Australian Government

Murray–Darling Water & Environment Research

Murray–Darling Water and Environment Research Program

Annual Progress Update 2023-24

March 2025

Contents

Cover image: Kaitlin O'Mara from Griffith University presented a poster on 'Connectivity of persistent aquatic habitat in the Darling (Baaka) River channel' at the MD-WERP Annual Symposium in June 2024.

Chair's Foreword

As we approach the end of the Murray–Darling Water and Environment Research Program (MD-WERP) our research teams are working feverishly to complete their projects, with a particular emphasis on research publication and public outreach. When the program started five years ago, we set out to affect a step change in our understanding of the interactions between climate, hydrology, ecology, economics and the social and cultural dynamics of the Basin. Our intent was to undertake research that was innovative but also highly practical because we wanted the knowledge generated to affect Basin policies and management settings. That required great diligence in planning and forging strong relationships between researchers, knowledge users in government and Basin communities. Much has been learnt and much of the new knowledge is being deployed for public benefit.

As the research projects matured there has been greater focus placed on using the outputs in the important Basin planning processes underway, most notably the Basin Plan Review. Different types of outputs are being used, including new conceptual understanding, new data sets and new predictive models that help us better understand the impacts of various management and policy options. Empowering end users in government agencies and Basin communities with these outputs is adding great value to the planning processes underway. We have redressed important knowledge gaps in 'mature' research areas like hydrology and ecology, and we have made major inroads in 'newer' research areas such as climate impacts and Basin societies and economies. Some great early steps have been taken in the area of First Nations interests and Indigenous knowledge, but much more is needed and will hopefully feature prominently in future research programs for the Basin.

In closing, I sincerely thank all of the research teams and the Basin management practitioners in the government agencies supporting MD-WERP. The breadth and depth of collaboration between these groups has been really impressive. I also want to call out the MD-WERP administration team based in the MDBA for their excellence in Program management. Keeping tabs on a large number of projects and a huge number of project deliverables has been no small feat. To my fellow Governing Panel members, I want to say a big thank you for your professionalism in governing this Program. And finally, I want to record my appreciation for the trust placed in us by the Australian Government who have generously funded MD-WERP over these last five years.

Professor Rob Vertessy

Independent Chair

MD-WERP Governing Panel

1. Introduction

The Murray–Darling Basin Water and Environment Research Program (MD-WERP; the Program) is a 5-year, up to $20 million Australian Government initiative aimed at strengthening scientific knowledge of the Murray–Darling Basin.

The MD-WERP is one of a range of measures announced by the Australian Government on 10 April 2019 in response to the findings and recommendations of the Independent assessment of the 2018-19 fish deaths in the lower Darling.[1]

The Australian Government, through the Department of Climate Change, Energy, the Environment and Water (DCCEEW) has committed to providing up to $20 million for the implementation of MD-WERP from the Sustainable Rural Water Use and Infrastructure Program. DCCEEW and the Murray–Darling Basin Authority (MDBA) have agreed through a Memorandum of Understanding (MoU) to implement the Program. The MD-WERP Governing Panel (see Section 11 Governance) has been established to oversee the implementation of the Program.

The Program is delivering 3 components:

- **Strategic research** – collaboration between the Australian Government and Research consortia (led by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and La Trobe University) to co-design, co-invest and deliver practical, applied multi-year research. Four themes were developed by researchers in collaboration with Murray–Darling Basin end users with the aim of encouraging engagement and cooperation to deliver the best possible outcomes for the Basin and to ensure the adoption of the Program's research.
    - Theme 1: Climate Adaptation
    - Theme 2: Hydrology
    - Theme 3: Environmental Outcomes
    - Theme 4: Social, Economic and Cultural Outcomes
- **Tactical projects** – delivery of short-term and responsive outputs to assist decisions and policy makers on water management, river operations, and Basin Plan implementation.
- **Communication, adoption, transparency and engagement (CATE) activities** – synthesis and explainer products for a variety of audiences, cross-theme integration or research outcomes, facilitate adoption and end-user engagement.

[1] Vertessy, R., Barma, D., Baumgartner, L., Mitrovic, S., Sheldon, F. and Bond, N (2019) *Independent assessment of the 2018-19 fish deaths in the lower Darling: Final Report*, prepared for the Australian Government.

The MD-WERP is over halfway through implementation of the research. The Program is discovering new research findings which are already supporting water managers and decision makers to plan for the future. The Program's outcomes and findings are being shared with Basin communities and industries, which will continue as more projects are completed and reported. The contents of this report demonstrate to DCCEEW that the MD-WERP is on track to achieve its objectives as set out in the MoU.

2. Key Achievements 2023-24

Strategic Research

- 4 projects completed in Theme 3 and 2 projects completed in Theme 4 (Section 5 Strategic Research Progress.
- 48 key deliverables/milestones from strategic research projects completed (Table 1).
- 14 deliverables published on the MD-WERP website (Table 1).
- 7 journal articles published, 5 journal articles submitted.
- 7 presentations at 5 conferences.

Tactical Projects

- 2 tactical project reports published on the MD-WERP website (Table 1).
- 1 tactical sub-project completed (Table 1).
- 2 tactical projects commenced (Section 6 Progress of Tactical Projects).

