundwater management in food systems and reducing nutrient and sediment runoff.

CRC for Zero Net Emissions from Agriculture examines climate impacts on inland water use, carbon sequestration in riparian/wetland zones, and water-efficient farming. Researchers are involved in projects about riparian restoration and soil-water carbon dynamics and water as a vector for methane and nitrogen emissions.

The CRC for Water Sensitive Cities is now operating as Water Sensitive Cities Australia and continues to fund relevant research for urban environments. One of its current projects is the establishment of a framework for sustainable urban water management, by integrating water sensitive cities and circular economy principles to improve urban water management.

National Environmental Science Program (NESP)

The NESP Resilient Landscapes Hub is delivering applied research to support management of Australia's terrestrial and freshwater habitats, including a focus on bushfire recovery, feral animals and invasive species impacts, and accessible science to assist land managers develop and maintain resilient, sustainable and productive landscapes and inland waters. Previous NESP hubs have also provided a significant body of science and knowledge to support the sustainable use and management of Australia's tropical rivers and estuaries.





Interstate and overseas research and expertise relevant to Western Australia

Research undertaken both interstate and overseas is likely to be informative for delivering this prioritised research program, even if the work does not take place within WA. For example, due to climatic similarities and many biodiversity problems, opportunities exist across Australia and our wider region for improved collaboration in researching and implementing inland waters conservation and management practices and knowledge sharing.

Credit: Sonja Mennen (main)

Navigating knowledge gaps for Western Australia's inland waters

6.

PROGRAM SCOPING AND DEVELOPMENT

The program development process

A process to scope, define and prioritise research needs with regards to inland waters in WA was undertaken broadly following the WABSI program development pathway. This approach follows an iterative model with stakeholder engagement led by end users, and with ongoing engagement between end users and research expertise throughout a series of workshops and discussions. Stakeholders help scope, define and set research priorities (Figure 1).

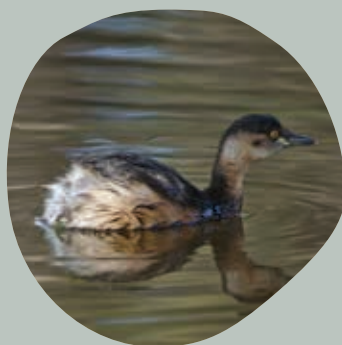




FIGURE 1. The WABSI research program development pathway

End user engagement

Stakeholder mapping identified a broad range of involved parties: Research experts, all levels of government, industry (incl. agriculture), regulators, Traditional Owners, and not-for-profit organisations with relevant interests in a research program for inland waters in WA.

Developing the Inland Waters program at a statewide level required careful consideration of the distinct cultural knowledge and responsibilities held by Traditional Owners for their respective Countries. As custodians of their own lands and waters, their insights are deeply rooted in their specific cultural contexts, making it culturally inappropriate to speak for other Nations. Acknowledging the crucial value of their contributions, WABSI reached out to a number of ranger groups and academics to gather their expertise.

Initial scoping sessions

'Inland waters' is a broad topic, and WA is a vast state. To initiate the program, a series of scoping sessions took place with a cross section of stakeholders identified. To guide the initial scoping process the focus of the program is described as:

Knowledge priorities associated with the health of inland waters to support Western Australia's biodiversity and provide ecosystem services.

To explore and determine current and future inland water challenges, WABSI organised scoping sessions with several end user organisations and researchers between March and October 2024, refer to Appendix 1 and Figures 2 and 3.

The scoping sessions were undertaken as either one-on-one sessions, or as a group facilitated discussion, generating a considerable amount of information on which issues need addressing across WA on a wide range of inland water related topics.



Credit: Megan Hele

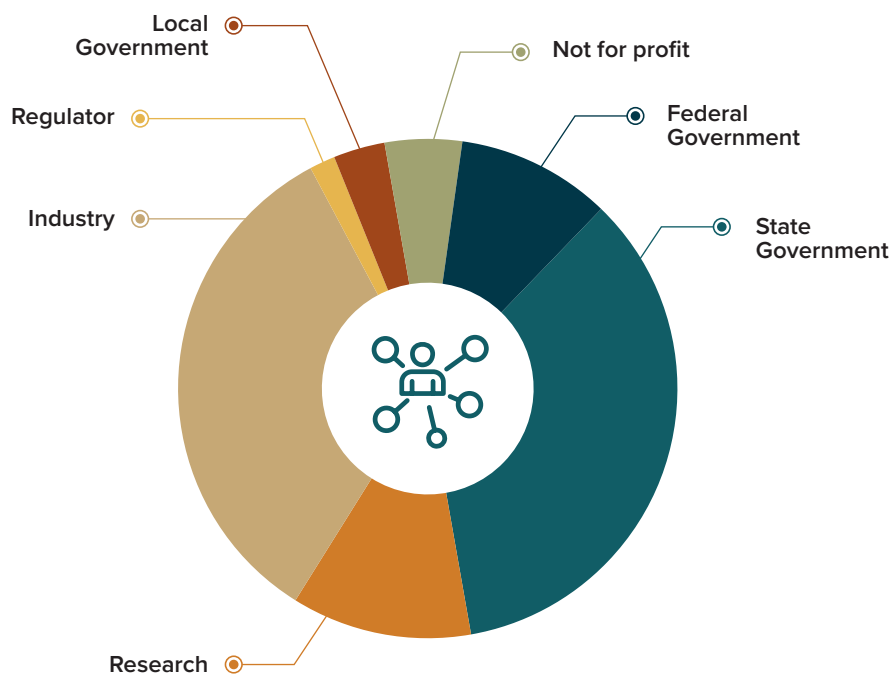


FIGURE 2. Breakdown of participants of the initial scoping sessions by sector

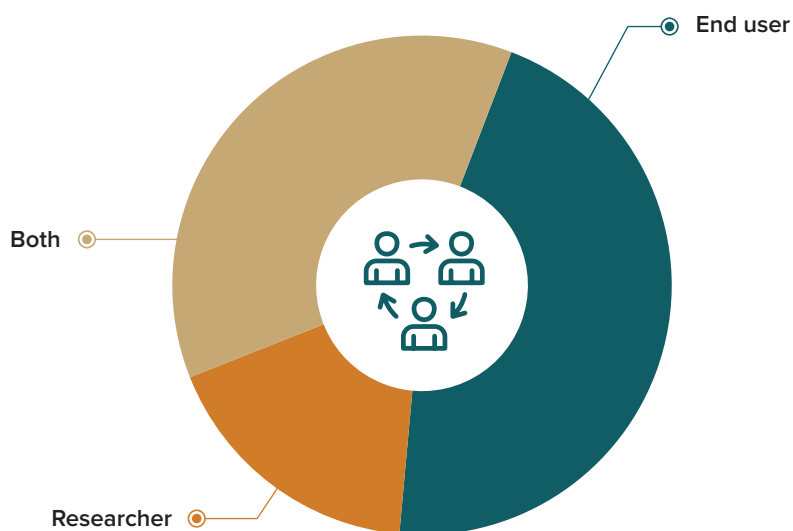


FIGURE 3. Breakdown of participants of the initial scoping sessions — end users vs researchers



Outcomes initial scoping sessions

A total of 96 issues were identified during these sessions. To provide more structure, an analysis was undertaken to determine how to categorise the issue and what the solution would be to help address it. As a result, all issues were grouped into and into eight initial categories (Table 2) and five solution components (Figure 4).

Within the solution components WABSI's remit relates specifically to the research category, as well as where the other four categories interact or overlap with research to improve outcomes. Therefore, issues that were identified but that could not be categorised under 'research' were not taken further.

TABLE 2. Issues identified were grouped into eight categories

1.	Water quality	5.	Climate change
2.	Environmental protection	6.	Data (collecting, sharing and maintaining)
3.	Habitat restoration	7.	Regulation
4.	Mining/Industry/Agriculture	8.	Subterranean fauna

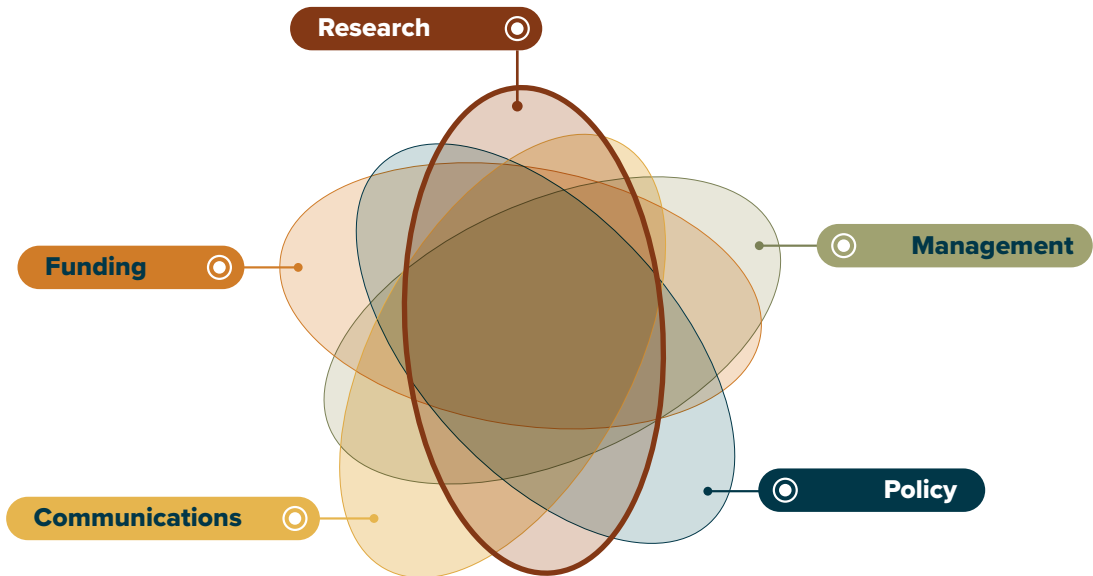


FIGURE 4. Inland waters challenges can be grouped into five solution components: research, funding, communications, policy and management





Areas

Due to its size, WA has a diverse range of climates; tropical conditions in the Kimberley, deserts in the interior (including the Great Sandy Desert, Little Sandy Desert, Gibson Desert, and Great Victoria Desert) and a Mediterranean climate in the South West and southern coastal areas. These differences in climate, geology, landscape and soils lead to different issues for inland waters in different areas. It is therefore likely that inland aquatic research needs throughout the state will vary according to regional climate, biodiversity, population and development.

After the scoping sessions, three key areas for inland waters issues throughout the State emerged: North, Mid and South. Issues that apply statewide were referred to as 'All'.

Figure 5 provides an overview of the different regions of WA and Table 3 explains the categorisation of those regions into the different areas and their key threats and impacts.



FIGURE 5. Map of WA regional areas

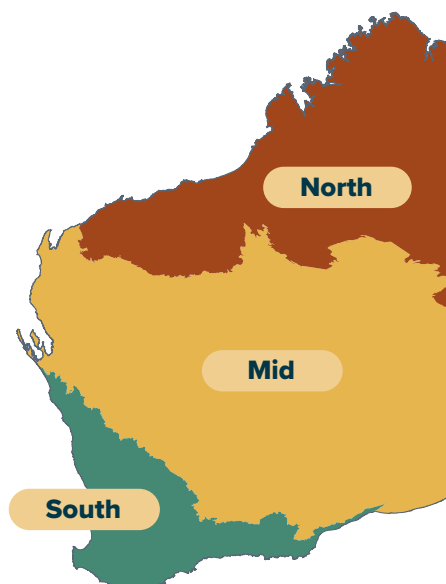


FIGURE 6. Three key areas for inland waters issues

TABLE 3. WA regional area categorisation and key threats/impacts to inland waters

WA regional areas	Interim Biogeographic Regionalisation for Australia (IBRA)	Key threats/impacts to inland waters
North The northernmost region of WA, including the Kimberley, the Pilbara and East Pilbara	Northern Kimberley, Victoria Bonaparte, Central Kimberley, Dampierland, Ord Victoria Plain, Pilbara, Tanami, Great Sandy Desert	Mining and industry, livestock, increasing annual rainfall
Mid Part of this area is also referred to as arid shrublands. The area includes the Gascoyne, Murchison, Arid Interior and the Goldfields	Carnarvon, Gascoyne, Little Sandy Desert, Gibson Desert, Central Ranges, Yalgoo, Murchison, Great Victoria Desert, Coolgardie, Nullarbor, Hampton	Pastoralism, mining and industry
South This area includes the Mid West, Wheatbelt, Metropolitan Perth and the Peel region, the South West and the South Coast	Geraldton Sandplains, Avon Wheatbelt, Swan Coastal Plain, Jarrah Forest, Warren, Mallee, Esperance Plains	Urbanisation, dryland salinity, intensification of agriculture, decreasing rainfall
All: The issues that apply statewide, are marked as 'All'		Climate change, invasive species

A complete overview of the outcomes of the initial scoping sessions can be found in Appendix 2. The outcomes were summarised in a report which was shared with scoping session participants, WABSI Board members and WABSI's Collaborative, Leverage and Integration Committee members, plus other interested stakeholders.

Further analysis of the scoping session outcomes led to a refinement of the initial categories, and six focus areas emerged, each with their own research topics. The remaining issues were classified under each research topic and split into North/Mid WA, South WA and statewide. Issues that related to knowledge gaps with regards to subterranean fauna were not taken further but will be referred to WABSI's [Subterranean fauna research program](#). As a result, the following research program proposal was developed and taken to subsequent prioritisation workshops (Table 4).

TABLE 4. WABSI's research program proposal taken to the prioritisation workshops

	Focus areas	Research topics
1.	 Water quality	1.1: Legacy issues 1.2: Future impacts
2.	 Water extraction and discharge	2.1: Cumulative impacts 2.2: Impacts on GDEs 2.3: Dewatering discharge
3.	 Ecosystem functioning	3.1: Ecological water needs 3.2: Aquatic ecosystem values 3.3: Threat mitigation 3.4: Ecosystem restoration
4.	 Climate change impacts	4.1: Extreme rainfall events 4.2: Drying climate
5.	 Data collection	5.1: Biological data 5.2: Spatial data
6.	 Principles and guidance	6.1: Review inland water principles 6.2: Update guidance



Credit: Megan Hele



7.

RESEARCH PRIORITISATION PROCESS

Prioritisation workshops

To continue engagement with end users and researchers and to further develop the program, WABSI organised two prioritisation workshops late 2024. Issues specific to North and Mid WA were discussed in the first workshop, and during the second workshop issues for South WA were addressed. Issues identified for the whole of WA were discussed at both workshops. The aims of the workshops were to:

1. Discuss and confirm the research program proposal
2. Identify potential gaps in the analysis so far
3. Prioritise research needs and questions according to end user requirements





Credit: Sonja Mennen

The workshops were conducted as interactive discussions, and participants also completed an online exercise to prioritise research focus areas, determine whether the issues identified were ‘high’, ‘medium’, or ‘low’ priority and identify a top three of urgent issues.

The exercise was later emailed to participants who were unable to attend the workshop on the day, and a separate session was organised with Water Corporation to receive their input.

Refer to Appendix 3 for a list of participants who contributed to workshops and prioritisation exercise and Appendix 4 for the full list of questions from the online exercise.

Outcomes prioritisation workshops

Both workshops fostered productive discussions regarding priorities for inland waters research and knowledge. Participants generally agreed that while progress exists, substantial further work is crucial, especially considering the changing climate. A strong consensus emerged that climate change should be integrated across all research focus areas, rather than treated separately. Similarly, input from Traditional Owners was deemed relevant and necessary for all focus areas.



Credit: Megan Hele (right)

Navigating knowledge gaps for Western Australia's inland waters



Participants

In total 37 stakeholders took part in the prioritisation exercise for North and Mid WA. Twenty-nine participated in the workshop and eight completed the exercise afterwards. For the workshop focusing on South WA, 33 stakeholders took part in the prioritisation exercise. Twenty-five participated in the workshop and eight completed the exercise afterwards.

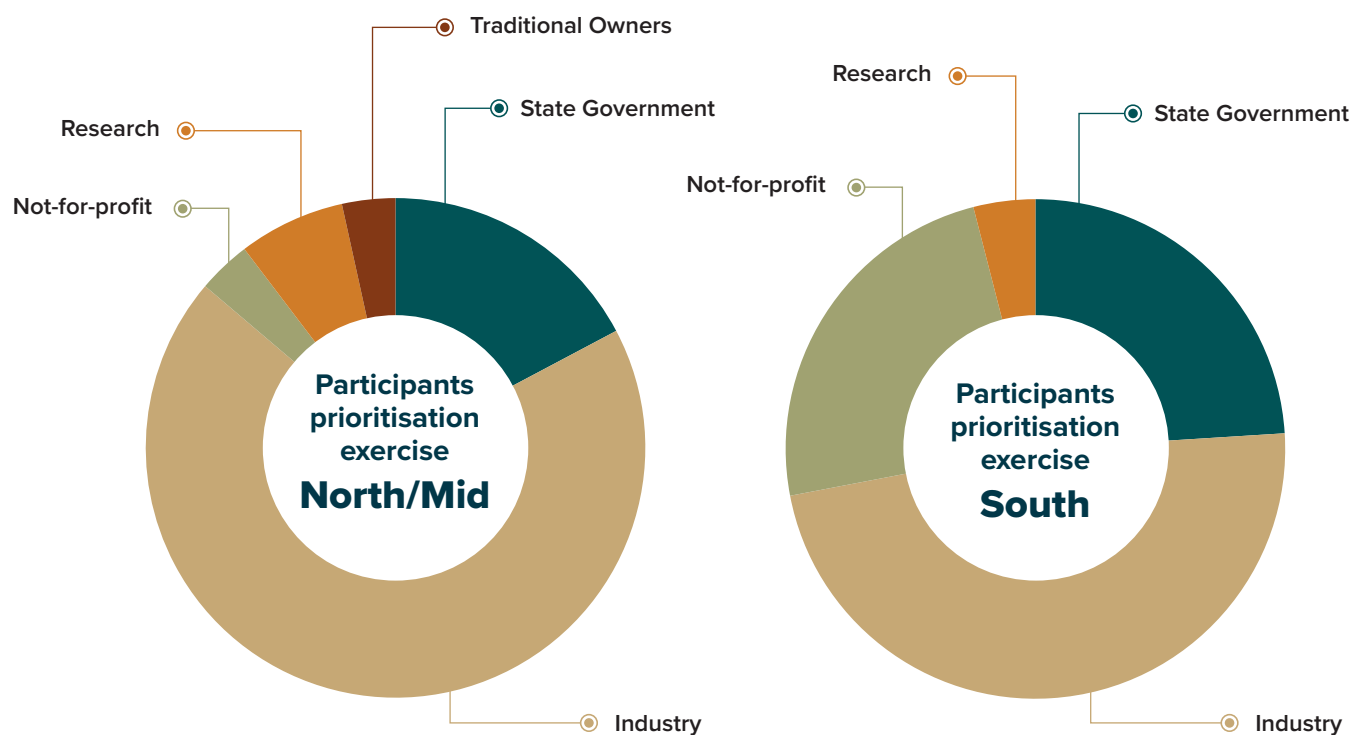


FIGURE 7. Stakeholders by sector completing the prioritisation exercise for inland waters



Ranking focus areas

Participants were asked to rank the six focus areas (refer to Table 3) from most important to least important, according to their interests. 'Ecosystem functioning' was found most important, followed by 'Water extraction and discharge' for North/Mid and 'Climate change impacts' for South. 'Data collection' was viewed as least important for both North/Mid and South.