Communication, Adoption, Transparency, Engagement

- Delivering the 2023 and 2024 MD-WERP Annual Symposiums.
- Publication of research deliverables, and symposium livestream and posters.
- Transfer of the MD-WERP web content from Get Involved to the MDBA website.
- 1 edition of the MD-WERP e-newsletter published (Appendix 3 – MD-WERP).
- Review of the Engagement and Adoption Plan and benefits mapping.
- Contracting an external CATE delivery partner.
- Recruitment and onboarding of the MD-WERP Engagement and Adoption Lead and Science Outreach Officer.
- Engagement with End User Advisory Groups (EUAGs), river operators, MDBA's Groundwater Advisory Panel.

Table 1. Strategic research and tactical projects key deliverables/milestones in 2023-24.

Theme	Project	Key Deliverable	Status
STRATEGIC RESEARCH			
1. Climate Adaptation	FS. Climate Adaptation Foundational Science	FS3. Report on the impacts of bushfires on water availability under climate change	Completed Published
	SA. Showcasing Adaptability and Pilots	SA1. Technical paper describing the system for classification of adaptation options and adaptation investigations	Published
		SA3. Hydroclimate scenarios for use in adaptation investigation	Completed
		SA4. Synthesis report describing architecture of adaptation investigation and summary of key findings and messages	Completed
		SA5. Scoping document outlining a possible values-market related adaptation investigation	Completed
	SI. Synthesis and Implementation	SI1. Report outlining framework for Basin-wide monitoring and management	Published
		SI5. Scoping document outlining a shared approach to Indigenous involvement in Theme 1	Completed
	TK. Science Applications and Assessment Toolkit	TK4. Values and vulnerabilities report	Completed Published
		TK9. Report outlining additional functionality of the toolkit and new module developments	Completed
		TK8. Scoping document outlining how the Science Applications and Assessment Toolkit will be applied in a possible values-based adaptation investigation	Completed
2. Hydrology	RQ6. Enhancing low flow prediction to support water resources planning	6.4. Progress towards enhancing low flow predictions	Completed Published
		6.5. First draft of Report on research progress towards final deliverable 6.7	Completed
		6.6. Second draft of report and/or research paper on low flow outcomes under different flow conditions	Completed

Theme	Project	Key Deliverable	Status
	RQ7. Enhancing floodplain inundation and volume prediction to support environmental watering and water resource planning	7.3. Description and metadata for two monthly maximum flood water extent and depth for the Murray–Darling Basin	Completed
		7.4. Report on development and application of hybrid flood inundation model to several locations	Completed Published
		7.7. first draft of report of method/tool for flow prediction final deliverable 7.6	Completed
	RQ8a. Enhancing river operation outcomes using forecasts and optimisation	8a.3. Short technical report or research paper on evaluation of forecast-informed river operation for the second case study	Completed
		8a.4. Technical research paper describing benefits of forecast-informed river system operations	Completed Published
		8a.7. First draft report of deliverable 8a.5	Completed
		8a.5. Final report describing an evaluation of the value of forecasts for environmental water decision-making in the northern Basin	Completed
	RQ8b. Groundwater as an adaptation to current water resources management	8b.3. Scripts and tools developed for trend and cluster analysis, GDE analysis, salinity mapping and time series analysis	Completed Published
		8b.4. Research paper on opportunities to enhance groundwater use in the Basin	Completed Published
		8b.5. Map and spatial dataset of SW-GW interactions in key alluvial systems	Completed Published
		8b.7. First draft of report of research progress towards final deliverable 8b.6	Completed
		8b.8. Second draft of report on deliverable 8b.6	Completed
	RQ-H. Impact of hydrological non-stationarity and changing catchment conditions on runoff in the northern Basin	H.1. Technical report and/or research paper on climate and development drivers on the hydrology of the Northern Basin	Published
		H2. Hydroclimate and catchment processes impacting runoff in the northern Murray–Darling Basin	Completed Published
		H.3. First draft of report of deliverable H.4	Completed

Theme	Project	Key Deliverable	Status
3. Environmental Outcomes	RQ9.1 Drivers of ecological resilience and persistence during low and cease-to-flow conditions in the northern Murray–Darling Basin	9.1.2a. Project plan for field work	Completed
		9.1.2b. Low flow ecology of the Barwon-Darling River	Completed
		9.1.2b(1). Draft report on low flows in the northern MBD	Completed
		9.1.3. Progress report summarising Year 2 activities and outcomes	Completed
		9.1.4a. Completion of Year 3 fieldwork and data analysis	Completed
		9.1.4b. Progress report summarising Year 3 activities and outcomes	Completed
	RQ9.2 Forecasting risks to fish and their available habitat from low flows and hypoxia	9.2.1. Progress report summarising progress on data collation, field work and model simulations	Completed
		9.2.2. Summary report containing key model outputs and interpretation of results (including scenario modelling), presentation of report and factsheet	Completed
	RQ10.1 A data atlas for conservation prioritisation	10.1.3. Final geodatabase and metadata	Completed
	RQ10.2 Evaluating protection gaps and conservation prioritisation	10.2.1b. Annual progress report	Completed
		10.2.3. Finalised gap analysis report	Completed
	RQ11.1 Spatially explicit population models for fish in the Barwon–Darling river system	11.1.3. Population modelling, results, final report	Completed
	RQ11.3 Predicting change in floodplain habitat availability at the Basin scale	11.3.3. Final report	Completed Published
	RQ11.4 Assessing future vulnerability of species and ecological communities	11.4.3. Summary report, Shiny App and factsheet	Completed Published
4. Social, Economic and Cultural Outcomes	RQ12.1 The mental health benefits from improvements to riverine ecosystem health	12.1.1b. Progress report on literature review, focus group, conceptual model	Completed
		12.1.2. Progress report on questionnaire and sampling strategy	Completed
	RQ12.2 The recreational and tourism value of healthy rivers	12.2.7. Progress report Extension B: Quantifying additional economic activity from condition improvements at birdwatching sites	Completed
	RQ14.1 Basin-wide socio-economic, socio-demographic and biophysical data platform	14.1.2. Data platform (draft version) as a GIS database containing relevant temporally and spatially linked socio-economic, socio-demographic and biophysical data across the Basin	Completed

Theme	Project	Key Deliverable	Status
		14.1.3. Maps and info-graphics to show variation in socio-demographic contexts, socio-economic capitals and biophysical conditions across the Basin, and through time	Completed
	RQ14.2 Pathways to community resilience	14.2.2. Interim report on initiation stage	Completed
	RQ14.3 Navigating change	14.3.1. 50% interviews complete	Completed
	RQ14.4 Water Cultures of the MDB – ARC grant top-up	14.4.3. Detailed progress report	Completed
		14.4.4. Final project closure summary report	Completed
TACTICAL			
	TP09 Waterbirds foraging habitat	Foraging habitats for colonial nesting waterbirds in the Murray–Darling Basin	Published
	TP12 Riverbank Stability and Erosion	TP12b. Communicating current knowledge on bank erosion along the River Murray	Completed
	TP13 Summary and analysis of blue-green algal trends in the Basin	Synthesis of Blue Green Algae (Cyanobacteria) bloom knowledge and analysis of recent trends in the MDB	Published

3. Progress Towards Program Objectives

1. Invest in applied research that delivers better informed environmental water management decisions by Commonwealth agencies and improved outcomes for communities.

The mid-term evaluation found that the MD-WERP research is well balanced and likely to produce new knowledge of relevance to the Basin Plan Review and other Australian government policy and management needs (Section 9 Monitoring, Evaluation, Reporting and Improvement).

- The research is enhancing our ability to assess and compare the outcomes of adaptation options for catchment and Basin-scale water planning under a changing climate.
- New methodologies that improve the simulation of low flows in both regulated and unregulated river systems have been developed. These improved models are being tested on selected river reaches and if integrated into existing river system models, the research can support more accurate predictions of low flow conditions, thereby enabling more effective water resource management and planning to sustain environmental and community needs.
- Research is showing the importance of incorporating diverse stakeholder perspectives to develop comprehensive strategies that recognise the multifaceted values of water.

2. Maximise value to water reform and management from investment.

Benefits realisation and impact of the research is continuing, delivering value to the policy and program outcomes.

- The Murray–Darling Basin Sustainable Yields 2 study will incorporate the investigations into impacts of farm dams and bush fires on water availability under climate change analysis of non-stationarity in rainfall-runoff relationships.
- The farm dams analysis is being considered by an intergovernmental working group canvassing options for improvement of accounting practices for take from farm dams. The report will also be the subject of future engagement with the Inspector-General of Water Compliance (IGWC) 'Risk Assessment of Modelled Take' project currently being undertaken with support from the University of Melbourne.
- The MDBA is currently integrating the Theme 1 toolkit into the analytical framework for assessing the environmentally sustainable level of take (ESLT). Work on the toolkit has also catalysed further internal MDBA engagement with programs including the Integrated River Model Uplift and Enhanced Environmental Water Delivery Program.

- Application case studies have been developed to demonstrate opportunities for water forecasts to inform decision making to support river operation and environmental watering.
- The Theme 3 data atlas for conservation prioritisation is a compilation of spatial layers of assets, functions, and values in the MDB to inform a gap analysis, vulnerability assessment, and conservation prioritisation analyses.
- The Theme 4 data platform has organised a broad range of data sources and indicators into social capital subsets for ease of analysis and reporting conditions related to social wellbeing. Maps and info-graphics will provide useful entry points for discussions with Basin communities around topics such as water literacy, emergent understandings of the importance and value of water in all its forms, and the multiple pathways through which improvements in the condition of rivers, lakes, wetlands and floodplains can enhance mental health and increase economic activity.

3. Leverage co-investment with research providers and key stakeholders.

The consortia bring $7 million of their own resources and numerous multi-disciplinary collaborators, significantly extending the reach of the program and contributing to the program's strategic objective to leverage co-investment.

- In 2023-24 the Research Consortia in-kind contribution was equivalent to 60% of the Australian Government cash investment in MD-WERP (Section 5 Financial Summary).
- The MDBA Basin Condition Monitoring Program is investing $180,000 in a complementary project engaging with the Barkandji Nation, to build up a body of local knowledge, attributes and values (including cultural, historical and environmental) aligned to features on historic Darling River paddle-steamer navigation scrolls.

4. Facilitate adoption of research by advancing cooperation between users and researchers.

The path to adoption of the new knowledge being generated by MD-WERP is being guided by the Engagement and Adoption Plan (Section 8 Communication, Adoption, Transparency and Engagement).

- End-users (MDBA, CEWH, DCCEEW) are confident that the Program's outputs will be of use to them (Section 9 Monitoring, Evaluation, Reporting and Improvement).
- Discussions between the Research and Commonwealth Theme leads indicate that collaboration has been very effective and should result in research outputs that are both high quality and focused on end-user needs (Section 9 Monitoring, Evaluation, Reporting and Improvement).

- A regular avenue of communication between researchers and end-users is being maintained to provide timely feedback on the development and delivery of the research via the end-user advisory groups (Section 8 Communication, Adoption, Transparency and Engagement).
- Regular meetings of the Science Leadership Team, a transdisciplinary group of end users and research leaders promoting thought leadership (Section 11 Governance).
- An external CATE delivery partner is being engaged to advise on how to best activate end-user engagement and championing, and assist in end-user agencies transitioning from interested observers to active users of the research.