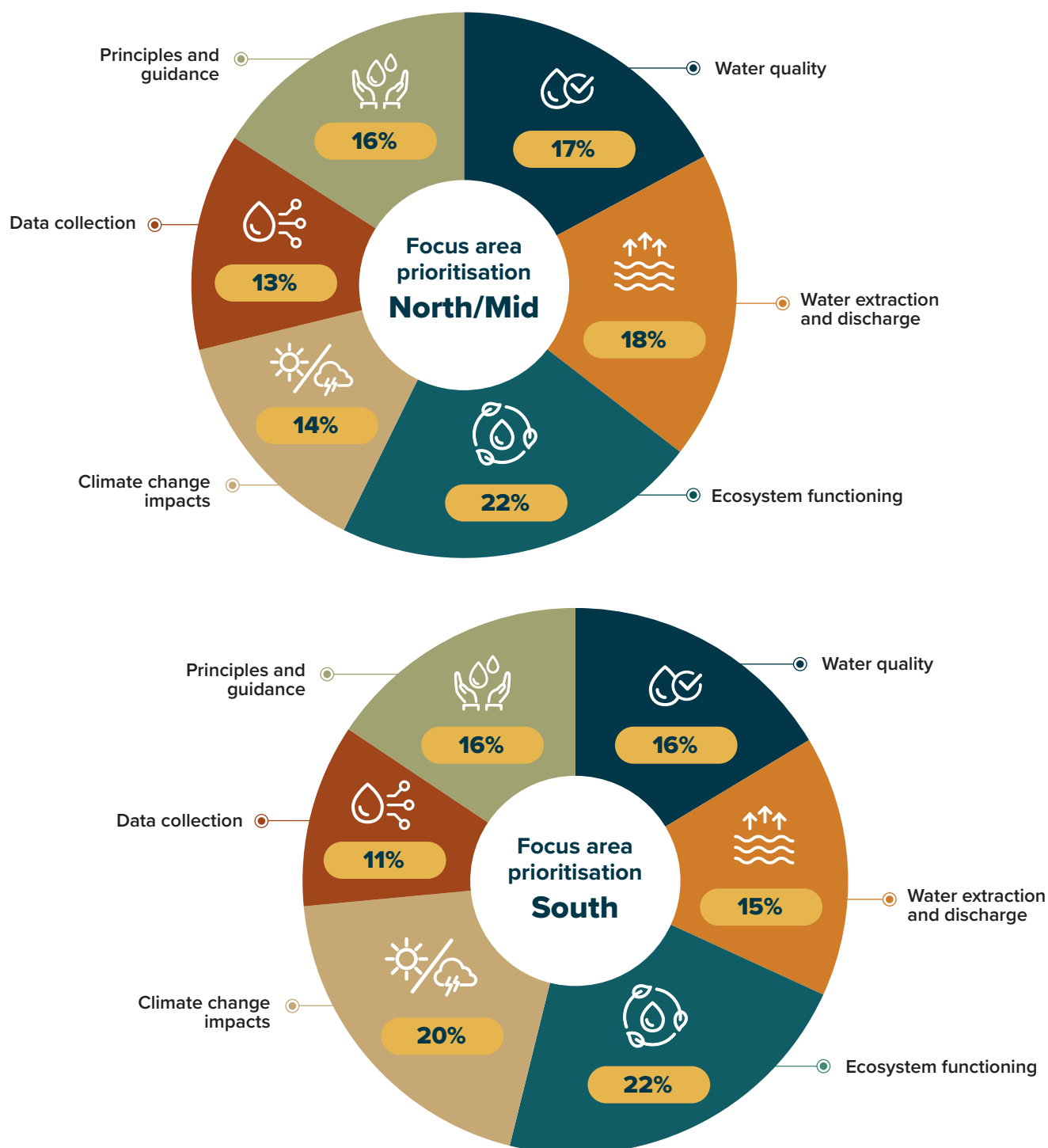


FIGURE 8. Outcomes prioritisation of research focus areas for the inland waters workshop (weighted)

Adapted focus areas

As a result of the feedback during both workshops that 'Climate change impacts' should be across all focus areas, the focus areas were adapted further and reduced from six to five. Integrating climate change into all research themes and mainstreaming the effect of climate change more broadly into the development of research projects will lead to a more holistic approach according to workshop participants.

The research questions that were initially categorised under focus area 4 'Climate change impacts' have been integrated into the other focus areas. Table 5 provides the adapted focus areas:

TABLE 5. Adapted focus areas after feedback during prioritisation workshops

	Focus area 1 – Water quality
	Research topic 1.1 – Legacy issues
	Research topic 1.2 – Future impacts
	Focus area 2 – Water extraction and discharge
	Research topic 2.1 – Cumulative impacts
	Research topic 2.2 – Impacts on GDEs
	Research topic 2.3 – Dewatering discharge
	Focus area 3 – Ecosystem functioning
	Research topic 3.1 – Ecological water needs
	Research topic 3.2 – Aquatic ecosystem values
	Research topic 3.3 – Threat mitigation
	Research topic 3.4 – Ecosystem restoration
	Focus area 4 – Data collection
	Research topic 4.1 – Biological data
	Research topic 4.2 – Spatial data
	Focus area 5 – Principles and guidance
	Research topic 5.1 – Review inland water principles
	Research topic 5.2 – Update guidance



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Navigating knowledge gaps for Western Australia's inland waters

Credit: Megan Hele

Prioritised knowledge needs for inland waters – North/Mid and South WA

Tables 6 and 7 provide an overview of the outcomes of the priority ranking exercise of the research questions and/or knowledge gaps for North/Mid and South respectively. To highlight the inter-related nature of the focus areas a 'Linked focus area' column has been added, plus a column to indicate linkage with other WABSI research programs.

To provide a more structured overview, the specific research questions and/or knowledge gaps have been broadly divided into enabling priorities and research priorities. Enabling priorities are described as the science or knowledge that would not be deemed new academic research, and primarily include baseline monitoring, synthesis of current knowledge and updating of operational numerical models and mapping. These enabling priorities are critical to underpin both management and advanced research. All listed research questions/knowledge gaps are grouped under one of the five adapted focus areas and its corresponding research topic. All are recognised as important, but their relative priorities have been ranked according to stakeholders' interests.

TABLE 6. Research questions for North/Mid WA ranked

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Focus area 1 – Water quality				
Enabling priorities				
Baseline water quality monitoring and reporting	Establish baseline monitoring (where gaps exist) as foundation to management and scientific analyses and reporting to communicate condition and trends.	High	Data collection	Data
Better access to water quality data for priority areas in WA	Research and publish specific default guideline values DGVs for local/regional environments under the Water Quality Guidelines, e.g. for the Indian Ocean drainage ecoregion, which includes the Pilbara.	High	Data collection	Data
Predictive models to assess the impacts of intensified and changing land use on future water quality	Intensified and changing land use, e.g. agricultural expansion and intensification can have significant impacts on water quality in the receiving environment. Predictive models are commonly used to assess these impacts.	Medium	Data collection	Data
Research priorities				
Research topic 1.1: Legacy issues				
Additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)	Research into additive future impacts of introduced persistent pollutants such as heavy metals, hydrocarbons, and industrial chemicals in light of a changing climate.	Medium	Ecosystem functioning	
Cost-effectively stripping of contaminants out of water (phosphorus, PFAS, nitrogen)	Research into emerging technologies to destruct contaminants affecting freshwater quality in the environment.	Low	Ecosystem functioning	
Research topic 1.2: Future impacts				
Monitoring of large natural catchments to detect and treat contaminants prior to them entering water bodies	Assess the best way to detect and monitor contaminants in large natural catchment areas to prevent contamination of water bodies.	Medium	Ecosystem functioning	

TABLE 6. Research questions for North/Mid WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Focus area 2 — Water extraction and discharge				
Enabling priorities				
Groundwater models to assess interactions of climate factors, seasonal variability and proponents' impacts of dewatering	Climate factors, seasonal variability and proponents' impacts of dewatering – how are they interacting and what are the impacts on GDE and groundwater levels (in other words: what is a result from mining and what is due to climate change).	High	Data collection	Data
Regional groundwater models to assess cumulative impacts outside of mining/agriculture	Investigate the cumulative impacts of major water drawdowns for mining and other industries such as intensive agriculture (with the use of centre pivot irrigation) on regional areas.	Top	Data collection	
Research priorities				
Research topic 2.1: Cumulative impacts				
Cumulative impacts from land use change on Pilbara surface water flows	Deeper understanding how interruption of surface water flows through railway corridors, water course diversion etc. impact the receiving environment.	High	Ecosystem functioning	Data
Cumulative impacts from land use change on Pilbara groundwater dependent ecosystems (GDEs) and groundwater levels	Conduct studies to integrate hydrogeological modelling, remote sensing, and ecological assessments to identify trends and inform sustainable water management strategies for protecting Pilbara's GDEs.	High	Ecosystem functioning	Data
What are the cumulative impacts of mining on the Fortescue Marsh through changes of water inflows and water quality as a result of mine dewatering, discharges as well as linear infrastructure/rail corridors	The cumulative impacts of mining activities are altering the hydrological balance and ecological integrity of this unique ecosystem through changes in water inflows and hydrology and degrading water quality. Research is needed to track long-term groundwater changes and ecosystem responses to implement adaptive water management strategies.	High	Ecosystem functioning	Data
Reduce environmental impact of future salt mining by learning from the past. How have past salt mining sites regenerated?	Historic salt mining has left lasting environmental impacts, including habitat destruction, groundwater salinisation, and altered hydrology. Lessons from past salt mining sites show that strategic rehabilitation efforts can support ecosystem recovery.	Low	Ecosystem functioning	
Research topic 2.2: Impacts on GDEs				
Impacts of water drawdown in groundwater dependent ecosystems (GDEs) to aquatic/freshwater species	Groundwater is used by industry, agriculture and for watering public open space and private gardens in urban areas. This alters groundwater levels, which has an impact on aquatic/freshwater species.	Top	Ecosystem functioning	Data Urban
Impacts of water drawdown in groundwater dependent ecosystems (GDEs) to reeds, riparian vegetation and buffers	Groundwater is used by industry, agriculture and for watering public open space and private gardens in urban areas. This alters groundwater levels, which has an impact on reeds, riparian vegetation and buffers.	Top	Ecosystem functioning	Data Urban
Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction	Quantifying the contribution of groundwater in maintaining refuge pools is essential to assess the impact of groundwater extraction on aquatic ecosystems. This will help to determine the quantity and timing of environmental surface water flows.	High	Ecosystem functioning	



TABLE 6. Research questions for North/Mid WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research topic 2.3: Dewatering discharge				
Better practice and novel solutions to improve dewatering discharging and reinjecting to the receiving environment	Using better practices and novel solutions for dewatering discharge and reinjection is essential to enhance sustainability, regulatory compliance, and operational efficiency while minimising environmental harm. Improved methods help protect groundwater levels, prevent aquifer depletion, and reduce land subsidence by ensuring that extracted water is returned in a controlled and beneficial manner.	High	Principles and guidance	
Improved information/knowledge on the management of tailing storage facilities	Improved information and knowledge on the management of tailings storage facilities (TSFs) are critical for ensuring safety, environmental protection, and operational efficiency. By advancing knowledge in TSF management, industries can minimise risks, optimise resources, and build public and stakeholder trust.	Medium	Principles and guidance	
Impact of long-term surplus water discharge on riparian rooting patterns, ecosystem resilience and future restoration efforts	While surplus water discharge can sustain riparian zones in the short term, long-term changes in rooting depth, species composition, and soil stability can reduce resilience and complicate restoration efforts. Adaptive management is essential to mitigate these impacts.	Medium	Ecosystem functioning	
Focus area 3 — Ecosystem functioning				
Enabling priorities				
Local scale hydrological models to better understand functioning of wetlands from the Kimberley to the Arid zone to the South West	By providing high-resolution, site-specific data, local-scale hydrological models help to understand the functioning of wetlands, as they provide detailed insights into water movement, storage, and interactions with groundwater and surface water.	Medium	Data collection	Data
Research priorities				
Research topic 3.1: Ecological water needs				
Enhance understanding of ephemeral (seasonal) arid zone drainage systems to quantify the relative contributions of groundwater and surface water	Improved knowledge of ephemeral arid zone drainage systems helps to clarify how water moves through the landscape. These systems are characterised by infrequent surface flows, rapid infiltration, and strong interactions with groundwater. A better understanding of these drainage systems contributes to optimising regional water balance assessments.	High	Data collection	
Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency	With a changing climate there is a need for increased knowledge how inland water systems reacts under today's climate, to predict how they will change in the future.	High	Data collection	
Evaluate the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change	Understanding how aquatic ecosystems rely on different aquifer types is crucial for determining which ecosystems are most and least vulnerable to climate change-driven shifts in groundwater availability and helps to develop targeted strategies to protect vulnerable groundwater-dependent ecosystems.	High	Data collection	



TABLE 6. Research questions for North/Mid WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research topic 3.2: Aquatic ecosystem values				
Improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management	Building on historical knowledge to increase understanding on how salt lakes work and adapt to a changing climate and increasing development.	Medium	Principles and guidance	
Create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations	Created waterbodies can provide significant biodiversity benefits when designed, managed, and regulated properly. Integrating them into licensing requirements helps to align long-term ecological sustainability with development.	Low	Principles and guidance	
How cost effective is a specific intervention to save an inland water system from the impacts of climate change?	Assessment of the cost-effectiveness of a specific intervention aimed at protecting an inland water system from climate change impacts helps to balance financial feasibility with maximum ecological benefit, ensuring sustainable inland water system management for the future.	Low	Principles and guidance	Economics
Quantify the economic value of healthy receiving environments	Quantifying the economic value of healthy receiving environments (e.g., rivers, wetlands, estuaries, and groundwater systems) is essential for making informed decisions about water management, conservation, and development. Understanding their economic value helps in balancing environmental protection with economic growth.	High	Principles and guidance	Economics
Research topic 3.3: Threat mitigation				
Investigate the potential of inland groundwater desalination to restore natural waterways and mitigate dryland salinity	Inland groundwater desalination could present a viable tool for restoring degraded waterways and mitigating dryland salinity.	Medium	Water extraction and discharge	
Determine tolerance levels of local/native species to deteriorating water quality	What are the extinction thresholds of key species - what are the tipping points, interactions between salinity, pH, aeration, turbidity / light, water temperature etc, and toxicological elements.	High	Water quality	
Impact of invasive aquatic species on native aquatic ecosystems	Invasive species outcompete native species, alter habitats, and disrupt ecological balance. They can degrade water quality and decrease biodiversity. More research is needed on their impact and management.	High	Data collection	
Effects of episodic rainfall events due to a changing climate on salt lake systems	Investigate whether changes in frequency of floodwaters, which leads to dilution of brine could impact biodiversity. Dilution may lead to increased biodiversity.	Medium	Data collection	



TABLE 6. Research questions for North/Mid WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research topic 3.4: Ecosystem restoration				
Impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems	The effects on downstream aquatic ecosystems depend on how effectively restoration mitigates mining-related disturbances. What are optimal post-closure restoration efforts to help rehabilitate waterways, improve water quality, and restore biodiversity?	High		Restoration
Review risk analysis systems for wetland and riparian ecosystem restoration: prioritising functional resilience (hybrid ecosystems) over historical state restoration	Investigate which restoration approach provides the most sustainable and resilient restoration approach for wetlands and riparian ecosystems.	High		Restoration Urban
Focus area 4 — Data collection				
Enabling priorities				
Inventory of vulnerability and resilience of inland water systems to climate change and other threats (e.g. salinisation, eutrophication, siltation)	Develop and populate a database on up-to-date information with regards to inland water systems.	High	Ecosystem functioning	Data
Pilbara-wide freshwater pool inventory and wetland mapping	Gather existing information from departments and proponents and fill in the gaps with regards to mapping.	Top	Ecosystem functioning	Data
Create a baseline understanding of pre-development hydrogeology of the Pilbara	It is important to measure the impact of development/land use change and understand what the contrast is against what was there. We need science on what is an agreed baseline to know what was there before development.	High	Ecosystem functioning	Data
Enhance groundwater-surface water connectivity mapping through improved depth to groundwater data acquisition and integration	Undertake mapping exercise, first for priority areas and build on that for the rest of WA.	High	Ecosystem functioning	Data
Focus area 5 — Principles and guidance				
Enabling priorities				
Integrate input from Traditional Owners into the management of water	Identify ways to better integrate Indigenous knowledge into the western way of water management thinking and guidance. Further consultation is required and opportunities should be sought considering the upcoming bicentenary of proclamation of WA in 2029.	High		



TABLE 6. Research questions for North/Mid WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research priorities				
Research topic 5.1: Review inland water principles				
Develop key ecohydrological principles which can be used to guide the assessment/ understanding of ecohydrological functioning in riparian ecosystems.	Improved knowledge of ephemeral arid zone drainage systems helps to clarify how water moves through the landscape. These systems are characterised by infrequent surface flows, rapid infiltration, and strong interactions with groundwater. A better understanding of these drainage systems contributes to optimising regional water balance assessments.	Top		
Research topic 5.2: Update guidance				
Develop a standardised set of definitions for key water-related terminology to use in the environmental impact assessment (EIA) process	Scientific consensus on key water-related terminology that can be used by regulators and proponents.	High		
Develop more specific technical sampling guidance with the help of adequately qualified specialists	Collaboration between regulators, proponents and experts can lead to more specific technical guidelines.	Top		



TABLE 7. Research questions for South WA ranked

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Focus area 1 — Water quality				
Enabling priorities				
Baseline water quality monitoring and reporting	Establish baseline monitoring (where gaps exist) as foundation to management and scientific analyses and reporting to communicate condition and trends.	High	Data collection	Data
Predictive models to assess the impacts of intensified and changing land use on future water quality	Intensified and changing land use, e.g. agricultural expansion and intensification can have significant impacts on water quality in the receiving environment. Predictive models are commonly used to assess these impacts.	Medium	Data collection	Data
Research priorities				
Research topic 1.1: Legacy issues				
Impact of metals and other contaminants from past land use on groundwater in the urban context	Study contamination trends over decades to assess legacy pollution dynamics, and understand how metals and other contaminants behave in different soil and water conditions.	Medium	Water extraction and discharge	Urban
Additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)	Research into additive future impacts of introduced persistent pollutants such as heavy metals, hydrocarbons, and industrial chemicals in combination with higher water temperatures due to a changing climate.	Top	Ecosystem functioning	
Cost-effectively stripping of contaminants out of water (phosphorus, PFAS, nitrogen)	Research into emerging technologies to destruct contaminants affecting freshwater quality in the environment.	Medium	Ecosystem functioning	
Improve water quality of drains/waterways	Invest in research to use alternative methods to improve water quality such as making use of aquifers or using Carter's Freshwater Mussels and/or other organisms.	Medium	Ecosystem functioning	
Research topic 1.2: Future impacts				
Risks of bushfires/prescribed burns to the quality of water in a waterway, wetland or drinking water catchment	Investigate the impacts of bushfires and prescribed burns on water quality in inland waters. Fire alters soil structure, increases erosion, and mobilises contaminants, leading to changes in hydrology and water chemistry.	Medium	Ecosystem functioning	
Monitoring of large natural catchments to detect and treat contaminants prior to them entering water bodies	Assess the best way to detect and monitor contaminants in large natural catchment areas to prevent contamination of water bodies.	Medium	Ecosystem functioning	
Focus area 2 — Water extraction and discharge				
Enabling priorities				
Regional groundwater models to assess cumulative impacts outside of mining/agriculture	Investigate the cumulative impacts of major water drawdowns for mining and other industries such as intensive agriculture (with the use of centre pivot irrigation).	High	Data collection	



TABLE 7. Research questions for South WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research priorities				
Research topic 2.2: Impacts on GDEs				
Impacts of water drawdown in groundwater dependent ecosystems (GDEs) to aquatic/freshwater species	Groundwater is used by industry, agriculture and for watering public open space and private gardens in urban areas. This alters groundwater levels, which has an impact on aquatic/freshwater species.	High	Ecosystem functioning	Data Urban
Impacts of water drawdown in groundwater dependent ecosystems (GDEs) to reeds, riparian vegetation and buffers	Groundwater is used by industry, agriculture and for watering public open space and private gardens in urban areas. This alters groundwater levels, which has an impact on reeds, riparian vegetation and buffers.	High	Ecosystem functioning	Data Urban
Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction	Quantifying the contribution of groundwater in maintaining refuge pools is essential to assess the impact of groundwater extraction on aquatic ecosystems. This will help to determine the quantity and timing of environmental surface water flows.	Top	Ecosystem functioning	
Research topic 2.3: Dewatering discharge				
Improved information/knowledge on the management of tailing storage facilities	Improved information and knowledge on the management of tailings storage facilities (TSFs) are critical for ensuring safety, environmental protection, and operational efficiency. By advancing knowledge in TSF management, industries can minimize risks, optimise resources, and build public and stakeholder trust.	Medium	Principles and guidance	
Focus area 3 — Ecosystem functioning				
Enabling priorities				
Local scale hydrological models to better understand functioning of wetlands from the Kimberley to the Arid zone to the South West, including urban wetlands	By providing high-resolution, site-specific data, local-scale hydrological models help to understand the functioning of wetlands, as they provide detailed insights into water movement, storage, and interactions with groundwater and surface water.	Medium	Data collection	Data Urban
Indigenous understanding, and cultural knowledge relevant to landscape function, erosion control, and dryland salinity mitigation	Identify ways to better integrate Indigenous knowledge into the Western way of water management knowledge. Further consultation is required and opportunities should be sought considering the upcoming bicentenary of proclamation of WA in 2029.	Medium	Principles and guidance	



TABLE 7. Research questions for South WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research priorities				
Research topic 3.1: Ecological water needs				
Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency	With a changing climate there is a need for increased knowledge how inland water systems reacts under today's climate, to predict how they will change in the future.	Top	Data collection	
Minimal environmental flows to maintain waterway values, function and processes	How to best determine the minimal environmental flows required for preserving waterway values, ecological functions, and natural processes in a changing climate.	Top	Data collection	
Impact of a drying climate on clay pans of the Swan Coastal Plain	Additional data are required to rethink whether more surface water should be diverted to these biodiversity assets.	High	Data collection	
Evaluate the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change	Understanding how aquatic ecosystems rely on different aquifer types is crucial for determining which ecosystems are most and least vulnerable to climate change-driven shifts in groundwater availability and helps to develop targeted strategies to protect vulnerable groundwater-dependent ecosystems.	High	Data collection	
Research topic 3.2: Aquatic ecosystem values				
Improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management	Building on historical knowledge to increase understanding on how salt lakes work and adapt to a changing climate and increasing development.	Medium	Principles and guidance	
Quantify the benefits of wetland buffers to restoring biodiversity and ecological values, carbon capture and help with flood mitigation	The use of natural infrastructure to act as buffers to absorb the energy of floods, wind and storms, rather than, or along with, engineering solutions. Maintaining and restoring coastal wetlands can also offer additional benefits for biodiversity, as well as for carbon capture and storage.	High	Principles and guidance	Economics
Create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations	Created waterbodies can provide significant biodiversity benefits when designed, managed, and regulated properly. Integrating them into licensing requirements helps to align long-term ecological sustainability with development.	Medium	Principles and guidance	
How cost effective is a specific intervention to save an inland water system from the impacts of climate change?	Assessment of the cost-effectiveness of a specific intervention aimed at protecting an inland water system from climate change impacts helps to balance financial feasibility with maximum ecological benefit, ensuring sustainable inland water system management for the future.	Medium	Principles and guidance	Economics
Quantify the economic value of healthy receiving environments	Quantifying the economic value of healthy receiving environments (e.g., rivers, wetlands, estuaries, and groundwater systems) is essential for making informed decisions about water management, conservation, and development. Understanding their economic value helps in balancing environmental protection with economic growth.	Medium	Principles and guidance	Economics

TABLE 7. Research questions for South WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Research topic 3.3: Threat mitigation				
Optimal revegetation of wetland buffers, considering wetland hydrology and climate resilience	What is the best way to revegetate wetland buffers, taking into consideration their location and ecosystem function.	High	Principles and guidance Data collection	
Lake Clifton — long-term impacts of salinisation on the lake hydrology and the thrombolites	The thrombolites at Lake Clifton are of great scientific importance because they contain the oldest evidence of life on Earth, as well as geologic timelines of past environments. More research is needed to understand the impact of salinisation and a changing climate on the structures.	Medium	Data collection	
Investigate the potential of inland groundwater desalination to restore natural waterways and mitigate dryland salinity	Inland groundwater desalination could present a viable tool for restoring degraded waterways and mitigating dryland salinity.	Medium	Water extraction and discharge	
What is the impact of restoration on the drawdown of water, particularly with the impacts of climate change	Restoration mitigates groundwater drawdown by improving infiltration, reducing runoff, and enhancing landscape water retention. As climate change intensifies water scarcity, integrating restoration into water management strategies can be an important tool for ensuring sustainable water availability.	Medium	Water extraction and discharge	Data Restoration
Develop effective techniques/strategies for recovering eutrophic wetlands, lakes, and estuaries influenced by nutrient recycling from bottom sediments	Many urban wetlands increasingly have toxic algal blooms in summer. These decimate food sources for birds and disrupt the life cycle of turtles, frogs, fish etc. How can we treat the water to remove phosphorus especially?	Medium	Principles and guidance	Data
Determine tolerance levels of local/native species to deteriorating water quality	What are the extinction thresholds of key species — what are the tipping points, interactions between salinity, pH, aeration, turbidity / light, water temperature etc, and toxicological elements.	High	Water quality	
Impact of invasive aquatic species on native aquatic ecosystems	Invasive species outcompete native species, alter habitats, and disrupt ecological balance. They can degrade water quality and decrease biodiversity. More research is needed on their impact and management.	Medium	Data collection	
Investigate population genetics across key aquatic invertebrate groups in the South West	Research to examine the genetic diversity and structure of key aquatic invertebrate populations in the South West. Identifying patterns of genetic connectivity and isolation will inform targeted conservation strategies to preserve biodiversity in freshwater ecosystems.	Medium	Data collection	
Effects of potential episodic rainfall events due to a changing climate to near shore environments – positive and negative	A changing climate may bring more frequent heavy rain events that bring big pulses of water. This can have both positive and negative consequences.	Medium	Data collection	



TABLE 7. Research questions for South WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Develop integrated management strategies for coastal aquifers facing tidal influences, seawater intrusion and groundwater depletion	Lower groundwater levels and higher sea-levels are leading to more tidal influences and seawater intrusion. How can we manage these changes?	High	Principles and guidance	
Investigate managed aquifer recharge to offset reduction in natural recharge as the South West gets hotter and drier	As climate change reduces natural groundwater recharge in South West WA, MAR could be used for sustaining water resources, protecting ecosystems, and enhancing climate resilience. How can MAR be integrated into regional water management strategies?	High	Water extraction and discharge	
Research topic 3.4: Ecosystem restoration				
Identify optimal approaches for improving landscape and catchment connectivity through targeted stream zone restoration	In South West WA, targeted stream zone restoration efforts focus on enhancing waterway health and biodiversity. What are the optimal approaches that provide the most sustainable and resilient outcomes?	High	Principles and guidance	Restoration
Assess effects of re-snagging rivers and drains on biodiversity and population connectivity	Assess whether re-snagging of rivers and drains has positive impacts on biodiversity, and what is the best way to undertake re-snagging?	Medium		
Impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems	The effects on downstream aquatic ecosystems depend on how effectively restoration mitigates mining-related disturbances. What are optimal post-closure restoration efforts to help rehabilitate waterways, improve water quality, and restore biodiversity?	Medium		Restoration
Utilise artificial pools to maintain native biodiversity (dams, created wetlands)	Many artificial waters attract and sustain life in much the same way as natural refuge pools. Investment into improving the quality and retention of water in these dams may bring benefits to water quality and to biodiversity on farms.	Medium		
Investigate saline water management in the Wheatbelt by comparing approaches such as modified (hybrid) ecosystems with those focusing solely on historic state	Investigate which management approach provides the most sustainable and resilient outcome for saline water management in the Wheatbelt.	Medium		Restoration
Review risk analysis systems for wetland and riparian ecosystem restoration: prioritising functional resilience (hybrid ecosystems) over historical state restoration	Investigate which restoration approach provides the most sustainable and resilient restoration approach for wetlands and riparian ecosystems.	Medium		Restoration Urban
Reuse of storm- and wastewater to restore Perth's urban landscape and maintain a green environment	There is increasing interest in reuse of seasonal stormwater, and year-round wastewater streams for non-potable use. How feasible is this?	High	Water extraction and discharge	Restoration Urban

TABLE 7. Research questions for South WA ranked (continued)

Knowledge gaps	Description	Priority	Linked focus area	Other WABSI programs
Focus area 4 — Data collection				
Enabling priorities				
Inventory of vulnerability and resilience of inland water systems to climate change and other threats (e.g. salinisation, eutrophication, siltation)	Develop and populate a database on up-to-date information with regards to inland water systems.	High	Ecosystem functioning	Data
Focus area 5 — Principles and guidance				
Enabling priorities				
Integrate input from Traditional Owners into the management of water	Identify ways to better integrate Indigenous knowledge into the western way of water management thinking and guidance. Further consultation is required and opportunities should be sought considering the upcoming bicentenary of proclamation of WA in 2029.	High	Ecosystem functioning	Data
Research priorities				
Research topic 5.1: Review inland water principles				
Develop key ecohydrological principles which can be used to guide the assessment/ understanding of ecohydrological functioning in riparian ecosystems	Scientific consensus on key ecohydrological principles that can be used by regulators and proponents.	High		
Research topic 5.2: Update guidance				
Develop a standardised set of definitions for key water-related terminology to use in the environmental impact assessment (EIA) process	Scientific consensus on key water-related terminology that can be used by regulators and proponents.	Medium		
Develop more specific technical sampling guidance with the help of adequately qualified specialists	Collaboration between regulators, proponents and experts can lead to more specific technical guidelines.	High		



Top 5 overall research questions

At the end of the survey, participants were asked to review all focus areas, research topics and their questions again. They were then asked to rank the overall top three research questions they felt were most urgent to be answered. Tables 8 and 9 below show the outcomes of the overall ranking exercise. The 'Ranking previous questions' column shows how participants ranked the urgency of each research question (high, medium, or low) earlier in the survey. Appendix 5 provides an overview of the ranking of urgency of all research questions for both North/Mid and South.

TABLE 8. Top 5 most urgent research questions North/Mid WA

Ranking question 19	Research question no.	Research question	Ranking previous questions
1	6.2.3.	Develop more specific technical sampling guidance with the help of adequately qualified specialists, e.g. sampling guidance for inland waters and different types of waterbodies, with the inclusion of sediments.	High
2	2.2.1.	What are the impacts of water drawdown in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts to reeds, riparian vegetation and buffers.	High
3	2.1.1.	What are the cumulative impacts of major water drawdowns for mining and agriculture? We need more regional groundwater models to assess impacts outside of where mining occurs.	High
4	6.1.1.	Develop key ecohydrological principles which can be used to guide the assessment/understanding of ecohydrological functioning in riparian ecosystems.	High
5	5.2.2.	There is a need for a Pilbara-wide freshwater pool inventory and wetland mapping to inform cumulative impact assessment.	High

TABLE 9. Top 5 most urgent research questions South WA

Ranking question 19	Research question no.	Research question	Ranking previous questions
1	3.1.2.	Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.	High
2	2.2.2.	Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.	High
3	3.1.3.	What are the minimal environmental flows needed to ensure waterway values, function and processes are maintained?	High
4	1.1.2.	What is the additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures).	Medium
5	2.1.1.	What are the cumulative impacts of major water drawdowns for mining and agriculture? We need more regional groundwater models to assess impacts outside of where mining occurs.	High

Additional issues raised after further stakeholder engagement

After the workshops and the analysis of the outcomes of the survey, WABSI undertook another round of consultation with 13 additional stakeholders to verify and confirm outcomes, refer to Figures 9 and 10. A list of stakeholders consulted can be found in Appendix 6.

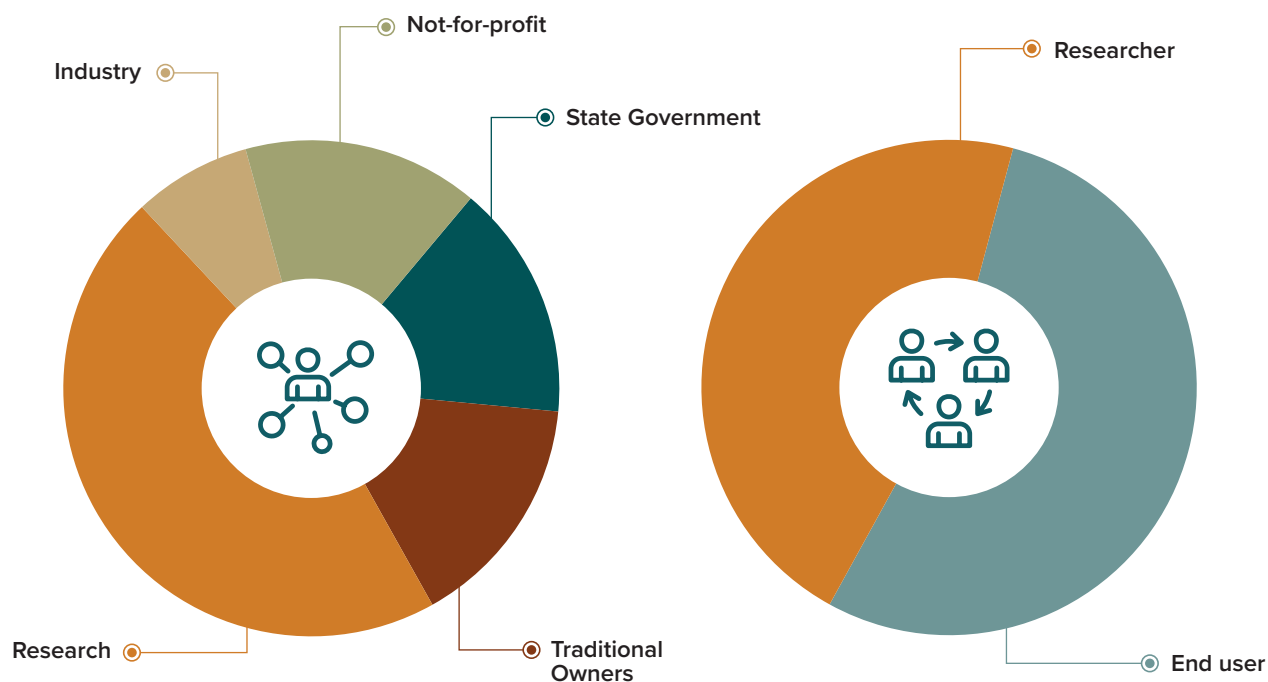


FIGURE 9. Post prioritisation workshops engagement by sector

FIGURE 10. Post workshop engagement — end users and researchers



Several additional issues were raised during these engagement sessions, including:

- **Climate change**

Climate change underpins all aspects of the system, but there is a need to distinguish between the drivers in northern and southern WA. Understanding these regional differences is crucial and climate modelling (which is already being undertaken) will be an input to understand current and future impact.

- **Baseline understanding**

There is a need to agree on a defined environmental baseline, potentially spanning back 100 to 1,000 years. This includes understanding natural variability within a historical context and assessing how future climate conditions might impact ecosystems. 'Climate baselining' — examining past climates — will help identify how far current conditions have shifted and improve the ability to respond to future impacts.

- **Use of advanced tools and technology**

Emphasise the use of advanced techniques such as isotopic analysis, geophysics, and environmental DNA (eDNA) to enhance measurement and monitoring capabilities.

- **Traditional Owner knowledge and collaboration**

Research should integrate Traditional Owner knowledge respectfully and effectively. This includes:

- Developing culturally appropriate guidelines for conducting research on Traditional Owner Country.
- Ensuring research outcomes are interpreted with cultural sensitivity.
- Including funding provisions to allow time on-Country for mutual benefit and deeper understanding through Healthy Country planning.
- Capturing Traditional Owner knowledge, identifying what empowers Indigenous rangers to maintain and revitalise wetland practices, and defining values, actions, and priorities from an Indigenous perspective.

It was suggested that like 'climate change', 'Traditional Owner knowledge' should be included as an overarching theme to ensure both Indigenous and western knowledge systems are integrated into the development of research projects.

- **Expert advisory panel**

Establish a regulatory expert panel to provide real-time, holistic guidance on emerging issues, challenges, and needs during research processes and the environmental impact assessment procedure. This panel would offer advice without engaging in formal decision-making.

- **Wetland decision-making framework**

Develop a framework for assessing cumulative impacts on wetlands, like the existing frameworks for urban stormwater management. The focus should begin with the wetland ecosystem itself, rather than only evaluating the effects of surrounding land use changes.

This topic was also raised in WABSI's [Building biodiversity for thriving urban ecosystems](#). Dropping groundwater levels, reduced streamflow and increased development are threatening the health and existence Perth's urban wetlands (Mennen 2023).



- **Managing modified ecosystems**

Recognise that some ecosystems, such as those in the Wheatbelt, cannot be fully restored to their original state. Instead, focus on creating new aquatic values and parallel systems that fit the modified environment. This approach can drive nature-positive and carbon initiatives by exploring what can realistically thrive under current conditions.



8.

RESEARCH PROGRAM FRAMEWORK AND DETAILS

Stakeholder engagement during the Inland Waters Research Program development helped to build a framework for research priorities for WA's inland waters.

The WABSI Inland Waters biodiversity resilience research framework covers critical gaps in knowledge about Inland Waters as highlighted by end users. Within each theme, research focus areas and associated knowledge gaps are identified.



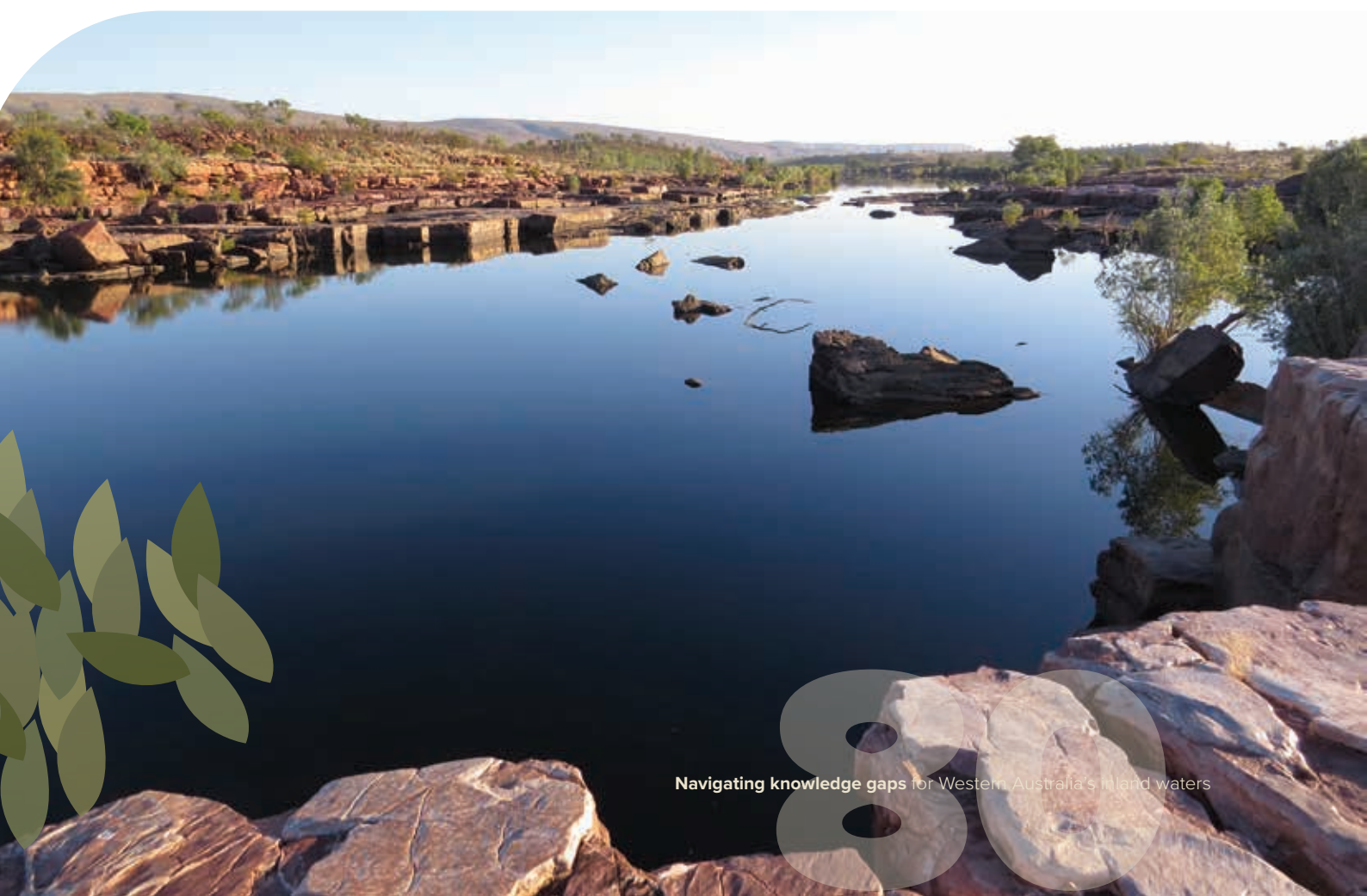


FIGURE 11. The WABSI framework to address knowledge gaps in inland waters research



TABLE 10. Themes, goals and timing for WA's Inland Waters biodiversity resilience research framework

Theme	Climate change					
	Traditional Owner knowledge					
	Mitigate	Restore	Monitor	Forecast	Equip	Value
Focus area	Impact reduction	Adaptive management solutions	Land use impacts	Data-informed predictive modelling	Enhanced data and information supply chain	Intrinsic value
	Climate change resilience	Novel Solutions	Threats to nature		Clear and holistic guidance	Instrumental value
Goal	Reduce or offset harm	Repair and regenerate ecosystems	Track changes and assess outcomes	Predict future challenges or opportunities	Provide necessary tools and resources	Assign worth or importance
Timing	Proactive or concurrent with impact	Reactive, after damage has occurred	Continuous, during and after actions	Proactive, before impacts occur	Ongoing, depending on needs	Proactive or concurrent with impact
Focus	Impact reduction and compensation	Ecological recovery	Data collection and evaluation	Anticipating risks and informing actions	Empowering conservation efforts	Recognition of biodiversity's multifaceted benefits



Overarching themes

WABSI's Inland Waters research framework comprises of two overarching themes and six individual themes. Feedback from end users confirmed that 'Climate change' and 'Traditional Owner knowledge' are integral across all themes and that it would be impractical to separate them from the individual themes given their relevance across all or most of them.

Climate change

Climate change is a crucial overarching theme because it fundamentally reshapes the hydrological patterns and ecological dynamics of inland water systems. Rising temperatures, shifting rainfall patterns, increased evaporation, and more frequent extreme weather events directly impact the quantity, quality, and reliability of surface water and groundwater resources. These changes can exacerbate existing environmental pressures, reduce the resilience of ecosystems, and complicate efforts to manage and restore water systems.

Seasonal regimes in terrestrial, freshwater, and marine realms are rapidly altering because of a changing climate, thereby disrupting the natural rhythm of ecological processes. Seasonality is so fundamental to ecosystems that these shifts are affecting natural systems at different levels, from the genetic structure of populations to whole ecosystem functions. These connections reveal unexplored pathways through which changes in seasonality could affect biodiversity (Hernández-Carrasco et al. 2025).

Research increasingly recognises that climate change and biodiversity loss are intertwined. Climate change will affect the efficacy of protected areas, as species move to track shifting climate niches. Climate-smart conservation planning could be improved by integrating approaches across spatial scales, promoting transboundary conservation planning, and exchanging ideas across realms (Buenafe et al. 2025).

Integrating climate change into all research themes and mainstreaming the effect of climate change more broadly into the development of research projects would ensure more holistic consideration of climate change and ensures that its impacts on current conditions and future outcomes are a primary consideration from the outset.

Traditional Owner knowledge

Aboriginal and Torres Strait Islander peoples are key custodians of land and sea Country across Australia. Country refers to the land, waterways, and sky to which Traditional Owners are deeply connected through laws, customs, language, spiritual beliefs, ancestral ties, and cultural practices.