5. Be a platform from which to launch a more enduring research program that supports effective water management over the long term.

The MDBA is developing a 10-year science strategy that will draw on the experience of MD-WERP and knowledge gaps that have been identified through the research. Additionally, the CATE delivery partner will facilitate cross-theme workshops to generate ideas for integrating research outcomes as a foundation for future research programs.

4. Policy and Program Outcomes

The objective of the MD-WERP is to advance knowledge, understanding and response options for water and environmental management in the Murray–Darling Basin, and improve the investment in, and the coordination of, applied research and knowledge generation. A focus of the program is applied research that serves the information needs associated with Basin Plan implementation.

The program aims to generate new knowledge to support adaptive management to improve water policy, reduce risk in management decisions and enhance outcomes of water management. The primary areas where the program is expected to deliver value are set out below.

Policy Outcomes

Adaptive management activities and policy responses rely on knowledge to address climate change threats to water resources and ecosystems.

The Basin Plan is founded on complementary adaptive management activities which are informed by specific statutory reviews (for example the 2023 Productivity Commission inquiry, the 2025 Basin Plan Evaluation, and the 2026 Basin Plan Review). These adaptive management activities depend on an evolving body of knowledge such as that being

generated by MD-WERP, both to evaluate the contribution of actions to achieving Basin Plan objectives and to identify appropriate policy responses.

Policies must recognise the interconnectedness of water, land use, and community needs. The research from MD-WERP can support the development of integrative policies by providing data and models that help policymakers understand the complex interactions between water resources, ecosystems, and human activities.

How the research can deliver value

Theme 1 is developing a comprehensive vulnerability assessment framework to identify the Basin's economic, social, environmental, and cultural values that are most vulnerable to flow-related impacts of a changing climate. The research highlights specific values at risk, such as agricultural productivity, ecosystem health, and community wellbeing. This nuanced understanding of vulnerabilities may inform targeted adaptation strategies to protect and enhance the resilience of these critical values in the face of climate change.

Through assessing the potential outcomes of adaptation strategies against projected climate scenarios, the research can inform decision-makers on the most effective approaches to enhance resilience and safeguard the Basin's critical values in the face of climate change.

The Theme 1 research will enhance our ability to assess and compare the outcomes of adaptation options for catchment and Basin-scale water planning under a changing climate. Strategically selected case studies identify and explore adaptation pathways at multiple scales and across values, including through community participation

Theme 2 is delivering robust knowledge and modelling of hydrological and water resources characteristics to inform water resources management and planning. This includes improving our understanding, quantification and communication of drivers of northern Basin hydrology.

The research from Theme 3 includes predicting aquatic ecosystem health and responses to changes in flow by developing integrated models that combine hydrological, ecological, and biogeochemical data. These models utilise historical flow data, water quality metrics, and biological indicators to assess ecosystem conditions and forecast potential impacts of varying flow scenarios. Through the incorporation of factors such as temperature, dissolved oxygen, and habitat connectivity, the research will enable the identification of critical thresholds and ecological responses to changes in flow. This predictive capability can support proactive management strategies aimed at maintaining ecosystem health and resilience in the face of changing hydrological conditions.

The research from Theme 3 (RQ9) addresses the question of low flow needs of the environment by identifying critical ecological requirements during low flow periods, particularly in river systems like the Barwon-Darling. It emphasises the importance of understanding specific low flow metrics that support biodiversity, water quality, and habitat

connectivity. The research highlights that maintaining adequate low flows is essential for sustaining aquatic ecosystems, as these flows influence key ecological processes such as nutrient cycling, habitat availability, and the health of fish populations. Through the development of methods to predict and manage low flows, the research can inform water resource planning and environmental management, ensuring that ecological needs are met even during periods of reduced water availability.

The Theme 4 (RQ14) research is showing the importance of incorporating diverse stakeholder perspectives to develop comprehensive strategies that recognise the multifaceted values of water. By prioritising community-led initiatives and promoting sustainable practices, these communities can better navigate the challenges posed by reduced water availability and environmental change.

Risk Management Outcomes

Improved knowledge enhances the capacity to manage risks from reduced water availability and increased extreme events.

The Basin Plan requires the MDBA and the Basin states to identify and manage risks to the condition of or the continued availability of Basin water resources. It is expected that under current and future climates water availability in the Basin will, on average, be reduced and more variable. This will lead to increased uncertainty and risk in water management.

How the research can deliver value

The research from Theme 1 is exploring how other threats, such as land-use changes, bushfires, invasive species, and socio-economic pressures, interact with a changing climate to exacerbate vulnerabilities within the Basin. Theme 1 is employing a systems-based approach, assessing the cumulative impacts of these stressors on water resources and associated values. It will improve our understanding of the water-related impacts of the future climate, both through direct (i.e. hydrological) and indirect (e.g. bushfires) changes.

Theme 2 is exploring opportunities for water security in key alluvial aquifers where most of the groundwater extraction takes place (RQ8b). It is also enhancing our ability to predict and model low flows to inform water resource and risk management (RQ6).

By analysing representation gaps and assessing vulnerabilities to threats like climate change and flow alteration, the Theme 3 (RQ10) research will provide a framework for targeting management actions that effectively protect and restore representative populations and communities of native flora and fauna. This prioritisation will assist conservation efforts to strategically focus on the most critical ecosystems, maximising the benefits for biodiversity and ecological health.

Improved predictive capability using models and tools will also allow research end-users to understand the spatial distribution of environmental assets and values, how they respond over time to water management, and the risks to future species population and ecosystem sustainability.

The research from Theme 4 (RQ12) is demonstrating that the condition of the riverine ecosystem is closely linked to social, economic, and cultural values, particularly the impact of river condition on mental health outcomes and tourism. Healthier river environments contribute positively to the mental well-being of communities by providing opportunities for recreation and connection to nature, which can reduce stress and enhance life satisfaction. Furthermore, the research demonstrates that improved river health can lead to increased tourism visitation and expenditure, as visitors are drawn to vibrant ecosystems for activities such as bird watching, thereby benefiting local economies. This interplay underscores the importance of maintaining riverine health to support both community well-being and economic vitality through tourism.

River Operations and Water Management Outcomes

Better information leads to more effective operational planning and real-time decision-making for water delivery and management.

Operational decisions will also benefit from the knowledge generated by the program. There is a sophisticated set of operational decisions that are made to deliver water effectively to users and to deal with operational constraints in the system. Better information on water needs, flow regimes, water forecasting, ground-surface water connectivity, constraints and changing circumstances can lead to better operational planning and real-time decision making.

How the research can deliver value

Theme 1 is developing tools to enable the Australian Government to evaluate potential water management arrangements. This includes a comprehensive assessment toolkit that incorporates both qualitative and quantitative metrics to evaluate the effectiveness of water management arrangements. The toolkit will allow for the systematic evaluation of various management strategies against specific performance indicators related to environmental, economic, social, and cultural outcomes.

Theme 2 is enhancing floodplain and low flow prediction and modelling to inform environmental watering and water resources management, exploring new applications of water forecasts and improving our knowledge of groundwater use to enhance water resources management.

The research from Theme 2 (RQ6) is developing new methodologies that improve the simulation of low flows in both regulated and unregulated river systems. This involves refining hydrological models to better represent the interactions between surface water and groundwater, accounting for uncertainties in low flow observations, and establishing consistent low flow metrics that inform ecological outcomes. These improved models are being tested on selected river reaches and by integrating these findings into existing river system models, the research can support more accurate predictions of low flow conditions, thereby enabling more effective water resource management and planning to sustain environmental and community needs.

Hybrid modelling integrating remote sensing data with hydrological modelling techniques (RQ7) is improving the prediction of floodplain flow volumes, components, and inundations. This approach allows for enhanced accuracy of floodplain inundation extent, depth and duration estimates by simulating the water balance across floodplains and analysing the interactions between river flows and floodplain characteristics. The research will provide valuable insights into how environmental watering can be optimised under varying climatic and operational scenarios, by understanding the relationships between flow hydrographs and floodplain responses.

The research from Theme 2 (RQ8a) will provide a framework for optimising river operations in response to changing climate conditions and water availability challenges. Adaptation through enhanced river operations management can improve water outcomes by integrating advanced forecasting techniques and optimisation methods into river management practices. By utilising ensemble water forecasts, the research will enable river operators to make more informed decisions regarding water allocations, environmental flow releases, and flood management. A proactive approach allows for better coordination of water delivery to meet both consumptive and environmental demands, ultimately leading to more efficient use of water resources and improved ecological health of river systems.

Theme 2 (RQ8b) is also enhancing our understanding of groundwater management by integrating resilience, stress, and sustainability indicators into water resource practices. The research is providing critical insights into the health and sustainability of groundwater systems through the analysis of long-term groundwater level trends, groundwater use patterns, and the identification of priority aquifers. This knowledge will inform better decision-making in water resource management, enabling the development of strategies such as Managed Aquifer Recharge and conjunctive use of surface and groundwater. These insights can support the optimisation of water resource practices to ensure the sustainable use of groundwater, mitigate stress on aquifers, and support ecological and community needs in the face of climate variability and increasing water demands.

Theme 2 (RQ-H) is combining data analysis, hydrological modelling, and innovative analytical frameworks to address the challenge of disentangling and modelling the impacts of climate and development drivers on the hydrology of the Basin. Through a literature review and

integration of various data sources, the research identifies key climate variables and development factors that influence hydrological responses. Additionally, the research utilises advanced modelling techniques to simulate the interactions between these drivers and hydrological processes, allowing for a comprehensive understanding of the cumulative effects on water availability and flow patterns. This approach will facilitate the identification of critical knowledge gaps and uncertainties, ultimately improving the capacity to predict hydrological changes and inform water management strategies in response to both climate change and human development pressures.

Theme 3 (RQ11) is developing methods to predict and manage low flows, which can inform water resource planning and environmental management, ensuring that ecological needs are met even during periods of reduced water availability.

The research from Theme 4 (RQ14) is suggesting that communities can adapt to and become more resilient to a future with less water by fostering strong social networks, enhancing economic diversity, and receiving support to collaborate in the decision-making processes around river management. Resilient communities are characterised by their ability to leverage local knowledge, maintain social cohesion, and access resources that support adaptive capacity, such as education and infrastructure.

The tactical projects underway are also contributing to river operations and water management outcomes (Section 7 Progress of Tactical Projects).

5. Strategic Research Progress

The Strategic Research component consists of applied research investments delivered by a collaboration between the Australian Government and the MD-WERP Research Consortium. The 2 consortia are led by CSIRO and La Trobe University, each with additional collaborators – CSIRO have partnered with Deakin University; La Trobe University have partnered with Griffith University, the University of Canberra, Macquarie University and Sarah Martin Consultant Archaeologist.