Traditional Owner knowledge is recognised as an essential and enriching theme that spans all individual themes. This knowledge offers deep insights into the values, rhythms, and sustainable management of inland water systems. It includes cultural, spiritual, and ecological understandings that are often overlooked in conventional scientific frameworks. Integrating Traditional Owner knowledge across all research themes ensures that water management is not only scientifically robust but also culturally respectful and inclusive.

While Traditional Owner knowledge and guidance are invaluable, especially when research is planned on their Country, meaningful involvement requires time, trust, and respectful engagement. It is essential that Traditional Owners are involved from the earliest stages of project development, so that their values, priorities, and cultural knowledge can shape the research alongside western scientific approaches (Moro et al. 2024). This ensures the work is grounded in local context, is culturally appropriate, and honours the deep and ongoing connection Traditional Owners have with inland waters.



THEME 1

Mitigate

Rationale

This theme recognises the need to reduce anthropogenic impacts to protect aquatic ecosystems. WA's inland waters are increasingly threatened by cumulative impacts such as land clearing, water extraction, pollution, a changing climate and infrastructure development. To limit direct human-induced harm and enhance the capacity of freshwater ecosystems to withstand and adapt to changing environmental conditions, targeted research can inform on-ground actions that aim to mitigate these impacts and build resilient inland waters.

Mitigate	Reduce or offset harm	Proactive or concurrent with impact	Impact reduction and compensation
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Credit: Megan Hele



FOCUS AREA 1 – Impact reduction

End users expressed concern about the impact of contaminants, particularly on groundwater and surface water in urban areas. Research suggests that the quality of surface water may be affected by the release of legacy solutes, such as nutrients, as well as new sources associated with urban land use (Barron et al. 2013). There is also renewed concern about the presence of PFAS (Per- and poly-fluoroalkyl substances) from firefighting foam which has contaminated some groundwater supplies, particularly around air force bases.

To actively improve water quality and reduce ongoing degradation, interventions such as desilting or desludging are undertaken, and introducing regenerative aquaculture species are being trailed. The concept of using filter feeding shellfish for nutrient removal directly from the water is gaining momentum (Bricker et al. 2018). In the South West of WA Carter’s Freshwater Mussel (*Westralunio carteri*) are important components of freshwater ecosystems as they can act as ecosystem engineers and improve water quality through filtration (Beatty et al. 2017).

The drying climate, particularly in the South West of WA, is a significant factor in increasing the risk of bushfires. Fires can pose a complex threat to water quality by introducing a range of contaminants, altering water chemistry and increasing erosion and sedimentation (Australian Government 2025).

With regards to the mining industry, tailings storage facilities (TSFs) were mentioned as a potential risk to water quality. More research into best-practice management of these facilities can help inform better guidance to prevent the uncontrolled release of waste material into the environment (Mills 2022).

Outcome	Objective	Knowledge gaps	Ranking
Past, present and future anthropogenic harm to inland waters is actively reduced	Understand the specific drivers of degradation (e.g. altered flows, pollution, habitat fragmentation) in different catchments	Impact of metals and other contaminants from past land use on groundwater in the urban context	Medium
		Additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)	Top 5 South
		Improve water quality of drains/ waterways/lakes (desilting/desludging natural and built waterways and using regenerative aquaculture)	Medium
		How to mitigate the risks of bushfires/ prescribed burns to the quality of water in a waterway, wetland or drinking water catchment	Medium
		How to reduce the environmental impact of future salt mining by learning from the past	Low
		Improved information/knowledge on the management of tailing storage facilities	Medium

FOCUS AREA 2 – Climate change resilience

WA, particularly the South West, is becoming hotter and drier. Annual rainfall in the lower part of the South West has decreased by up to 20 per cent since the 1970s and is projected to decline further. Annual temperatures have increased by more than 1°C since the start of the 20th century (DPIRD 2023).

Over the last 60 years, annual rainfall has increased over northern and interior WA. Five of the 10 wettest years in the last 210 years occurred in the last two decades. In addition to increased annual rainfall, the seasonality (that is, the difference between rainfall amount in the driest and wettest periods) has also increased in northern WA. The Pilbara region has a highly variable climate, with rain largely from unpredictable thunderstorms and tropical cyclones in summer (Charles et al. 2015).

Hydroclimate volatility—marked by abrupt transitions between extreme dryness and intense rainfall—has intensified in recent years and is projected to increase further with global warming. This growing instability heightens the risk of hazards such as flash floods and wildfires (Swain et al. 2025). WA's nearshore environments are facing increased stress from episodic rainfall events; a change linked to climate change. While the overall trend is toward less rainfall, particularly in the South West, heavy rainfall events are becoming more intense and can disrupt coastal ecosystems (BOM and CSIRO 2024). In the Wheatbelt, increasingly unpredictable water availability threatens the health of saline waterways and wetlands. Over recent decades, aquatic organisms in the region have adapted their life cycles to cope with seasonal changes in salinity and dry periods (DoE, 2005). However, these adaptations may be at risk as climate conditions become more unpredictable.

In 2024, Perth experienced its driest six months on record. Long hot and dry periods are expected to become more common as a result of the warming climate. These prolonged periods of droughts are taking their toll on freshwater ecosystems and species in the biodiversity hotspot of Southwest WA. Species in the region may struggle to adapt to rapid climate change due to a history of relative climate stability (Buckley et al. 2024).

Impacts of unusually hot and dry summers can be seen across inland water systems across the South West of WA. Changes to the natural hydrology of the claypans of the Swan Coastal Plain are a significant threat to ecological communities, as the vegetation suite is dependent on the wetlands filling and drying at appropriate times of the year. In the face of a drying climate, the winter-spring inundation that the clay pan community is dependent on is likely to be significantly reduced (DCCEE 2012).

Outcome	Objective	Knowledge gaps	Ranking
Reducing or preventing future climate change impacts on groundwater and surface waters	Identify and quantify climate-sensitive pressures on groundwater and surface water systems	Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency	Top 5 South
		Minimal environmental flows to maintain waterway values, function and processes	Top 5 South
	Prioritise water protection actions under projected climate impacts	Evaluate the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change.	High
		Impact of a drying climate on clay pans of the Swan Coastal Plain	High
		Mitigate the effects of potential episodic rainfall events due to a changing climate on salt lake systems	Medium
		Mitigate the effects of potential episodic rainfall events due to a changing climate to near shore environments	Medium

THEME 2

Restore

Rationale

Ecological restoration seeks to repair and regenerate degraded inland water ecosystems, aiming to recover vital ecological functions and biodiversity. Degradation of aquatic ecosystems disrupts fundamental processes such as nutrient cycling, primary production, and food web dynamics, resulting in habitat loss and threatening species survival, e.g. the endangered western swamp tortoise (DCCEEW 2023). Wetlands and riparian vegetation naturally filter water by trapping sediments, nutrients, and pollutants; their degradation threatens this crucial function, leading to poor water quality in various water bodies (DWER 2023). Restoration aims to reinstate these essential functions, fostering healthier and more resilient inland water ecosystems.

WABSI has published a roadmap towards a sustainable restoration industry: [The Western Australian Restoration Economy](#) (Young et al. 2023) and a prioritised research program has been released: [Scaling up the Western Australian Restoration Economy](#) (Young 2025). Research questions about carbon capture and offsets, and ecosourcing will be an integral part of this WABSI research program.

Restore	Repair and regenerate ecosystems	Reactive, after damage has occurred	Ecological recovery
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Credit: Lisa Mazzella



FOCUS AREA 3 – Adaptive management solutions

Restoring inland waters in WA requires approaches that are responsive to dynamic environmental conditions, changing land uses, and climate change. Since most aquatic ecosystems are already altered to varying degrees, restoration decisions should be based on the extent of that change. In highly modified systems, interventions should focus on current ecosystem values—such as their capacity to provide functions, services, and conservation outcomes—while considering the full range of restoration options beyond traditional methods. Recognising the presence of novel ecosystems need not undermine existing policy or management; instead, it offers an opportunity to develop integrated, flexible restoration strategies that align with the reality of rapid ecosystem change (Hobbs et al. 2014).

Outcome	Objective	Knowledge gaps	Ranking
Restored inland waters provide critical habitat and food resources, enhanced ecological connectivity plus healthier waters and soils	Develop adaptive restoration strategies that enhance the ecological function of inland waters under current and future climate and land use conditions Identify and prioritise restoration sites where interventions will maximise habitat quality, biodiversity support, and connectivity across the landscape Investigate nature-based and hybrid approaches for their ability to restore ecosystem services	What is the best way to revegetate wetland buffers, considering wetland hydrology and resilience of plantings to a hotter climate?	High
		Effective techniques/strategies for recovering eutrophic wetlands, lakes, and estuaries influenced by nutrient recycling from bottom sediments	Medium
		How to develop integrated management strategies for coastal aquifers facing tidal influences, seawater intrusion and groundwater depletion	High
		How to best improve connectivity through the landscape/catchment by undertaking stream zone restoration?	High
		How to rethink and guide restoration strategies and priorities for wetlands and riparian ecosystems - shift from restoring ecosystems to their historical state toward restoring them for functional resilience in a changing climate	High
		How to rethink and guide restoration strategies and priorities for saline water management in the Wheatbelt - shift from restoring ecosystems to their historical state toward restoring them for functional resilience in a changing climate	Medium
		Develop and evaluate adaptation strategies to increase aquatic ecosystems resilience to the growing frequency and severity of hot droughts under climate change	No ranking – raised after prioritisation workshop

FOCUS AREA 4 – Novel solutions

In a rapidly changing environment novel solutions for adaptive management of inland waters in WA could explore innovative technical and nature-based approaches to address hydrological degradation and support ecosystem recovery. In the South West enhancing woody habitats, called ‘snags’ can provide a source of shade, shelter, food and a place to rest out of the water for aquatic fauna (Ozfish 2024).

In the North, solutions include improving the management of dewatering discharges from mining and other developments to reduce ecological harm, as well as advancing managed aquifer recharge (MAR) techniques to reinject treated water and stabilise groundwater systems.

In Perth and the South West, the reuse of storm- and wastewater poses a challenge but could be considered in the longer term (Water Corporation 2025). Injecting this water underground could help maintaining Perth green and cool in summer. The impact of climate change and management on recharge to the unconfined aquifer under Perth is complex and requires a good understanding of trends, processes, consequences and interactions. Increasing water supply through managed aquifer recharge could prevent Perth becoming a browner, hotter and drier city than it needs to be (McFarlane et al. 2025).

In the Wheatbelt, trials are being undertaken with inland groundwater desalination, which has the potential to reduce salinity pressures and contribute to the restoration of natural flow regimes and wetland health (DPIRD 2024). These technical solutions represent a shift toward more adaptive, engineered responses that complement nature-based restoration.

Research is progressing to develop more economical and environmentally friendly solutions to remove contaminants such as PFAS from groundwater. The widespread presence of PFAS in the environment is a result of their unique properties, which have led to them being widely used for many decades. PFAS are persistent and highly resistant to physical, chemical and biological degradation, and addressing the wide range of issues associated with PFAS contamination, including the management of PFAS-contaminated material, represents a challenge for environmental regulators (HEPA 2025).

New technology approaches open the door to doing research differently. Opportunities such as the use of environmental DNA (eDNA), isotopes and geophysics for environmental monitoring and management include detecting pest species, detecting rare and threatened species, providing data on multiple species to characterise ecosystems and detecting changes in environmental condition (de Brauer and Berry 2025).

Environmental DNA (eDNA) metabarcoding is being increasingly used as a tool for rapid biodiversity assessments across a wide range of ecosystems. A recent New South Wales study demonstrates the potential for eDNA to be incorporated into waterbird monitoring programmes (Davis et al. 2025). In WA the Living waters of Western Australia (LiWA) project aims to enhance the ability to monitor wetland health in WA using DNA-based survey methods (Curtin University 2024).



Outcome	Objective	Knowledge gaps	Ranking
Novel solutions (both nature-based and human-engineered) contribute to restoring degraded ecosystem in the face of ongoing ecological transformation	Identify, test and implement innovative nature-based and human-engineered restoration approaches that enhance the ecological function, resilience, and connectivity of degraded inland waters, particularly in landscapes undergoing rapid environmental and climatic change	Better practice and novel solutions to improve dewatering discharging and reinjecting to the receiving environment	High
		Investigate the potential of inland groundwater desalination to restore natural waterways and mitigate dryland salinity	Medium
		Investigate managed aquifer recharge to offset reduction in natural recharge as the South West gets hotter and drier	High
		Assess effects of re-snagging rivers and drains on biodiversity and population connectivity	Medium
		Utilise artificial pools to maintain native biodiversity (dams, created wetlands)	Medium
		Reuse of storm- and wastewater to restore Perth's urban landscape and maintain a green environment	High
		Cost-effectively stripping of contaminants out of water (phosphorus, PFAS, nitrogen)	Medium
		What are the frontiers of new technology and how can they be applied (isotopes, geophysics, eDNA)?	No ranking – raised after prioritisation workshop



THEME 3

Monitor

Rationale

Monitoring over time is essential to understanding how land use changes are affecting the condition and biodiversity of WA's inland waters. Expanding agriculture, mining, urban development, and infrastructure projects are altering hydrological regimes, degrading water quality, and fragmenting habitats. By establishing baseline conditions and tracking changes over time, monitoring can support evidence-based decisions to reduce ecological degradation, guide restoration efforts, and ensure that land use planning considers the needs of freshwater ecosystems.

Collecting consistent, long-term data to detect trends, identify emerging risks, and inform management responses will lead to more efficient water usage, the preservation of aquatic biodiversity, and the protection of the diverse ecological, social, cultural, and economic values that these inland waters provide.

Monitor	Track changes and assess outcomes	Continuous, during and after actions	Data collection and evaluation
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FOCUS AREA 5 – Land use impacts

When monitoring water quality over time, research suggests that water quality trends are largely attributable to changes in catchment processes and conditions, due to factors such as land use/land cover changes, human activities and management interventions (Guo et al. 2025).

In the South West of WA dryland salinity has contributed to the degradation of land and water because of the abundant clearing of deep-rooted endemic woodlands to accommodate predominately cereal and pasture-based farming systems (Caccetta et al. 2022).

How to mitigate the impact of mining on the receiving environment is another area of interest as mining can disrupt geochemical stability of land and water, flows of surface and groundwater, and water quality (Mills 2022). For example, new mining pit lakes can positively contribute to regional ecological values (van Etten et al. 2014), however good monitoring and management interventions are necessary to reduce impacts on downstream aquatic ecosystems.

Ecological thinning, a targeted reduction in tree density to restore a more natural forest structure, can have important long-term benefits for forest health and environmental flows. Researchers have found that streamflow increases with a reduction of forest cover (through deforestation or thinning) and decreases with reforestation and reduced rainfall. Stream salinity increases with deforestation and decreases with reforestation (Harper et al. 2019).

The transition to renewable energy sources is a critical component of efforts to mitigate climate change and promote sustainable development. However, it has a multifaceted impact on aquatic ecosystems, influenced by the type of technology, geographic location, and implementation practices. Studies from different regions have consistently shown that hydro-electric dams and on and offshore wind farms and concentrated solar power systems have the potential to lead to habitat fragmentation, disrupting the natural flow of rivers and impeding the migration of aquatic species. This emphasises the need for integrated planning, environmental assessments, and the implementation of best practice (Baranovskaya and Fursov 2025).

Outcome	Objective	Knowledge gaps	Ranking
High-quality monitoring over time protects the resilience of inland water systems	Collect consistent, long-term data Establish baseline conditions and tracking land use changes over time	Monitoring of large natural catchments to detect and treat contaminants prior to them entering water bodies	Medium
		Lake Clifton – long-term impacts of salinisation on the lake hydrology and the thrombolites	Medium
		Impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems	Medium
		What is the impact of restoration on the drawdown of water, particularly with the impacts of climate change	Medium
		Effects of ecological thinning on long-term forest health and possible environmental flows	No ranking – raised after prioritisation workshop
		What are the ecological consequences and mitigation strategies associated with renewable energy deployment	No ranking – raised after prioritisation workshop





FOCUS AREA 6 – Threats to nature

Groundwater-dependent ecosystems (GDEs) require access to groundwater to maintain their current composition and functioning. Removal of groundwater from these ecosystems, or a change in the timing, quantity, quality or distribution of groundwater may influence these ecosystems by, for example, changing the availability of water for transpiration by vegetation and the recruitment of seedlings into the adult population. This generally results in changes in associated fauna assemblages (Murray et al. 2003).

It is increasingly acknowledged that groundwater is of great importance in the context of prolonged drought conditions and climatic change (Glanville et al. 2023). For example, the presence of the permanent pools at Millstream wetlands in WA’s Pilbara has created refuges for water-dependent flora, uncommon in arid parts of the Pilbara, and subsequently species with a high degree of endemism have evolved (Yindjibarndi Aboriginal Corporation 2024). Increased understanding of the contribution of groundwater to these GDEs and the impacts of groundwater extraction can be vital when these pools are increasingly relied on as refuge pools.

Potential synergistic effects of climate change and pollution highlight the need for multiple stress approaches to better predict the impacts of human activities on inland waters and its aquatic fauna (Jacquin et al. 2019). Diverse threats such as deteriorating water quality, the impact of invasive species and the consequences of grazing cattle close to water sources all contribute to deteriorating aquatic ecosystem health. Livestock grazing in proximity of a waterway can be effective at reducing exotic vegetation cover, but this is at the cost of native vegetation and ground condition (Jones et al. 2022).

Outcome	Objective	Knowledge gaps	Ranking
High-quality monitoring over time protects water-dependent biodiversity	Collect consistent, long-term data	Impacts of water drawdown in groundwater dependent ecosystems (GDEs)	Top 5 North/Mid
	Establish baseline conditions and tracking threats to nature over time	Impacts of water drawdown in groundwater dependent ecosystems (GDEs) to reeds, riparian vegetation and buffers	Top 5 North/Mid
		Impact of long-term surplus water discharge specifically on riparian rooting patterns and more general on ecosystem resilience and future restoration efforts	Medium
		Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction	Top 5 South
		Determine tolerance levels of local/ native species to deteriorating water quality	High
		Impact of invasive aquatic species on native aquatic ecosystems	High
		Impact of grazing cattle on native aquatic ecosystems	No ranking – raised after prioritisation workshop

THEME 4

Forecast

Rationale

Aquatic ecosystems are dynamic and shaped by a range of factors, including weather patterns, water extraction, pollution, nutrient runoff, and climate change.

Regions undergoing significant industrial and agricultural development face multiple pressures on ecosystem health. For example, the Pilbara region is experiencing cumulative impacts from mining operations, including mine dewatering and water discharge. Additionally, infrastructure developments like roads and railways are altering the landscape. Climate change further complicates efforts to assess and predict these cumulative effects on aquatic biodiversity in the region and beyond.

Predictive models that use historical and real-time data can help forecast future conditions—such as water quality, water availability, and the impacts on flora and fauna.

Forecast	Predict future challenges or opportunities	Proactive, before impact occurs	Anticipating risks and informing actions
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Credit: Megan Hele



FOCUS AREA 7 – Data-informed predictive modelling

The key to informed and adaptable environmental decision-making lies in fostering a continuous loop that integrates data collection, analysis, translation of insights into decisions, and finally, the implementation of management actions (Ncube and Ngulube 2024). Integrating data provides a means to apply knowledge to explain, explore, and predict environmental-system response to natural and human-induced stressors (Laniak et al. 2013).

Predictive models can identify potential threats at an early stage, and act as early warning systems, allowing for timely interventions to mitigate negative impacts before they become severe and costly to reverse, particularly when developing previously undisturbed land.

Modelling cumulative pressures allows for the projection of future scenarios, which helps to identify effective strategies for managing aquatic ecosystems. Incorporating a ‘no-intervention’ or baseline scenario in these assessments can help identify ecological tipping points—thresholds beyond which ecosystem degradation may become difficult or impossible to reverse.

Outcome	Objective	Knowledge gaps	Ranking
Improved capacity to anticipate and respond to environmental changes affecting inland water ecosystems	Quantify cumulative impacts of multiple pressures	Predictive models to assess the impacts of intensified and changing land use on future surface and groundwater quality	Medium
	Develop and refine predictive models that integrate historical, real-time, and spatial data	Groundwater modelling to assess interactions of climate factors, seasonal variability, and industry/agricultural development on GDEs and groundwater levels	High
	Identify ecological tipping points and thresholds	Regional groundwater modelling to evaluate cumulative impacts across areas beyond mining and agriculture	Top 5 North/Mid and South
	Enhanced decision-making frameworks	Local scale hydrological models to better understand functioning of wetlands from the Kimberley to the Arid zone to the South West	Medium
		Enhance understanding of ephemeral (seasonal) arid zone drainage systems to quantify the relative contributions of groundwater and surface water	High
		Assess and forecast the cumulative impacts of mining activities—such as mine dewatering, discharges, and linear infrastructure—on water inflows, water quality, and ecological function in the Pilbara	High
		Cumulative impacts of multiple stressors in the urban environment (climate change, pollution, decreasing groundwater levels) on ecological health of inland waters, and where to focus management efforts	No ranking – raised after prioritisation workshop
		Research to understand what would happen over time without any intervention, to serve as a baseline for comparison	No ranking – raised after prioritisation workshop

One of the knowledge gaps that emerged is *Improved local scale hydrological modelling to better understand the functioning of wetlands in WA*. WA has both nationally and internationally recognised wetlands of importance.