Theme 1: Climate Adaptation

The Murray–Darling Basin is one of the world's most variable hydroclimate regions. Catchment inflow can be more than 20 times greater in a wet year than in a dry year. The system also faces profound future challenges to adapt to a hotter, drier climate. The Climate Adaptation Theme will address 5 research questions (Table 2) with the aims:

- better understand how climate change will impact the Murray–Darling Basin
- identify and evaluate options to adapt to change
- evaluate potential outcomes for Basin values.

Table 2. Summary of key research questions (RQ), outputs and outcomes for the climate adaptation theme.

Key questions	Key outputs and outcomes
RQ1. Which of the Basin's economic, social, environmental, and cultural values are most vulnerable to the flow-related impacts of climate change? RQ2. How do other threats interact with climate change to affect vulnerabilities? RQ3. What is the best way to evaluate the effectiveness of water management arrangements to manage risks, including climate change? RQ4. What adaptation options can provide better protection to vulnerable values in the Basin? RQ5. How do we undertake climate adaptation at regional scales that are most relevant to communities and environmental assets?	An improved understanding of the water-related impacts of the future climate, both through direct (that is, hydrological) and indirect (for example bushfires) changes. An enhanced ability to assess and compare the outcomes of adaptation options for catchment and Basin-scale water planning under climate change. 4 to 6 strategically selected case studies to identify and explore adaptation pathways at multiple scales and across values, including through community participation. Develop tools to enable the Australian Government to evaluate potential water management arrangements.

Due to the inter-related and overlapping nature of these research questions, 4 projects were designed to address 5 research questions holistically.

- The **Climate Adaptation Foundational Science** (FS) project is developing modelling methods to provide insights into the indirect impacts of climate change on water supply, demand and management.
- The **Showcasing Adaptability and Pilots** (SA) project is investigating adaptation to climate change in the including identifying adaptation options and assessing their potential impacts on Basin values through a series of case-studies.
- The **Synthesis and Implementation** (SI) project is synthesising outputs and learnings from the main research activities to ensure understanding of processes and constraints and develop acceptance of tools and address potential mismatch of scale of research and decision making.
- The **Science Applications and Assessment Toolkit** (TK) project is enhancing the ability of the Australian Government, and other stakeholders, to identify and assess the likely future impacts of climate change across social, environmental and economic values in the Basin.

Key outputs and outcomes for the climate adaptation theme

- An improved understanding of water-related impacts of the future climate, both through direct (i.e. hydrological) and indirect (e.g. bushfires) changes.

- An enhanced ability to assess and compare the outcomes of adaptation options for catchment and Basin-scale water planning under a changing climate.
- Strategically selected case studies to identify and explore adaptation pathways at multiple scales and across values, including through community participation.
- Develop tools to enable the Australian Government to evaluate potential water management arrangements.
- Synthesis of climate adaptation research and capacity development.

Progress and Achievements

Each project under the climate adaptation theme has progressed well across the reporting period. The body of work produced by the theme (including over previous years) is increasingly influencing Basin planning and management as adoption and uptake activities increase.

At the end of 2023-24 there were 27 key deliverables for the climate adaptation theme, of which:

- 16 have been completed, with 8 of these in Year 3 (2023-24)
- 11 are on track to be completed in Year 4
- one was a new deliverable (TK10) approved by the Governing Panel for completion in Year 4.

Foundational Science (FS)

This project aims to provide insights into the indirect impacts of climate change on water supply, demand and management within the Basin. This year the project has one new deliverable – a report on the sensitivity of hydroclimate projections to non-stationarity hydrological processes (T1.FS4 Understanding the impacts of hydrological non-stationarity on runoff). The assessment of the sensitivity of hydroclimate projections to non-stationarity hydrological processes has followed two lines of investigation.

The first investigation related to the impacts of using short records of streamflow observations to calibrate hydrological models for generating hydroclimate projections. Computational experiments were undertaken to assess hydroclimate projection sensitivity to the length of record used to calibrate hydrological models and the statistical characteristics of the calibration periods. This work has shown that there is variable sensitivity of hydroclimate projections to the period of calibration across the Basin. Projections are least sensitive to the calibration period in the high rainfall areas in the southeast of the Basin and sensitivity increases to the west and north. Projections of mean annual total flow tend to be less sensitive to calibration periods relative that indicators of high and low flow. Projections from different hydrological models variably sensitivity to calibration periods, with models showing stronger elasticity of runoff to rainfall tending to be more sensitive.

The second line of investigation sought to address limitations in the ability of existing rainfall models to model changes in rainfall-runoff responses under dry conditions. The Data Assimilation Informed model Structure Improvement (DAISI) approach has been developed to refine the structure of calibrated hydrological models and shown to improve the ability of simulations from the GR2M monthly rainfall-runoff model to characterise changes in rainfall-runoff processes. The DAISI approach has also been applied to refine the structure of a daily rainfall-runoff model.

Preliminary scoping of methods on the next investigation on the impacts of climate change on hypoxic blackwater events has identified that a high-level risk assessment is an appropriate way forward, and that the study should consider the risks of low dissolved oxygen events in the northern Basin in addition to blackwater events.

Showcasing Adaptability and Pilots (SA)

This project aims to investigate adaptation to climate change in the MDB including identifying adaptation options and assessing their potential impacts on Basin values through a series of case-studies. This year, the project is completing the hydroclimate analysis adaptation investigation in the Macquarie catchment and commencing the water trade adaptation investigation in the southern Basin.

The Hydroclimate Analysis Adaptability Investigation has investigated the impacts of changing environmental water management and the recovery of water for environmental water as climate adaptation options in the Macquarie River catchments. These adoption options were identified collaboratively with the project steering group (consisting of representatives from NSW DCCEEW, MDBA and CEWH). Partners are continuing to be engaged through identifying river-system model improvements, adaptation options and in the interpretation of project output.

Modifications have been made to the NSW Macquarie River IQQM model which represent these adaptations and simulations under a wide range of climate scenarios generated. Analysis of the model output has included assessments of the catchment water balances, streamflow characteristics at stream gauges of interest, Environmental Water Requirement (EWR) metrics, water allocations and agricultural economic benefits. Results are indicating that, under a drying climate scenario and the strategies investigated, the impacts on EWRs are likely to be substantially larger than can be mitigated by changed water management or recovery of water for the environment.

The Water Trade Adaptability Investigation has been co-designed with key stakeholders within MDBA and ABARES (Australian Bureau of Agricultural and Resource Economics) to ensure that the scope is relevant and complements other existing programs (e.g. MDB Outlook). The project commenced with a process of stakeholder interviews identifying possible trends for future adaptation using water trade and to highlight existing opinions regarding the current efficacy of the practice. A draft report summarising stakeholder

interviews has been completed, with findings used to identify possible adaptations to further investigate through more detailed modelling. A series of scenarios to determine how different relative levels of water trade might influence water prices and reliability under three climate scenarios are now being modelled by ABARES using their water trade model.

Synthesis and Implementation (SI)

This project aims to ensure understanding of processes and constraints, develop acceptance of tools, and address potential mismatch of scale of research and decision making by synthesising outputs and learnings from the main research activities.

In 2023-24 the project has focused on working with First Nations peoples to develop a Traditional Owner-led co-designed approach to evaluating the impact of climate and water management changes on cultural values. The project team met with the Ngiyampaa Ngemba Wangaaypuwan Wayilwan (NNWW) Native Title applicant group[2] face-to-face in Nyngan during October 2023 where it was agreed that there would be ongoing interaction, including a 2-3 day on-country workshop and necessary preworkshop planning meetings. Over the last 6 months of the reporting period the Applicant group have been focussed on preparing their Native Title claim and as a result a variation to delay the project deliverable was approved by the Governing Panel. The MD-WERP project team have maintained contact with the Applicant group, solidifying relationships.

Science Applications and Assessment Toolkit (TK)

The project is intended to enhance the ability of the Commonwealth, and other stakeholders, to identify and assess the likely future impacts of climate change across social, environmental and economic values in the Basin, and to identify potential adaptation options and assess the outcomes associated with adopting them.

Progress has focused on refining the modular toolkit package and establishing workflows to use it with hydrologic modelling and on an ad-hoc basis across different computer systems. Further work has continued refining demonstrations of capabilities, both on the now-live website and for a demonstration paper which is in the final stages of preparation. The toolkit developments have been focused on:

- increasing the range of synthesis and visualisation features, associated with applications of the toolkit for a flow scaling demonstration
- the Basin Plan Review Environmentally Sustainable Level of Take (ESLT) Alpha and Beta program phases

[2] The Ngiyampaa Ngemba Wangaaypuwan Wayilwan (NNWW) Native Title applicant group are the elected representatives of the Traditional Owners covering the northern Macquarie River Basin, and particularly the Macquarie Marshes.

- the Macquarie Showcasing AdaptAbility Investigation (T1.SA3, T1.SA4 and T1.SA7).

The project team also developed an economic tool assessing the relative agricultural benefits of different scenarios in the Macquarie River catchment. The tool is supporting the assessment of impacts of changing water availability due to climate and management changes on the regional economy, primarily through impacts on agriculture. At the core of the economic tool is a hydro-economic model that optimises water use across sectors to maximise economic benefits, subject to a range of constraints. The model is currently being applied and refined as a part of the Macquarie Showcasing AdaptAbility Investigation.

Case Studies

TK. Applying HydroBOT, the climate assessment toolkit to the Macquarie Catchment

The HydroBOT toolkit aims to model environmental, social, and economic responses to hydrology, synthesising these responses to generate actionable insights for the MDBA. River flows affect a wide array of values, and the toolkit uses both historical and modelled flows as inputs for response models. The outputs from these models are then aggregated, analysed, and presented using consistent methods, resulting in graphics and other outputs that support decision making. Key features of the toolkit include modularity, allowing different components to be operated independently; reproducibility, which encompasses self-documentation; and consistency, ensuring a unified approach to analysing various hydrological responses.

The Macquarie Catchment in NSW was used as a case study to explore the potential impacts of climate change on water allocations, agricultural benefits, and key environmental outcomes. This analysis helped identify which values were most vulnerable to climate change and whether management actions, such as adjustments to the quantity and use of environmental water, could mitigate that vulnerability. Under severe climate change scenarios, environmental outcomes were seldom achieved, while the impact on agricultural benefits was less pronounced. Annual cropping dependent on low-security water allocations was found to be the most vulnerable. In contrast, under more probable moderate climate change, modifying flow delivery patterns proved as effective as changing the total licensed volume of environmental water, without negatively impacting agricultural benefits. Therefore, effective environmental water management has the potential to enhance environmental outcomes while still meeting essential economic needs.