Twelve wetlands throughout the State are listed as Ramsar Wetlands of International Importance (DBCA 2025). The Ramsar Convention is an international intergovernmental treaty which was adopted in the Iranian city of Ramsar in 1971 and came into force in 1975. The broad aims of the Ramsar Convention are to halt and, where possible, reverse, the worldwide loss of wetlands and to conserve those that remain through wise use and management.

The Convention's mission is "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". This means ensuring that activities which might affect wetlands will not lead to the loss of biodiversity or diminish the many ecological, hydrological, cultural or social values of wetlands.

The wise use of wetlands is "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development." The wise use provisions of the Convention apply, as far as possible, to all wetland ecosystems (DSEWPC 2012).

Another 120 nationally important wetlands and wetland systems are listed in the *Directory of Important Wetlands in Australia*, which is a key part of the *Australian Wetlands Database*. All internationally and nationally important wetlands in Australia are listed on the *Australian Wetlands Database* (DBCA 2025).

Credit: Sonja Mennen

THEME 5

Equip

Rationale

To effectively support and manage resilient inland water ecosystems in WA, conservation managers, regulators and proponents require access to a comprehensive suite of tools and resources. There is a critical need for accessible baseline data on water quality and quantity across priority ecological areas in WA. Due to the sheer geographical scale of WA, coupled with its exceptional levels of endemism in both flora and fauna, a significant portion of its biodiversity remains undescribed and poorly understood (Chapman et al. 2009). Knowledge can be advanced through further investigating the distribution of endemic flora and fauna and by undertaking biological surveys and research into population genetics.

Ecosystem health monitoring and reporting needs to be developed in the context of an adaptive process that is clearly linked to identified values and objectives, is informed by rigorous science, guides management actions, is responsive to changing perceptions and values of stakeholders (Bunn et al. 2010). Accessible analytical tools and communication products, such as report cards, can help support the interpretation and sharing of complex water data with stakeholders.

Equip	Provide necessary tools and resources	Ongoing, depending on needs	Empowering conservation efforts
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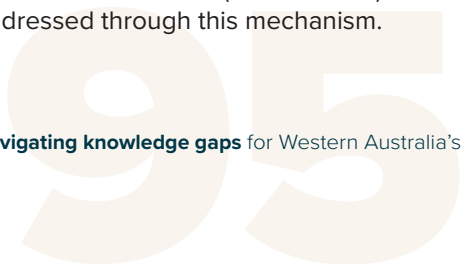
FOCUS AREA 8 – Enhanced data and information supply chain

Enhanced systematic data collection and monitoring programs across priority areas in WA can provide access to comprehensive baseline data. This will help to gain more insight of specific water requirements of many endemic species and the ecological processes that support them. It will also increase the capacity to detect and respond to emerging threats, such as pollution, climate change impacts on water regimes, and the spread of invasive species.

Extensive landscape fragmentation due to human activities has severely restricted the movement of many aquatic species. This isolation leads to increased interbreeding within fragmented populations, resulting in a loss of distinct genetic diversity, which can compromise their long-term survival and adaptive capacity (Frankham et al. 2017). Establishing comprehensive baseline data on water resources, and aquatic species is fundamental to addressing these challenges.

Conservation managers and regulators require timely and reliable access to up-to-date environmental data to effectively monitor, manage, and protect inland water ecosystems across diverse landscapes. Proponents undertaking environmental impact assessments (EIAs) and developing environmental management plans (EMPs) depend on the same quality data to ensure their proposals align with regulatory requirements and support sound environmental outcomes.

WABSI's *Biodiversity Data and Information Management research program* is developing the [Shared Environmental Analytics Facility \(SEAF\)](#), a mechanism for interpreting environmental data that has been developed in consultation with end users and stakeholders. It enables a trusted data and information supply chain that generates information products, like maps, reports and forecasting tools for use in research and decision making. Two pilot studies are undertaken, in the Pilbara and Cockburn Sound (WABSI 2025). Knowledge gaps that align with the SEAF initiative can be addressed through this mechanism.



Outcome	Objective	Knowledge gaps	Ranking
A reliable, accessible, and up-to-date data and information supply chain that enables timely, evidence-based decisions for the protection and management of inland waters	Improve availability and accessibility of inland water data	Better access to baseline water quality data for priority areas in WA	High
	Streamline data collection, integration, and sharing	Basic biological survey and systematics to describe distribution of flora and fauna – many species are still undescribed	No ranking – raised after prioritisation workshop
	Ensure data quality and relevance		
	Create accessible analytical tools and communication products	Investigate population genetics across key aquatic invertebrate groups in the South West	Medium
		Inventory of vulnerability and resilience of inland water systems to climate change and other threats (e.g. salinisation, eutrophication, siltation)	High
		A Pilbara-wide freshwater pool inventory and wetland mapping to inform cumulative impact assessment	Top 5 North/Mid
		Create a baseline understanding of pre-development hydrogeology of the Pilbara	High
		Enhance groundwater-surface water connectivity mapping through improved depth to groundwater data acquisition and integration	High
		How to best develop analytical products which provide easy access and interpretation of data (e.g. report cards)	No ranking – raised after prioritisation workshop

FOCUS AREA 9 – Clear and holistic guidance

WA's inland water ecosystems face significant threats from salinity, erosion, and the combined effects of land use, mining, and agriculture. To avoid fragmented and ineffective management, consistent, science-based frameworks that actively incorporate Indigenous knowledge are crucial. Establishing shared ecohydrological principles and clear definitions for water-related terms will ensure all stakeholders operate with a common understanding. Practical guidance, such as best-practice sampling methods, informed by robust science, is essential to support effective work in the field. Decision-making frameworks can act as a nexus between regulation and research and assist with the assessment of cumulative impacts of development, for example, for wetlands in urban areas.

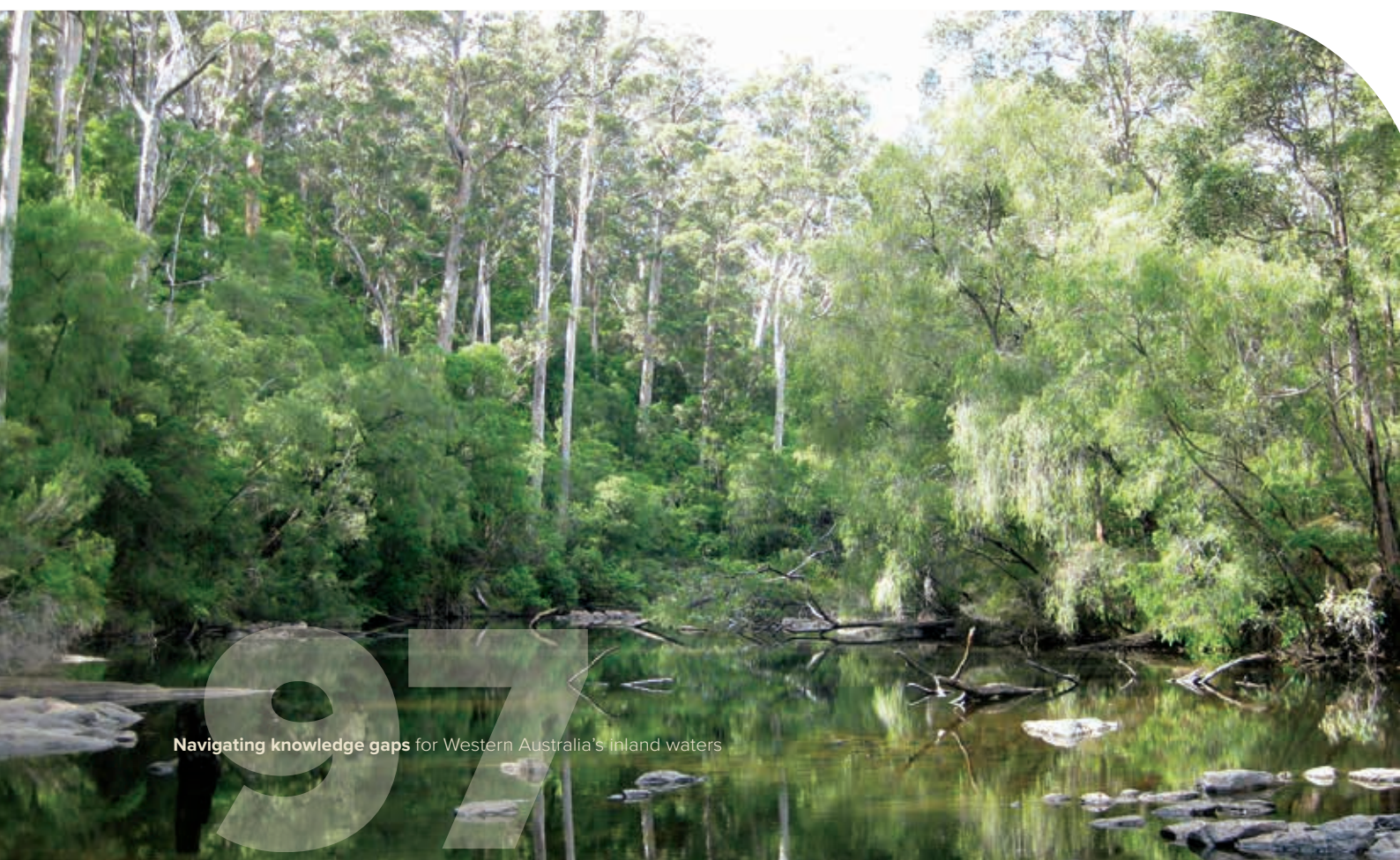
Incorporating the perspectives of Traditional Owners in water management offers valuable insights that complement western scientific knowledge. Indigenous communities possess a profound understanding and long-term observation of water and atmospheric processes, including climate shifts, water quality variations, and their interconnectedness within the hydrological cycle (Lopez-Maldonado et al. 2024).

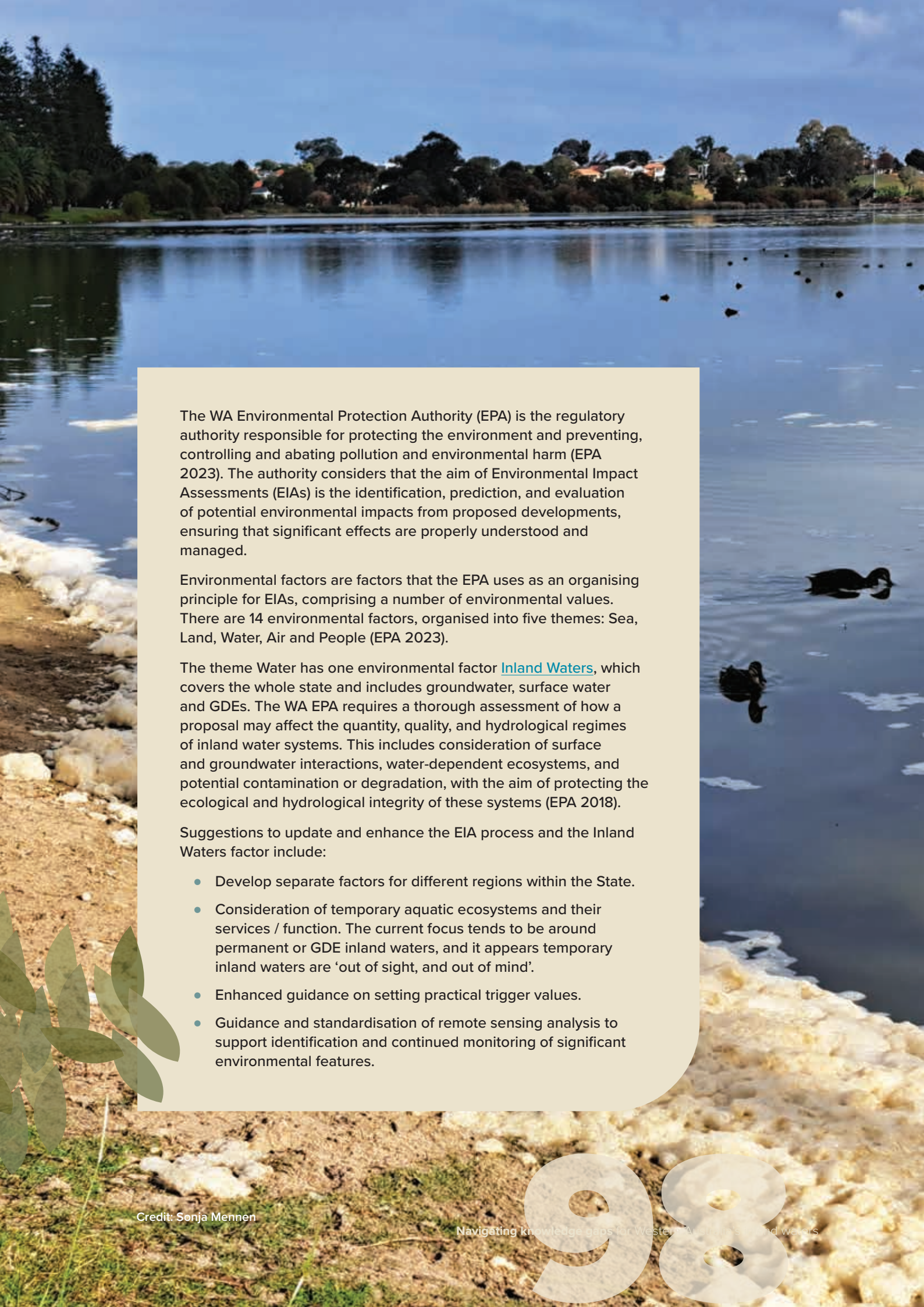


Outcome	Objective	Knowledge gaps	Ranking
Access to guidance that is informed by rigorous science, guides management and integrates both western and Indigenous knowledge	Develop and promote ecohydrological principles	How to best integrate input from Traditional Owners into the management of water	High
	Establish standardised terminology and technical guidance	Indigenous understanding, and cultural knowledge relevant to landscape function, erosion control, and dryland salinity mitigation	Medium
	Integrate Indigenous knowledge and cultural values	The need for cultural Traditional values to be integrated into assessments of water extraction	No ranking – raised after prioritisation workshop
		Develop key ecohydrological principles which can be used to guide the assessment/understanding of ecohydrological functioning in riparian ecosystems	Top 5 North/Mid
		Develop a standardised set of definitions for key water-related terminology to use in the environmental impact assessment (EIA) process	High
		Develop more specific technical sampling guidance with the help of adequately qualified specialists	Top 5 North/Mid
		Decision-making framework for wetlands to assess the cumulative impacts of development (similar to urban stormwater management framework)	No ranking – raised after prioritisation workshop



Credit: Sonja Mennen





The WA Environmental Protection Authority (EPA) is the regulatory authority responsible for protecting the environment and preventing, controlling and abating pollution and environmental harm (EPA 2023). The authority considers that the aim of Environmental Impact Assessments (EIAs) is the identification, prediction, and evaluation of potential environmental impacts from proposed developments, ensuring that significant effects are properly understood and managed.

Environmental factors are factors that the EPA uses as an organising principle for EIAs, comprising a number of environmental values. There are 14 environmental factors, organised into five themes: Sea, Land, Water, Air and People (EPA 2023).

The theme Water has one environmental factor [Inland Waters](#), which covers the whole state and includes groundwater, surface water and GDEs. The WA EPA requires a thorough assessment of how a proposal may affect the quantity, quality, and hydrological regimes of inland water systems. This includes consideration of surface and groundwater interactions, water-dependent ecosystems, and potential contamination or degradation, with the aim of protecting the ecological and hydrological integrity of these systems (EPA 2018).

Suggestions to update and enhance the EIA process and the Inland Waters factor include:

- Develop separate factors for different regions within the State.
- Consideration of temporary aquatic ecosystems and their services / function. The current focus tends to be around permanent or GDE inland waters, and it appears temporary inland waters are 'out of sight, and out of mind'.
- Enhanced guidance on setting practical trigger values.
- Guidance and standardisation of remote sensing analysis to support identification and continued monitoring of significant environmental features.

THEME 6

Value



Rationale

A better understanding of the extent of the value inland waters ecosystems provide in relation to native vegetation, groundwater, rivers and wetlands can help quantify the importance of WA’s natural aquatic resources. Once a value is attributed to an ecosystem service, investments can be directed towards protecting and conserving those areas that are most valued and will benefit most from targeted biodiversity enhancement.

Attributing value to WA’s aquatic ecosystems involves recognising both their intrinsic importance and their use or economic benefits plus applying diverse knowledge systems. This encounters various challenges within current legal and economic frameworks (Pandit and Thapa Magar 2024).

For Indigenous peoples, water and land are deeply interconnected living entities. Water is not merely a resource for trade or irrigation but holds cultural, spiritual, social, economic, and environmental values. These are seen as intrinsic to the water itself and the Country it sustains (DCCEEW 2023).

From a western economic perspective, aquatic ecosystems provide numerous services that have instrumental or material values contributing to human wellbeing and the economy. Natural capital, including aquatic elements, is considered vital to the Australian, and particularly the WA economy, especially for sectors like mining and agriculture (Pandit and Thapa Magar, 2024).

Research questions about how to understand, measure and value biodiversity and mechanisms to finance biodiversity conservation, and report on it, will be an integral part of a new WABSI research program, [Biodiversity Economics and Finance](#), which is under development.

Value	Assign worth or importance	Proactive or concurrent with impact	Recognition of biodiversity’s multifaceted benefits
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FOCUS AREA 10 – Intrinsic value

The idea that WA’s many inland waters have intrinsic value means that nature has value even if it does not directly or indirectly benefits humans. A deeper understanding of the environmental values and ecological tolerances of unique systems such as salt lakes is essential for developing effective regulatory and conservation strategies, that are tailored to their specific vulnerabilities. This includes building, documenting, and representing cultural values and Indigenous perspectives alongside western scientific knowledge.



Outcome	Objective	Knowledge gaps	Ranking
Recognition and integration of the intrinsic, cultural, and non-market values of inland waters into environmental management, planning, and policy	Build understanding and documentation of the intrinsic and cultural value	Improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management	Medium
	Demonstrate the ecological and societal importance of healthy inland water systems	The need to build, document, illustrate cultural value and health/condition of water alongside western scientific knowledge	No ranking – raised after prioritisation workshop
	Develop frameworks and tools to integrate non-market values		

FOCUS AREA 11 – Instrumental value

Understanding the economic value of healthy receiving environments—such as wetlands, rivers, and floodplains—can inform more strategic investment in conservation and restoration by making the benefits of ecosystem services like water filtration, carbon sequestration, and biodiversity protection visible in economic terms.

Quantifying the benefits of wetland and waterway buffers, and assessing the biodiversity value of artificial waterbodies, such as large private dams, can assist with the integration of these assets into regulatory systems and inclusion in land-use planning frameworks.

Evaluating the cost-effectiveness of targeted interventions to safeguard inland waters from climate impacts is crucial for prioritising actions that deliver the greatest ecological and social returns on investment.

Outcome	Objective	Knowledge gaps	Ranking
Enhanced recognition and application of the instrumental (use-based) values of inland waters—such as their contributions to ecosystem services, economic productivity, and climate resilience	Quantify the economic and ecosystem service benefits	Quantify the economic value of healthy receiving environments	High
	Assess the cost-effectiveness of management interventions	Quantify the benefits of wetland buffers to restoring biodiversity and ecological values, carbon capture and help with flood mitigation	High
	Evaluate the role of aquatic ecosystems in delivering tangible environmental and economic benefits	Create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations	Medium
	Develop tools and frameworks to integrate instrumental values	Define and regulate the critical needs of foreshore buffers (native vegetation protection areas) around wetlands and waterways	High
		How cost effective is a specific intervention to save an inland water system from the impacts of climate change?	Medium





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RESEARCH PROGRAM IMPLEMENTATION

Funding strategy

Due to the large scope of this research program a variety of funding models can be targeted. The research program is likely to involve a combination of short (one year), mid (five year) and long (>10 year) term projects, depending on the priority being addressed. Below is an overview of potential funding opportunities for inland waters research projects. This list is by no means exhaustive, but it shows the kind of opportunities that are available.

ARC Linkage Projects

The Australian Research Council (ARC) Linkage Projects scheme promotes collaboration and research partnerships between key end users in research and innovation including higher education institutions, government, business, industry and end users. Research and development are undertaken to apply advanced knowledge to problems, acquire new knowledge and as a basis for securing commercial and other benefits of research. The Linkage Projects scheme provides funding to eligible organisations (higher education institutions) to support research and development projects which are collaborative, are undertaken to acquire new knowledge and involve innovation. Proposals for funding under the Linkage Projects scheme must include at least one partner organisation. The partner organisation must contribute in cash and/or in-kind to the project. The combined (cash and in-kind) partner organisation contributions must at least match the total funding requested from the ARC. The Linkage Projects scheme provides project funding of A\$50,000 to A\$300,000 per year for two to five years.





CRC Project grants

The Australian Government provides funding for short-term industry-led research collaborations, with matched funding of between \$100,000 and \$3 million for up to three years. These grants are called CRC Project (P) grants. Funding rounds open yearly.

An eligible lead applicant must be a small/medium business. Project partners must include two Australian industry organisations and one Australian research organisation.

National Environmental Science Program (NESP)

The National Environmental Science Program Phase 2 (NESP2) provided A\$149 million between 2021 to 2027 of which A\$47 million has been allocated to the Resilient Landscapes Hub. This hub, led by Professor Michael Douglas of The University of Western Australia, will provide research to inform management of Australia's terrestrial and freshwater habitats to promote resilience, sustainability and productive practices.

Philanthropy and strategic alliances

Collaborative alliances with land managers linked to NGOs or philanthropic partnerships are an option for co-investing in complementary research. Not-for-profit groups such as the Australian Wildlife Conservancy and Bush Heritage Australia, Indigenous ranger groups, and the Centre for Invasive Species Solutions (CISS) all present well-aligned collaborative options in this regard.

Credit: Megan Hele (Inset left)

Navigating knowledge gaps for Western Australia's inland waters

Payment for ecosystem services

Payments for ecosystem services can occur when the beneficiaries or users of an ecosystem service make payments to the providers of that service, e.g. for planting trees or reintroduction of a species. In practice, this may take the form of a series of payments in return for receiving a flow of benefits or ecosystem services (Fripp 2014).

Impact investment

Impact investments are investments made into organisations, projects or funds with the intention of generating measurable social and environmental outcomes, alongside a financial return. Often made directly into an organisation or via a managed impact investment fund, they typically come in the form of a loan (debt) or a private stake in an entity (equity) and span different asset classes.

Impact investments are often directed towards on-ground projects but can also be used for research to develop innovative solutions, technologies, or practices to overcome key challenges.

Direct or pooled industry investment

Direct or pooled industry investment presents a significant opportunity to support inland waters research at scale in WA. Often able to be tailored to address immediate needs and be delivered in a timely manner, direct investment can offer a simpler path to overcome knowledge barriers. As industries are increasingly held accountable for their environmental footprints, these investments not only offer potential financial returns but also help companies align with sustainability goals, fulfill corporate social responsibility commitments, and contribute to biodiversity conservation.

The Community Stewardship Grants

The Community Stewardship Grants prioritise the direct involvement of local community groups in all project stages of design, planning and implementation, through which efficient and effective partnerships between government, industry, and community can be fostered.

Over the past seven years, \$53.2 million worth of Community Stewardship Grants have been issued. Collectively, the approved grants contribute to all six priorities of the WA NRM Framework 2018 and cover all nine development commission regions, some through multi-regional projects.

Lotterywest

Lotterywest funds environmentally focused projects of a range of size and duration that help understand and/or conserve the WA environment. Projects must be community focused, not-for-profit, end user led and involve a strong element of delivering on-ground outcomes. This funding structure is well suited to encourage stronger collaborations between community groups and researchers to undertake applied research and management programs.

NRM grants

State NRM grants as well as NRM group small grants can be used to fund components of research, usually embedded in a bigger management program primarily focused on delivering on-ground management outcomes.



Gunduwa Regional Conservation Association

The Gunduwa Regional Conservation Association (GRCA / Gunduwa) was formed in 2012 as a community-based incorporated association. Gunduwa supports individuals and groups to undertake biodiversity conservation and sustainability projects with demonstrable outcomes in the region (Parts of the Northern Avon Wheatbelt and Southern Yalgoo IBRA bioregions).

Healthy Estuaries WA

Launched in June 2020, Healthy Estuaries WA is a State Government funding program focused on improving the health of the Peel-Harvey Estuary, Leschenault Estuary, Vasse-Geographe waterways, Hardy Inlet, Wilson Inlet, Torbay Inlet and Oyster Harbour.

The Healthy Estuaries WA partnership supports community groups working to improve the health of seven of WA's most at-risk estuaries. Through funding rounds local groups and landholders are empowered to implement practical, evidence-based projects to reduce nutrient run-off and protect nearby waterways. The work is done in partnership with government agencies to ensure strong local involvement and tailored solutions for each region.

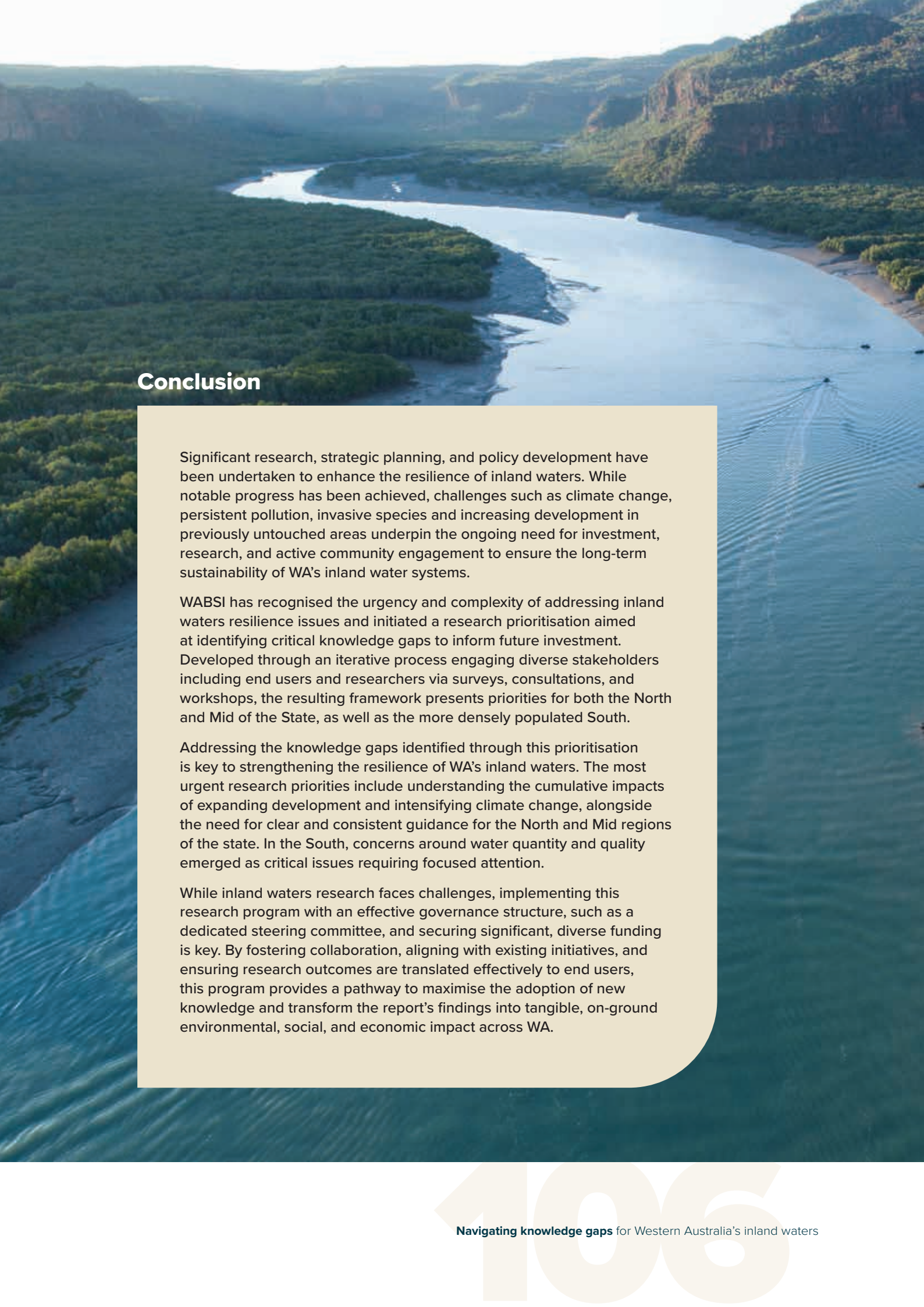
Governance

The successful delivery of this research program is dependent on an appropriate governance structure. The WABSI research program framework specifies that a steering committee be established to administer the program. Steering committees should comprise key stakeholders, researchers and at least one representative from the regulatory sector to ensure that outcomes are consistent with policy objectives. Following the WABSI approach will help ensure that this prioritised program is translated into research outputs and, in turn, on-ground outcomes. Whilst WABSI will provide project support, it is the independent steering committee that will facilitate prioritised research.

The primary role of the steering committee, guiding the implementation of the research program, would be to:

- Drive project development, ensuring projects are well integrated and aligned with the research prioritisation to achieve outcomes.
- Pursue relevant funding opportunities for prioritised projects.
- Assist in the scoping of projects and intended outcomes to meet the requirements of end users.
- Ensure the science being delivered is of a high standard without duplication of research effort.
- Ensure outcomes can be translated effectively to all knowledge end users to encourage adoption of research findings.
- Keep the research program plan on track, ensuring it is up to date and best reflects the current end user needs and research capability.
- Align activities to relevant state and Commonwealth objectives.





Conclusion

Significant research, strategic planning, and policy development have been undertaken to enhance the resilience of inland waters. While notable progress has been achieved, challenges such as climate change, persistent pollution, invasive species and increasing development in previously untouched areas underpin the ongoing need for investment, research, and active community engagement to ensure the long-term sustainability of WA's inland water systems.

WABSI has recognised the urgency and complexity of addressing inland waters resilience issues and initiated a research prioritisation aimed at identifying critical knowledge gaps to inform future investment. Developed through an iterative process engaging diverse stakeholders including end users and researchers via surveys, consultations, and workshops, the resulting framework presents priorities for both the North and Mid of the State, as well as the more densely populated South.

Addressing the knowledge gaps identified through this prioritisation is key to strengthening the resilience of WA's inland waters. The most urgent research priorities include understanding the cumulative impacts of expanding development and intensifying climate change, alongside the need for clear and consistent guidance for the North and Mid regions of the state. In the South, concerns around water quantity and quality emerged as critical issues requiring focused attention.

While inland waters research faces challenges, implementing this research program with an effective governance structure, such as a dedicated steering committee, and securing significant, diverse funding is key. By fostering collaboration, aligning with existing initiatives, and ensuring research outcomes are translated effectively to end users, this program provides a pathway to maximise the adoption of new knowledge and transform the report's findings into tangible, on-ground environmental, social, and economic impact across WA.



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Appendix 1.

Participants initial scoping sessions

Staff from end user and organisations and other experts that were consulted for the initial scoping sessions of WABSI's Inland Waters Research Program:

TABLE 11. Participants in initial scoping sessions

Organisation	Participants
Department of Water and Environmental Regulation	Lisa Mazzella, Romeny Lynch Adrian Goodreid, Tim Storer, Kelsey Hunt
Department of Primary Industries and Regional Development	Richard George, Renee Zuks
Department of Biodiversity, Conservation and Attractions	Adrian Pinder, Heidi Oswald, Fiona Felton, Jasmine Rutherford, Kerry Trayler, Michael Venarsky, Gavan McGrath
Murdoch University – Harry Butler Institute	Treena Burgess, John Ruprecht, Stephen Beatty, Peter Davies
BHP	Jennifer Carter, Suzi Wild
Fortescue	Damien Cancilla, Alan Puhlovich, Jane Humphrey, Michael Carroll, Anh Phu, Karen Fairweather
Rio Tinto	Dean Main, Jeremy Naaykens, Paul Hedley, Dilip Kumar Prankumar, Jason Rossendell, Michael Curran, Bianca Bertelli
EPA Services, Department of Water and Environmental Regulation	Hans Jacob
Water Corporation	Anthony Bodycoat
NatureLink Perth	Core Strategic Network
Alcoa	Lucy Commander, Karin Bankin
Stantec	Fiona Taukulis, Erin Thomas
Curtin University	Angus Lawrie
University of Western Australia	Don McFarlane
Geoscience Australia	Laura Gow, Stephen Hostetler, Zoe Thiele, Nadege Rollet, Prachi Dixon-Jain, Karol Czarnota



Appendix 2.



Issues initial scoping sessions

Table 12 provides an overview of the issues discussed by end users during the initial scoping sessions. The issues are grouped by regional area (Table 3) and one or several solution components for each issue have been suggested (Figure 4). The issues have been grouped into eight categories (Table 2).

TABLE 12. Issues that emerged (✓) from the initial scoping sessions categorised

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
North							
How to get better water quality data for priority areas in WA?	✓	✓	✓		✓		
Lack of groundwater monitoring – which areas need more monitoring bores, or can we use different methods?	✓			✓			
Impacts of water drawdown in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts on reeds, riparian vegetation, buffers.	✓		✓				
Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.	✓	✓	✓				
Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.		✓	✓		✓		
Understanding typical ephemeral arid zone drainage systems – determining the relative contribution of groundwater versus surface water.	✓	✓	✓				
How to employ techniques to allow surface water to infiltrate into the landscape and retain organic matter in soils so a previously disturbed landscape can be restored into profitable land?		✓	✓	✓			
Increase knowledge about water use for seed production and the early stages of restoration projects.		✓	✓				
Lack of regional groundwater models – to assess impacts outside of where mining occurs. What are the cumulative impacts of major water drawdowns for mining and center pivot agriculture?	✓		✓	✓		✓	

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TABLE 12. Issues that emerged (📍) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
North							
What are the cumulative impacts of mining on the Fortescue Marsh through changes of water inflows and water quality as a result of mine dewatering, discharges as well as linear infrastructure/rail corridors.		📍	📍				
Discharge of dewatering surplus water to the receiving environment needs innovative thinking about dewatering, discharging and reinjecting: how to do dewatering better – better practice and novel solutions.		📍	📍				
Climate factors, seasonal variability and proponents' impacts of dewatering - how are they interacting and what are the impacts on GDE and groundwater levels?	📍		📍	📍			
How to manage changing expectations of stakeholders (Native title holders/pastoralists) with regards to discharging water?		📍	📍	📍			📍
Reviewing the impacts of past salt Mining/industry and regeneration of areas (in light of new techniques for salt mining).	📍	📍	📍				
Improved information/knowledge on the management of tailing storage facilities.	📍	📍	📍	📍			
Impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems.	📍	📍	📍				
What is the influence of long-term surplus water discharge on riparian rooting changes and reductions in ecosystem resilience and restoration success.		📍	📍				
How to minimise the impact from development on Pilbara surface water flows?		📍	📍				
Need for a Pilbara-wide freshwater pool and wetland mapping inventory to inform cumulative impact assessment.		📍	📍	📍			
Need for a better regional surface water and groundwater measuring network.	📍	📍		📍		📍	
Create a baseline understanding of what groundwater in the Pilbara was like before development.	📍		📍				

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TABLE 12. Issues that emerged (✓) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
Mid							
Effect of episodic rainfall events on salt lake systems. Changes in frequency of floodwaters leads to dilution of brine which could impact biodiversity.		✓	✓		✓		
Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.		✓	✓				
What is the efficacy and economic viability of Landscape Rehydration to remediate land degraded by vegetation decline, erosion, waterlogging and dryland salinity.	✓	✓	✓				
Can inland groundwater desalination play a role in restoring natural waterways, and reducing dryland salinity?	✓	✓	✓	✓			
Reviewing the impacts of past salt mining and regeneration of areas (in light of new techniques for salt mining).	✓	✓	✓				
Need for a better regional surface water and groundwater measuring network.	✓	✓		✓		✓	
South							
Need for a broader investigation into metals and other contaminants from past land use and their impact on groundwater in the urban context.	✓	✓	✓		✓		
How can we improve water quality of drains/waterways?		✓	✓	✓	✓		
What risks do bushfires/prescribed burns pose to the quality of water in a waterway, wetland or drinking water catchment?		✓	✓	✓	✓		
Investigate population genetics across key invertebrate groups in the South West so we know where the biodiversity is in order to help guide management to conserve it.		✓	✓				
Lake Clifton – assessing long-term impacts of salinisation of the lake on hydrology and impact on thrombolites.		✓	✓				
Define and regulate the critical needs of foreshore buffers (native vegetation protection areas) around wetlands and waterways.		✓	✓		✓		

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TABLE 12. Issues that emerged (👍) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
South							
Lack of groundwater monitoring – which areas need more monitoring bores, or can we use different methods?	👍			👍			
Impacts of water drawdown in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts on reeds, riparian vegetation, buffers.	👍		👍				
Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.	👍	👍	👍				
How to best educate external stakeholders such as farmers, industry, community about the benefits of river health to ecosystem services?		👍	👍				👍
Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.		👍	👍		👍		
How can we recover eutrophic wetlands, lakes and estuaries that are fed by recycling nutrients from bottom sediments?			👍				
What insights can Indigenous understanding, and cultural knowledge relevant to landscape function, erosion control, and dryland salinity mitigation provide?	👍	👍	👍	👍			👍
Quantify the benefits of wetland buffers to restoring biodiversity and ecological values, carbon capture and help with flood mitigation.		👍	👍		👍		
Increase knowledge about water use for seed production and the early stages of restoration projects.		👍	👍				
How to best improve connectivity through the landscape/catchment by undertaking stream zone restoration?		👍	👍	👍			
What is the efficacy and economic viability of Landscape Rehydration to remediate land degraded by vegetation decline, erosion, waterlogging and dryland salinity.	👍	👍	👍				
More water is needed to restore the urban landscape and keep Perth green in a drying climate. How can we reuse storm- and wastewater resources that are currently being drained or pumped away?	👍	👍	👍	👍	👍		👍
What is the best way to support LGAs with the increased cost of watering trees (increased water volumes and frequency)?	👍				👍		👍

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TABLE 12. Issues that emerged (✓) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
South							
What are good examples of what can be done with Water Sensitive Urban Design (WSUD) that can be incorporated into a WA standard?	✓	✓	✓		✓		
What are the effects of re-snagging rivers and drains on biodiversity and population connectivity.		✓	✓				
How can we utilise artificial pools to maintain native biodiversity (dams, created wetlands).		✓	✓				
What is the impact of restoration on the drawdown of water, particularly with the impacts of climate change.	✓		✓				
Exploring the management of saline water in the Wheatbelt through the lens of modified ecosystems versus a sole focus on endemic systems.	✓	✓	✓	✓			
Can inland groundwater desalination play a role in restoring natural waterways, and reducing dryland salinity?	✓	✓	✓	✓			
What is the best way to revegetate wetland buffers, considering wetland hydrology and resilience of plantings to a hotter climate.		✓	✓	✓			
Lack of regional groundwater models – to assess impacts outside of where mining occurs. What are the cumulative impacts of major water drawdowns for mining and center pivot agriculture?	✓		✓	✓		✓	
Improved information/knowledge on the management of tailing storage facilities.	✓	✓	✓	✓			
Impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems.	✓	✓	✓				
Impact of a drying climate on clay pans of the Swan Coastal Plain.		✓	✓	✓			
A changing climate may bring more frequent heavy rain events. They may bring big pulses of water. What are the positive and negative impacts to the near shore environments?		✓	✓				
What are the minimal environmental flows needed to ensure waterway values, function and processes are maintained?		✓	✓	✓			
Lower groundwater levels and higher sea-levels are leading to more tidal influences and seawater intrusion. How can we manage these changes?		✓	✓	✓			

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TABLE 12. Issues that emerged (👍) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
South							
How can managed aquifer recharge (MAR) offset the inevitable reduction in natural recharge as the South-west gets hotter and drier?	👍		👍	👍			
All							
Increased knowledge of water quality tolerance of local species.	👍	👍	👍				
How to accurately predict the impacts of different/more intensified future land uses on water quality.	👍	👍	👍				
Need for better understanding of the additive relationship between contaminants and the added effects of other stresses.	👍	👍	👍				
How to cost-effectively strip contaminants out of water (phosphorus, PFAS, nitrogen).	👍	👍	👍			👍	
How do we best monitor large natural catchments and detect and treat contaminants prior to them entering water bodies?		👍	👍	👍			
Implement a reversed triage process – identify where restoration and improved management can make a difference.	👍	👍		👍	👍		
Improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management.		👍	👍	👍	👍		
More understanding about the impact of invasive aquatic species on native aquatic ecosystems.		👍	👍	👍			
How do we integrate input from Traditional Owners into the management of water?	👍	👍	👍	👍		👍	👍
Increase corporate social responsibility: how can proponents invest in increasing community awareness of endangered endemic aquatic species?	👍	👍	👍			👍	👍
Local scale hydrological models to understand functioning of wetlands from the Kimberley to the Arid zone to the South West		👍	👍				
Review risk analysis system for restoration of wetlands and riparian ecosystems – restore to their best ability to maintain function in a changing environment (hybrid ecosystem), not to its original state.		👍	👍	👍	👍		

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TABLE 12. Issues that emerged (✓) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
All							
Investigate alternative weed management options in catchment and riparian zones areas to contain the spread of weeds and protect ecosystem health.		✓	✓	✓	✓		
Which inland water systems are already showing the impacts of climate change? Which ones can be realistically saved from climate change and other threats (e.g. salinisation, eutrophication, siltation).	✓	✓	✓	✓			
Evaluate which ecosystems are dependent on different aquifer types to determine those features most and least susceptible to climate change.	✓		✓				
What are climate resilient vegetation species that can survive and flourish under future climate scenarios?			✓				
Ongoing monitoring program for high value waterways and wetlands: (Water levels, PH, salinity, water quality etc).		✓		✓	✓		✓
Use innovative technology/techniques for groundwater and surface water monitoring and measuring.	✓	✓			✓		
Improved and continuous management of datasets in WA for storage and access of water and associated biotic data.	✓	✓			✓		
How to enable/improve/facilitate data sharing between various stakeholders.	✓	✓	✓				
Groundwater-surface water connectivity mapping (depth to groundwater).	✓	✓	✓				
Governance on inland waters needs to be clarified.	✓	✓		✓			✓
Update the EPA factor guideline on Inland Waters – one guideline for the whole state of WA. Revise to address wetlands, waterways and groundwater and tailored to local conditions.	✓	✓		✓			
Greater emphasis on cultural heritage needs in the water allocation process.	✓	✓		✓			
No standard approach for industry on how to use satellite imagery.	✓	✓	✓	✓			

TABLE 12. Issues that emerged (👉) from the initial scoping sessions (cont.)

WA Regional area	Environment		Solution components				
	Groundwater	Surface water	Research	Management	Policy	Funding	Communications
All							
How do you deal with the uncertainty from science (margins/confidence intervals etc) in a transparent way?	👉	👉		👉			
How do you put a price on a healthy receiving environment – how much is it worth?	👉	👉	👉				
How cost-effective is a specific intervention to save an inland water system from the impacts of climate change?	👉	👉	👉		👉	👉	
No standard definitions for water terminology used in the EIA process.	👉	👉	👉				👉
How to create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations.		👉	👉		👉	👉	
Develop key ecohydrological principles which can be used to guide the assessment/understanding of ecohydrological functioning in riparian ecosystems.	👉	👉	👉		👉	👉	
Develop technical sampling guidance. For example, sampling guidance for inland waters and different types of waterbodies, inclusion of sediments and utilising adequately qualified specialists.	👉	👉	👉		👉		
What happens to stygofauna and troglofaunal when groundwater drawdown occurs?	👉		👉				
More research needed into stygofauna and troglofauna (sequencing).	👉		👉				
How does Managed Aquifer Recharge (MAR) impact stygofauna and troglofauna?	👉		👉				





Navigating knowledge gaps for Western Australia's inland waters

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Appendix 3.

Participants workshops

TABLE 13. Participants workshop and/or exercise North/Mid WA

Category	Organisation	Name
Industry	Bennelongia Environmental Consultants	Stuart Halse
Industry	BHP	Jen Carter
Industry	Biologic	Chris Hofmeester
Industry	Biologic	Jess Delaney
Industry	Biologic	Fintan J Angel
Industry	Biologic	Jess Delaney
Industry	Chamber of Minerals and Energy	Catherine Turnbull
Industry	Fortescue	Damien Cancilla
Industry	Fortescue	Michael Carroll
Industry	Fortescue	Karen Fairweather
Industry	HanRoy	Barbara Heemink
Industry	HanRoy	Allen Qin
Industry	Lateral	Adam Harman
Industry	Rio Tinto	Michael Curran
Industry	Rio tinto	Jeremy Naaykens
Industry	Rio Tinto	Bianca Bertelli
Industry	SLR Consulting	Nicole Carey
Industry	Stantec	Erin Thomas
Industry	Stantec	Fiona Taukulis
Not-for-profit	NACC NRM	Katherine Allen
Research	Murdoch University	John Ruprecht
Research	Murdoch University	Belinda Robson
State Government	Department of Biodiversity Conservation and Attractions	Kerry Trayler
State Government	Department of Biodiversity Conservation and Attractions	Gavan McGrath
State Government	Department of Biodiversity Conservation and Attractions	Mike Lyons
State Government	Department of Biodiversity, Conservation and Attractions	Heidi Oswald
State Government	Department of Water and Environmental Regulation	Lisa Mazzella
State Government	Department of Water and Environmental Regulation	Josephine Searle
State Government	Department of Water and Environmental Regulation	Jane Puthiaparampil
State Government	Department of Water and Environmental Regulation	Tim Storer
State Government	Water Corporation	James Leonard
State Government	Water Corporation	Paul Nolan
State Government	Water Corporation	Anthony Bodycoat
State Government	Water Corporation	Jeremy Maher
State Government	Water Corporation	Jacquie Bellhouse
Traditional Owners	Karlka Nyiyaparli Aboriginal Corporation	Sophia Boccardo



TABLE 14. Participants workshop and/or exercise South WA

Category	Organisation	Name
Industry	Alcoa	Karin Bankin
Industry	Alcoa	Lucy Commander
Industry	Biologic	Kim Nguyen
Industry	Biologic	Jess Delaney
Industry	Broderick and Associates	Kathleen Broderick
Industry	Chamber of Minerals and Energy	Catherine Turnbull
Industry	Savoir Consulting	Larissa Taylor
Industry	SLR Consulting	Melissa Tucker
Industry	South 32	Stacey Mckenzie
Industry	Stantec	Erin Thomas
Industry	Stantec	Fiona Taukulis
Industry	UWA / SLR Consulting	Andrew Storey
Not-for-profit	NACC NRM	Kane Watson
Not-for-profit	Perth NRM	Luke McMillan
Not-for-profit	Perth NRM	Ingrid Sieler
Not-for-profit	PHCC (formerly Peel-Harvey Catchment Council)	Danielle Eyre
Not-for-profit	Wheatbelt NRM	Dimity Boggs
Research	Murdoch University	Stephen Beatty
Research	Murdoch University	Belinda Robson
State Government	Department of Biodiversity Conservation and Attractions	Adrian Pinder
State Government	Department of Biodiversity Conservation and Attractions	Gavan McGrath
State Government	Department of Biodiversity Conservation and Attractions	Mike Lyons
State Government	Department of Biodiversity Conservation and Attractions	Kerry Trayler
State Government	Department of Biodiversity Conservation and Attractions	Heidi Oswald
State Government	Department of Biodiversity Conservation and Attractions	Shaun Molloy
State Government	Department of Water and Environmental Regulation	Lisa Mazzella
State Government	Department of Water and Environmental Regulation	Artemis Kitsios
State Government	Department of Water and Environmental Regulation	Tim Storer
State Government	Department of Water and Environmental Regulation	Romeny Lynch
State Government	Water Corporation	Paul Nolan
State Government	Water Corporation	Antonietta Torre
State Government	Water Corporation	Anthony Bodycoat
State Government	Water Corporation	Jeremy Maher

Appendix 4.

Prioritisation exercise North/Mid WA

North — Inland Waters workshop Nov 2024

Introduction

WABSI — Inland Waters Research Program

Western Australia has a wide variety of inland aquatic ecosystems. The Western Australian Biodiversity Science Institute (WABSI) is developing a new research program for inland waters to identify priority biodiversity science needs around the topic of inland waters, while taking into account the vast amount of work that is already being undertaken by industry, government agencies, institutes and organisations.

The program focus is:

Knowledge priorities associated with the health of inland waters to support Western Australia's biodiversity and provide ecosystem services.

The aim of this exercise is to build on previous engagement and to:

- Define/further refine research questions under topics established during the initial inland waters scoping sessions.
- Prioritise research topics and questions according to end user requirements.

*This survey is focusing on knowledge gaps for inland waters in the **North** and **Mid** area of Western Australia:*

- **North:** The northernmost region of WA, including the Kimberley, the Pilbara and East Pilbara.
- **Mid:** The area includes the Gascoyne, Murchison, Arid Interior, Goldfields and the Nullarbor.

Respondent details

Q1. Name _____

Q2. Organisation _____

Ranking focus areas

Q3. Focus areas

Please rank the research focus areas below from 1 to 6 by dragging and dropping the focus areas in the right order. (1 is most important to you and 6 is least important)

- Water quality
- Water extraction and discharge
- Ecosystem functioning
- Climate change impacts
- Data collection
- Principles and guidance

Focus area 1 – Water quality

Please rank the urgency for each of the research questions below.

Q4. Focus area 1 – Water quality

Research topic 1.1: Legacy issues

	High	Medium	Low
1. What is the additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)	☐	☐	☐
2. How can we cost-effectively strip contaminants out of water (phosphorus, PFAS, nitrogen)	☐	☐	☐

Q5. Focus area 1 – Water quality

Research topic 1.2: Future impacts

	High	Medium	Low
1. How can we accurately predict the impacts of different/more intensified future land uses on water quality?	☐	☐	☐
2. How do we best monitor large natural catchments and detect and treat contaminants prior to them entering water bodies?	☐	☐	☐

Focus area 2 – Water extraction and discharge

Please rank the urgency for each of the research questions below.

Q6. Focus area 2 – Water extraction and discharge

Research topic 2.1: Cumulative impacts

	High	Medium	Low
1. What are the cumulative impacts of major water drawdowns for mining and agriculture? We need more regional groundwater models to assess impacts outside of where mining occurs.	☐	☐	☐
2. What are the cumulative impacts of mining on the Fortescue Marsh through changes of water inflows and water quality as a result of mine dewatering, discharges as well as linear infrastructure/rail corridors?	☐	☐	☐
3. How to minimise the impact from development on Pilbara surface water flows.	☐	☐	☐
4. Climate factors, seasonal variability and proponents' impacts of dewatering – how are they interacting and what are the impacts on groundwater dependent ecosystems (GDEs) and groundwater levels?	☐	☐	☐
5. How can we reduce the environmental impact of future salt mining by learning from the past. How have past salt mining sites regenerated?	☐	☐	☐



Q7. Focus area 2 — Water extraction and discharge

Research topic 2.2: Impacts on GDEs

	High	Medium	Low
1. What are the impacts of water drawdown in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts to reeds, riparian vegetation and buffers?	☐	☐	☐
2. Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.	☐	☐	☐

Q8. Focus area 2 — Water extraction and discharge

Research topic 2.3: Dewatering discharge

	High	Medium	Low
1. How can we do dewatering better: discharge of dewatering surplus water to the receiving environment needs innovative thinking about dewatering, discharging and reinjecting – better practice and novel solutions?	☐	☐	☐
2. We need improved information/knowledge on the management of tailing storage facilities.	☐	☐	☐
3. What is the influence of long-term surplus water discharge on riparian rooting patterns, ecosystem resilience and future restoration efforts?	☐	☐	☐

Focus area 3 – Ecosystem functioning

Please rank the urgency for each of the research questions below.

Q9. Focus area 3 – Ecosystem functioning

Research topic 3.1: Ecological water needs

	High	Medium	Low
1. How can we increase our understanding of typical ephemeral (seasonal) arid zone drainage systems so we can better determine the relative contribution of groundwater versus surface water?	☐	☐	☐
2. There is a need to develop local scale hydrological models to better understand functioning of wetlands from Kimberley > Arid zone > South West.	☐	☐	☐
3. Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.	☐	☐	☐

Q10. Focus area 3 – Ecosystem functioning

Research topic 3.2: Aquatic ecosystem values

	High	Medium	Low
1. We need improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management.	☐	☐	☐
2. How to create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations.	☐	☐	☐

Q11. Focus area 3 – Ecosystem functioning

Research topic 3.3: Threat mitigation

	High	Medium	Low
1. Can inland groundwater desalination play a role in restoring natural waterways, and reducing dryland salinity?	☐	☐	☐
2. What is the impact of invasive aquatic species on native aquatic ecosystems?	☐	☐	☐



Q12. Focus area 3 — Ecosystem functioning

Research topic 3.4: Ecosystem restoration

	High	Medium	Low
1. What are the impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems?	☐	☐	☐
2. Review risk analysis system for restoration of wetlands and riparian ecosystems – restore to their best ability to maintain function in a changing environment (hybrid ecosystem), not to its historical state.	☐	☐	☐

Focus area 4 – Climate change impacts

Please rank the urgency for each of the research questions below.

Q13. Focus area 4 – Climate change impacts

Research topic 4.1: Extreme rainfall events

	High	Medium	Low
1. What are the effects of episodic rainfall events versus historic rainfall patterns on salt lake systems?	☐	☐	☐

Q14. Focus area 4 – Climate change impacts

Research topic 4.2: Drying climate

	High	Medium	Low
1. Which inland water systems are already showing the impacts of climate change? Which ones can be realistically saved from climate change and other treats (e.g. salinisation, eutrophication, siltation)?	☐	☐	☐
2. Undertake an evaluation of the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change.	☐	☐	☐

Focus area 5 – Data collection

Please rank the urgency for each of the research questions below.

Q15. Focus area 5 – Data collection

Research topic 5.1: Biological data

	High	Medium	Low
1. How do local/native species react to changes in water quality? What are their tolerance levels to deteriorating water quality?	☐	☐	☐

Q16. Focus area 5 – Data collection

Research topic 5.2: Spatial data

	High	Medium	Low
1. How to get better access to water quality data for priority areas in WA?	☐	☐	☐
2. There is a need for a Pilbara-wide freshwater pool inventory and wetland mapping to inform cumulative impact assessment.	☐	☐	☐
3. Create a baseline understanding of what groundwater in the Pilbara was like before development.	☐	☐	☐
4. How to create better groundwater-surface water connectivity mapping (depth to groundwater).	☐	☐	☐





Focus area 6 – Principles and guidance

Please rank the urgency for each of the research questions below.

Q17. Focus area 6 – Principles and guidance

Research topic 6.1: Review inland water principles

	High	Medium	Low
1. Develop key ecohydrological principles which can be used to guide the assessment/understanding of ecohydrological functioning in riparian ecosystems.	☐	☐	☐
2. How do you put a price on a healthy receiving environment – how much is it worth?	☐	☐	☐
3. How cost-effective is a specific intervention to save an inland water system from the impacts of climate change?	☐	☐	☐

Q18. Focus area 6 – Principles and guidance

Research topic 6.2: Update guidance

	High	Medium	Low
1. How do we integrate input from Traditional Owners into the management of water?	☐	☐	☐
2. What does it take to create standard definitions for water terminology to use in the environmental impact assessment (EIA) process?	☐	☐	☐
3. Develop more specific technical sampling guidance with the help of adequately qualified specialists, e.g. sampling guidance for inland waters and different types of waterbodies, with the inclusion of sediments.	☐	☐	☐

Overall top 3 research questions

Q19. Please review all focus areas, research topics and their questions again and rank your overall top 3

Which research questions are the most urgent to be answered? Please drag and drop your top 3 to the top of the list below.



Focus area 1 — Water quality

Research topic 1.1 – Legacy issues

Research topic 1.2 – Future impacts



Focus area 2 — Water extraction and discharge

Research topic 2.1 – Cumulative impacts

Research topic 2.2 – Impacts on GDEs

Research topic 2.3 – Dewatering discharge



Focus area 3 — Ecosystem functioning

Research topic 3.1 – Ecological water needs

Research topic 3.2 – Aquatic ecosystem values

Research topic 3.3 – Threat mitigation

Research topic 3.4 – Ecosystem restoration



Focus area 4 – Data collection

Research topic 4.1 – Biological data

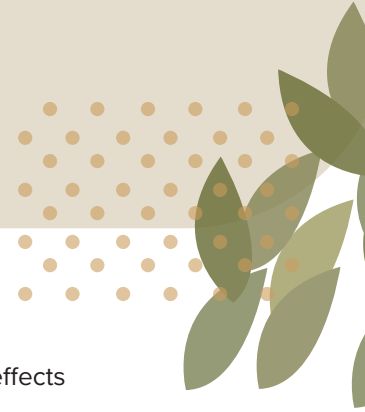
Research topic 4.2 – Spatial data



Focus area 5 – Principles and guidance

Research topic 5.1 – Review inland water principles

Research topic 5.2 – Update guidance



- **1.1.1.** What is the additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)?
- **1.1.2.** How can we cost-effectively strip contaminants out of water (phosphorus, PFAS, nitrogen)?
- **1.2.1.** How can we accurately predict the impacts of different/more intensified future land uses on water quality?
- **1.2.2.** How do we best monitor large natural catchments and detect and treat contaminants prior to them entering water bodies?
- **2.1.1.** What are the cumulative impacts of major water drawdowns for mining and agriculture? We need more regional groundwater models to assess impacts outside of where mining occurs.
- **2.1.2.** What are the cumulative impacts of mining on the Fortescue Marsh through changes of water inflows and water quality as a result of mine dewatering, discharges as well as linear infrastructure/rail corridors?
- **2.1.3.** How to minimise the impact from development on Pilbara surface water flows?
- **2.1.4.** Climate factors, seasonal variability and proponents' impacts of dewatering – how are interacting and what are the impacts on groundwater dependent ecosystems (GDEs) and groundwater levels?
- **2.1.5.** How can we reduce the environmental impact of future salt mining by learning from the past. How have past salt mining sites regenerated?
- **2.2.1.** What are the impacts of water drawdown in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts to reeds, riparian vegetation and buffers?
- **2.2.2.** Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.
- **2.3.1.** How can we do dewatering better: discharge of dewatering surplus water to the receiving environment needs innovative thinking about dewatering, discharging and reinjecting – better practice and novel solutions?
- **2.3.2.** We need improved information/knowledge on the management of tailing storage facilities.
- **2.3.3.** What is the influence of long-term surplus water discharge on riparian rooting patterns, ecosystem resilience and future restoration efforts?
- **3.1.1.** How can we increase our understanding of typical ephemeral (seasonal) arid zone drainage systems so we can better determine the relative contribution of groundwater versus surface water?
- **3.1.2.** There is a need to develop local scale hydrological models to better understand functioning of wetlands from Kimberley > Arid zone > South West.
- **3.1.3.** Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.

- **3.2.1.** We need improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management.
- **3.2.2.** How to create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations?
- **3.3.1.** Can inland groundwater desalination play a role in restoring natural waterways, and reducing dryland salinity?
- **3.3.2.** What is the impact of invasive aquatic species on native aquatic ecosystems?
- **3.4.1.** What are the impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems?
- **3.4.2.** Review risk analysis system for restoration of wetlands and riparian ecosystems – restore to their best ability to maintain function in a changing environment (hybrid ecosystem), not to its historical state.
- **4.1.1.** What are the effects of episodic rainfall events versus historic rainfall patterns on salt lake systems?
- **4.2.1.** Which inland water systems are already showing the impacts of climate change? Which ones can be realistically saved from climate change and other threats (e.g. salinisation, eutrophication, siltation)?
- **4.2.2.** Undertake an evaluation of the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change.
- **5.1.1.** How do local/native species react to changes in water quality? What are their tolerance levels to deteriorating water quality?
- **5.2.1.** How to get better access to water quality data for priority areas in WA?
- **5.2.2.** There is a need for a Pilbara-wide freshwater pool inventory and wetland mapping to inform cumulative impact assessment.
- **5.2.3.** Create a baseline understanding of what groundwater in the Pilbara was like before development.
- **5.2.4.** How to create better groundwater-surface water connectivity mapping (depth to groundwater).
- **6.1.1.** Develop key ecohydrological principles which can be used to guide the assessment/ understanding of ecohydrological functioning in riparian ecosystems.
- **6.1.2.** How do you put a price on a healthy receiving environment – how much is it worth?
- **6.1.3.** How cost-effective is a specific intervention to save an inland water system from the impacts of climate change?

- 
- **6.2.1.** How do we integrate input from Traditional Owners into the management of water?
 - **6.2.2.** What does it take to create standard definitions for water terminology to use in the environmental impact assessment (EIA) process?
 - **6.2.3.** Develop more specific technical sampling guidance with the help of adequately qualified specialists, e.g. sampling guidance for inland waters and different types of waterbodies, with the inclusion of sediments.

Anything missing?

Q20. Do you think any issue or challenge with regards to 'inland waters' is missing from this exercise?

If so, please provide feedback below. Please make sure that you click through to the final page to record your entries, thank you.

Prioritisation exercise South WA

South — Inland Waters workshop Dec 2024

Introduction

WABSI — Inland Waters Research Program

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Knowledge priorities associated with the health of inland waters to support Western Australia's biodiversity and provide ecosystem services.

The aim of this exercise is to build on previous engagement and to:

- Define/further refine research questions under topics established during the initial inland waters scoping sessions.
- Prioritise research topics and questions according to end user requirements.

*This survey is focusing on knowledge gaps for inland waters in the **South** area of Western Australia:*

- **South:** This area includes the Mid West, Wheatbelt, Metropolitan Perth and the Peel region, the South West and the South Coast.

Respondent details

Q1. Name _____

Q2. Organisation _____



Ranking focus areas

Q3. Focus areas

Please rank the research focus areas below from 1 to 6 by dragging and dropping the focus areas in the right order. (1 is most important to you and 6 is least important)

- Water quality
- Water extraction and discharge
- Ecosystem functioning
- Climate change impacts
- Data collection
- Principles and guidance

Focus area 1 – Water quality

Please rank the urgency for each of the research questions below.

Q4. Focus area 1 – Water quality

Research topic 1.1: Legacy issues

	High	Medium	Low
1. We need a broader investigation into metals and other contaminants from past land use and their impact on groundwater in the urban context.	☐	☐	☐
2. What is the additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)?	☐	☐	☐
3. How can we cost-effectively strip contaminants out of water (phosphorus, PFAS, nitrogen)?	☐	☐	☐
4. How can we improve water quality of drains/waterways?	☐	☐	☐

Q5. Focus area 1 — Water quality

Research topic 1.2: Future impacts

	High	Medium	Low
1. What risks do bushfires/prescribed burns pose to the quality of water in a waterway, wetland or drinking water catchment?	☐	☐	☐
2. How can we accurately predict the impacts of different/more intensified future land uses on water quality?	☐	☐	☐
2. How do we best monitor large natural catchments and detect and treat contaminants prior to them entering water bodies?	☐	☐	☐

Focus area 2 – Water extraction and discharge

Please rank the urgency for each of the research questions below.

Q6. Focus area 2 — Water extraction and discharge

Research topic 2.1: Cumulative impacts

	High	Medium	Low
1. What are the cumulative impacts of major water drawdowns for mining and agriculture? We need more regional groundwater models to assess impacts outside of where mining occurs.	☐	☐	☐

Q7. Focus area 2 — Water extraction and discharge

Research topic 2.2: Impacts on GDEs

	High	Medium	Low
1. What are the impacts of water draw-down in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts to reeds, riparian vegetation and buffers?	☐	☐	☐
2. Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.	☐	☐	☐



Q8. Focus area 2 — Water extraction and discharge

Research topic 2.3: Dewatering discharge

	High	Medium	Low
1. We need improved information/knowledge on the management of tailing storage facilities.	☐	☐	☐

Focus area 3 – Ecosystem functioning

Please rank the urgency for each of the research questions below.

Q9. Focus area 3 — Ecosystem functioning

Research topic 3.1: Ecological water needs

	High	Medium	Low
1. There is a need to develop local scale hydrological models to better understand functioning of wetlands from Kimberley > Arid zone > South West.	☐	☐	☐
2. Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.	☐	☐	☐
3. What are the minimal environmental flows needed to ensure waterway values, function and processes are maintained?	☐	☐	☐
4. What is the best way to revegetate wetland buffers, considering wetland hydrology and resilience of plantings to a hotter climate?	☐	☐	☐

Q10. Focus area 3 — Ecosystem functioning

Research topic 3.2: Aquatic ecosystem values

	High	Medium	Low
1. We need improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management.	☐	☐	☐
2. Quantify the benefits of wetland buffers to restoring biodiversity and ecological values, carbon capture and help with flood mitigation.	☐	☐	☐
2. How to create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations.	☐	☐	☐

Q11. Focus area 3 — Ecosystem functioning

Research topic 3.3: Threat mitigation

	High	Medium	Low
1. What insights can Indigenous understanding, and cultural knowledge relevant to landscape function, erosion control, and dryland salinity mitigation provide?	☐	☐	☐
2. Lake Clifton – what are the long-term impacts of salinisation on the lake hydrology and the thrombolites?	☐	☐	☐
3. Can inland groundwater desalination play a role in restoring natural waterways, and reducing dryland salinity?	☐	☐	☐
4. What is the impact of restoration on the drawdown of water, particularly with the impacts of climate change?	☐	☐	☐
5. Define and regulate the critical needs of foreshore buffers (native vegetation protection areas) around wetlands and waterways.	☐	☐	☐
6. How can we recover eutrophic wetlands, lakes and estuaries that are fed by recycling nutrients from bottom sediments?	☐	☐	☐
7. What is the impact of invasive aquatic species on native aquatic ecosystems?	☐	☐	☐



Q12. Focus area 3 — Ecosystem functioning

Research topic 3.4: Ecosystem restoration

	High	Medium	Low
1. How to best improve connectivity through the landscape/catchment by undertaking stream zone restoration?	☐	☐	☐
2. What are the effects of resnagging rivers and drains on biodiversity and population connectivity?	☐	☐	☐
3. What are the impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems?	☐	☐	☐
4. How can we utilise artificial pools to maintain native biodiversity (dams, created wetlands)?	☐	☐	☐
5. How to explore the management of saline water in the Wheatbelt through the lens of modified ecosystems versus a sole focus on endemic systems?	☐	☐	☐
6. Review risk analysis system for restoration of wetlands and riparian ecosystems – restore to their best ability to maintain function in a changing environment (hybrid ecosystem), not to its historical state.	☐	☐	☐

Focus area 4 – Climate change impacts

Please rank the urgency for each of the research questions below.

Q13. Focus area 4 – Climate change impacts

Research topic 4.1: Extreme rainfall events

	High	Medium	Low
1. A changing climate may bring more frequent intense rain events. They may bring big pulses of water. What are the positive and negative impacts to the near shore environments?	☐	☐	☐

Q14. Focus area 4 – Climate change impacts

Research topic 4.2: Drying climate

	High	Medium	Low
1. What is the impact of a drying climate on clay pans of the Swan Coastal Plain?	☐	☐	☐
2. Lower groundwater levels and higher sea levels are leading to more tidal influences and seawater intrusion. How can we manage these changes?	☐	☐	☐
3. How can managed aquifer recharge (MAR) offset the inevitable reduction in natural recharge as the South West gets hotter and drier?	☐	☐	☐
4. More water is needed to restore the urban landscape and keep Perth green in a drying climate. How can we reuse storm and wastewater resources that are currently being drained or pumped away?	☐	☐	☐
5. Which inland water systems are already showing the impacts of climate change? Which ones can be realistically saved from climate change and other threats (e.g. salinisation, eutrophication, siltation)?	☐	☐	☐
6. Undertake an evaluation of the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change.	☐	☐	☐

Focus area 5 – Data collection

Please rank the urgency for each of the research questions below.

Q15. Focus area 5 – Data collection

Research topic 5.1: Biological data

	High	Medium	Low
1. Investigate population genetics across key aquatic invertebrate groups in the South West so we know where the biodiversity is in order to help guide management to conserve it.	☐	☐	☐
2. How do local/native species react to changes in water quality? What are their tolerance levels to deteriorating water quality?	☐	☐	☐



Focus area 6 – Principles and guidance

Please rank the urgency for each of the research questions below.

Q16. Focus area 6 – Principles and guidance

Research topic 6.1: Review inland water principles

	High	Medium	Low
1. Develop key ecohydrological principles which can be used to guide the assessment/understanding of ecohydrological functioning in riparian ecosystems.	☐	☐	☐
2. How do you put a price on a healthy receiving environment – how much is it worth?	☐	☐	☐
3. How cost-effective is a specific intervention to save an inland water system from the impacts of climate change?	☐	☐	☐

Q17. Focus area 6 – Principles and guidance

Research topic 6.2: Update guidance

	High	Medium	Low
1. How do we integrate input from Traditional Owners into the management of water?	☐	☐	☐
2. What does it take to create standard definitions for water terminology to use in the environmental impact assessment (EIA) process?	☐	☐	☐
3. Develop more specific technical sampling guidance with the help of adequately qualified specialists, e.g. sampling guidance for inland waters and different types of waterbodies, with the inclusion of sediments.	☐	☐	☐

Overall top 3 research questions

Q18. Please review all focus areas, research topics and their questions again and rank your overall top 3

Which research questions are the most urgent to be answered? Please drag and drop your top 3 to the top of the list below.



Focus area 1 — Water quality

Research topic 1.1 – Legacy issues

Research topic 1.2 – Future impacts



Focus area 2 — Water extraction and discharge

Research topic 2.1 – Cumulative impacts

Research topic 2.2 – Impacts on GDEs

Research topic 2.3 – Dewatering discharge



Focus area 3 — Ecosystem functioning

Research topic 3.1 – Ecological water needs

Research topic 3.2 – Aquatic ecosystem values

Research topic 3.3 – Threat mitigation

Research topic 3.4 – Ecosystem restoration



Focus area 4 – Data collection

Research topic 4.1 – Biological data

Research topic 4.2 – Spatial data



Focus area 5 – Principles and guidance

Research topic 5.1 – Review inland water principles

Research topic 5.2 – Update guidance



- **1.1.1.** We need a broader investigation into metals and other contaminants from past land use and their impact on groundwater in the urban context.
- **1.1.2.** What is the additive relationship between contaminants in water and the added effects of other stresses (e.g. increasing water temperatures)?
- **1.1.3.** How can we cost-effectively strip contaminants out of water (phosphorus, PFAS, nitrogen)?
- **1.1.4.** How can we improve water quality of drains/waterways?
- **1.2.1.** What risks do bushfires/prescribed burns pose to the quality of water in a waterway, wetland or drinking water catchment?
- **1.2.2.** How can we accurately predict the impacts of different/more intensified future land uses on water quality?
- **1.2.3.** How do we best monitor large natural catchments and detect and treat contaminants prior to them entering water bodies?
- **2.1.1.** What are the cumulative impacts of major water drawdowns for mining and agriculture? We need more regional groundwater models to assess impacts outside of where mining occurs.
- **2.2.1.** What are the impacts of water drawdown in groundwater dependent ecosystems (GDEs), to aquatic/freshwater species, impacts to reeds, riparian vegetation and buffers?
- **2.2.2.** Quantify the contribution of groundwater in maintaining refuge pools to help understand the impact of groundwater extraction.
- **2.3.1.** We need improved information/knowledge on the management of tailing storage facilities.
- **3.1.1.** There is a need to develop local scale hydrological models to better understand functioning of wetlands from Kimberley > Arid zone > South West.
- **3.1.2.** Improve knowledge on ecological water dependency to inform how much environmental flows are needed, and timing, patterns and frequency.
- **3.1.3.** What are the minimal environmental flows needed to ensure waterway values, function and processes are maintained?
- **3.1.4.** What is the best way to revegetate wetland buffers, considering wetland hydrology and resilience of plantings to a hotter climate?
- **3.2.1.** We need improved understanding of environmental values and ecosystem tolerances of salt lakes to inform regulation and management.
- **3.2.2.** Quantify the benefits of wetland buffers to restoring biodiversity and ecological values, carbon capture and help with flood mitigation.
- **3.2.3.** How to create a framework for assessing the value of biodiversity in created waterbodies (e.g. large private dams) and how to integrate that into licensing requirements/ regulations.

- **3.3.1.** What insights can Indigenous understanding, and cultural knowledge relevant to landscape function, erosion control, and dryland salinity mitigation provide?
- **3.3.2.** Lake Clifton – what are the long-term impacts of salinisation on the lake hydrology and the thrombolites?
- **3.3.3.** Can inland groundwater desalination play a role in restoring natural waterways, and reducing dryland salinity?
- **3.3.4.** What is the impact of restoration on the drawdown of water, particularly with the impacts of climate change?
- **3.3.5.** Define and regulate the critical needs of foreshore buffers (native vegetation protection areas) around wetlands and waterways.
- **3.3.6.** How can we recover eutrophic wetlands, lakes and estuaries that are fed by recycling nutrients from bottom sediments?
- **3.3.7.** What is the impact of invasive aquatic species on native aquatic ecosystems?
- **3.4.1.** How to best improve connectivity through the landscape/catchment by undertaking stream zone restoration?
- **3.4.2.** What are the effects of resnagging rivers and drains on biodiversity and population connectivity?
- **3.4.3.** What are the impacts of land clearing and subsequent restoration after mine closure on downstream aquatic ecosystems?
- **3.4.4.** How can we utilise artificial pools to maintain native biodiversity (dams, created wetlands)?
- **3.4.5.** How to explore the management of saline water in the Wheatbelt through the lens of modified ecosystems versus a sole focus on endemic systems?
- **3.4.6.** Review risk analysis system for restoration of wetlands and riparian ecosystems – restore to their best ability to maintain function in a changing environment (hybrid ecosystem), not to its historical state.
- **4.1.1.** A changing climate may bring more frequent intense rain events. They may bring big pulses of water. What are the positive and negative impacts to the near shore environments?
- **4.2.1.** What is the impact of a drying climate on clay pans of the Swan Coastal Plain?
- **4.2.2.** Lower groundwater levels and higher sea-levels are leading to more tidal influences and seawater intrusion. How can we manage these changes?
- **4.2.3.** How can Managed Aquifer Recharge offset the inevitable reduction in natural recharge as the South-west gets hotter and drier?
- **4.2.4.** More water is needed to restore the urban landscape and keep Perth green in a drying climate. How can we reuse storm- and wastewater resources that are currently being drained or pumped away?



- **4.2.5.** Which inland water systems are already showing the impacts of climate change? Which ones can be realistically saved from climate change and other threats (e.g. salinisation, eutrophication, siltation)?
- **4.2.6.** Undertake an evaluation of the dependence of aquatic ecosystems on different aquifer types to determine those features most and least susceptible to climate change.
- **5.1.1.** Investigate population genetics across key aquatic invertebrate groups in the South West so we know where the biodiversity is in order to help guide management to conserve it.
- **5.1.2.** How do local/native species react to changes in water quality? What are their tolerance levels to deteriorating water quality?
- **6.1.1.** Develop key ecohydrological principles which can be used to guide the assessment/ understanding of ecohydrological functioning in riparian ecosystems.
- **6.1.2.** How do you put a price on a healthy receiving environment – how much is it worth?
- **6.1.3.** How cost effective is a specific intervention to save an inland water system from the impacts of climate change?
- **6.2.1.** How do we integrate input from Traditional Owners into the management of water?
- **6.2.2.** What does it take to create standard definitions for water terminology to use in the environmental impact assessment (EIA) process?
- **6.2.3.** Develop more specific technical sampling guidance with the help of adequately qualified specialists, e.g. sampling guidance for inland waters and different types of waterbodies, with the inclusion of sediments.

Anything missing?

Q19. Do you think any issue or challenge with regards to 'inland waters' is missing from this exercise?

If so, please provide feedback below. Please make sure that you click through to the final page to record your entries, thank you.

Appendix 5.

Outcomes Question Top 3 urgent priorities

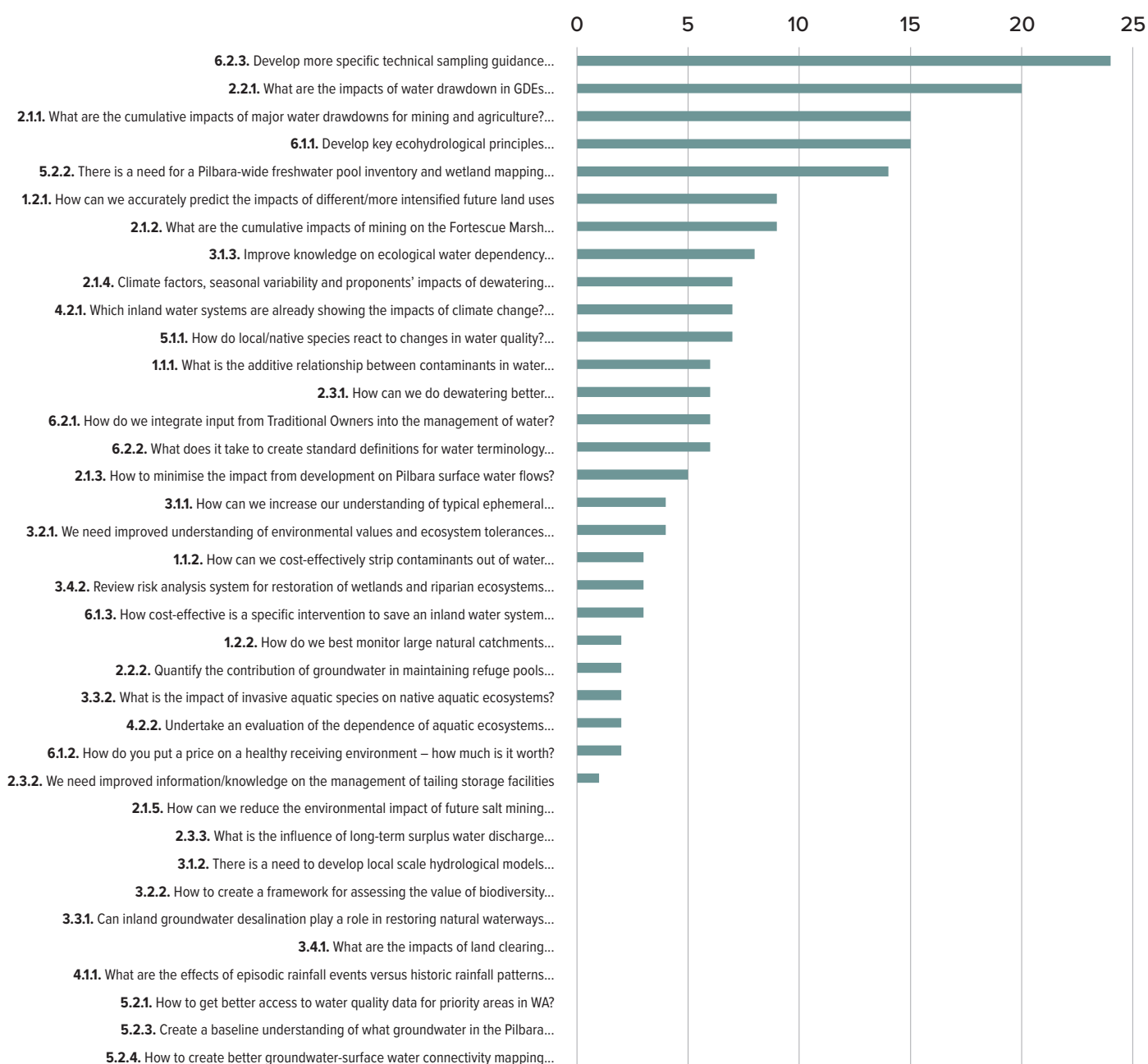


FIGURE 12. Outcomes question most urgent priorities North/Mid WA

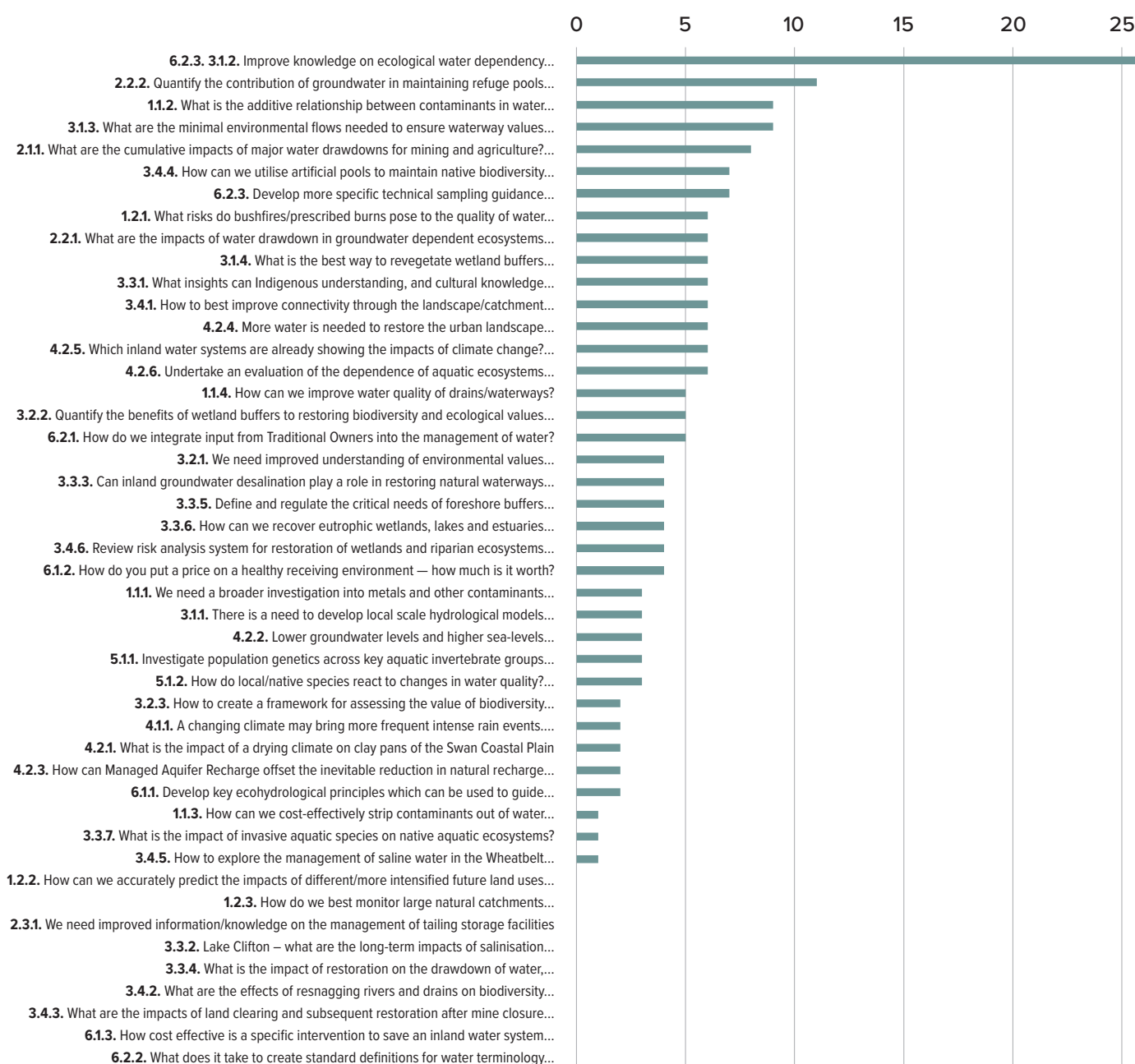


FIGURE 13. Outcomes question most urgent priorities South WA

Appendix 6.

Post prioritisation workshop engagement

After the prioritisation workshops and analysis of completed online surveys, WABSI undertook additional engagement to verify and confirm survey outcomes. The following stakeholders were consulted between January and April 2025:

TABLE 15. Stakeholders consulted after prioritisation workshops

Name	Organisation
Richard George	Department of Primary Industries and Regional Development
Josephine Searle	Department of Water and Environmental Regulation
Clare Meredith	Pilbara Ranger Network
Ebony Humble	Pilbara Ranger Network
Sally Thompson	UWA Centre for Water and Spatial Science
Pauline Grierson	University of Western Australia
Jeremy Naaykens	Rio Tinto
Jarna Kendle	NACC NRM
Sophie Querido	Edith Cowan University
Jane Chambers	Murdoch University
Rebecca Dobbs	University of Western Australia
Michelle Pyke	EnvironsKimberley
Philip Commander	Consultant Hydrogeologist





Credit: Sonja Mennen



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