FS4 Understanding the impacts of hydrological non-stationarity on climate change projections

Hydrologic non-stationarities are changes in the statistical properties of time series and in the relationship between variables, e.g. rainfall and runoff, and challenge many assumptions made in hydrological analysis and modelling undertaken to support water resource

management. The origins of hydrologic non-stationarities include global warming, vegetation change, water resources development activities, and the cumulative impact of interactions between changing surface and sub-surface processes. While there has been considerable research diagnosing non-stationarity in hydrological time series and simulations of rainfall-runoff models, there have been few assessments of the impacts of non-stationarity on runoff projections. The Foundational Science project of the Climate Adaption Theme has investigated the likely impacts of hydrologic non-stationarity on runoff projections for the Murray–Darling Basin.

Using hydrological modelling experiments, the study found that runoff projections are sensitive to hydrologic non-stationarity. The sensitivity of runoff projections to hydrologic non-stationarity is spatially variable and dependent on the hydrological model used. However, it was found that modelling the effects of hydrological non-stationarity may increase the range of projected changes in mean annual runoff by up to 20% for many catchments.

This study is providing evidence to support the interpretation of hydrological modelling and analysis for Sustainable Yields 2 and the Basin Plan Review.

Pathway to Impact

The FS project investigations into impacts of farm dams and bushfires on water availability under climate change has now been complemented by an analysis of non-stationarity in rainfall-runoff relationships. This work will be incorporated into the Murray–Darling Basin Sustainable Yields 2 study.

The farm dams analysis is also being considered by an intergovernmental working group canvassing options for improvement of accounting practices for take from farm dams. The report will also be the subject of future engagement with the Inspector-General of Water Compliance (IGWC) 'Risk Assessment of Modelled Take' project currently being undertaken with support from the University of Melbourne.

The Climate Adaptation theme has sought additional engagement on the Macquarie hydroclimate case study via a workshop between MDBA, researchers and NSW state government.

The TK project is on track to enhance capability to assess the impact of climate change and options for adaption measures. The MDBA is currently integrating the toolkit into the analytical framework for assessing the ESLT. Work on the toolkit has also catalysed further internal MDBA engagement with programs including the Integrated River Model Uplift and Enhanced Environmental Water Delivery Program.

Three journal articles were published in 2023-24, and two journal articles were submitted for peer review (see Appendix 2 – List of Journal Publications). Research from Theme 1 was also

presented at the 25th International Congress on Modelling and Simulation (MODSIM2023) and 68th Annual Conference of The Australasian Agricultural & Resource Economics Society.

CSIRO also presented more broadly on the hydroclimate work at the 5th World's Large Rivers Conference August 2023, 79th Murray Darling Association Conference in September 2023, and EGU24 General Assembly in April 2024.

Theme 2: Hydrology

Robust knowledge and modelling of hydrological and water resources characteristics under current and future climates is essential to inform water resources management and planning. The hydrology theme is addressing the research questions in Table 3.

The first 2 research questions aim to enhance prediction at the ends of the flow spectrum: low flow and floodplain flow. The third research question is exploring and demonstrating adaptation to enhance hydrological outcomes from the same amount of available water. The fourth research question links to Tactical Project 6.1 examining the causes of reduced flow in the northern Basin.

Table 3. Summary of key research questions (RQ), outputs and outcomes for the hydrology theme.

Key questions	Key outputs and outcomes
RQ6. How can low flow prediction be improved to support water resources management planning?	Enhanced low flow prediction and modelling to inform water resources management.
RQ7. How can floodplain flow volumes, components, and inundation prediction be improved to support environmental watering and water resources planning?	Enhanced floodplain flow prediction to inform environmental watering and water resources management.
RQ8. How can adaptation through enhanced river operations and water resources management improve water outcomes?	Knowledge of water forecasting application and groundwater use to enhance water resources management.
RQ-H. How can we better disentangle and model the impacts of climate and development drivers on the hydrology of the Basin?	Improved understanding, quantification and communication of drivers of northern Basin hydrology.

Key outputs and outcomes for the hydrology theme

- Enhanced low flow prediction and modelling to inform water resources management.
- Enhanced floodplain flow prediction to inform environmental watering and water resources management.
- Exploring new applications of water forecasts.
- Knowledge of groundwater use to enhance water resources management.

- Improved understanding, quantification and communication of drivers of northern Basin hydrology.

Progress and Achievements

A key strength of the Hydrology theme is the strong partnership between the CSIRO and MDBA. There is also a dedicated MDBA technical expert embedded into each of the research projects to enhance collaboration, uptake of research outputs, and build capability.

At the end of 2023-24 there were 23 key deliverables for the hydrology theme, of which:

- 18 have been completed, with 7 of these in Year 3 (2023-24)
- 5 are on track to be completed in Year 4
- 4 are new deliverables approved by the Governing Panel (8a.5, 8a.6, 8b.6, H.3)
- 1 is a new component (RQ-F) approved by the Governing Panel for completion in Year 4.

Enhancing low flow prediction to support water resources planning (RQ6)

In Year 3 this project focussed on further development and testing of new low flow parameterisation (conceptualisation of bed and bank storage, surface-groundwater gains/losses, dead store to represent waterholes) on river reaches in the northern Basin. The algorithm for river reach scale water exchange function (developed in Year 2) was improved by adding a dead store to represent waterholes. Results show that the new algorithm is improving the low flow simulations at little expense of the overall flow simulation.

Enhancing floodplain inundation and volume prediction to support environmental watering and water resource planning (RQ7)

The development of the remote sensing-based flood inundation model is near completion. The model was tested on four key river reaches and a full-day workshop was held to train all team members (including the MDBA) on the modelling. The MDBA modeller embedded in the project team has been actively involved in the testing, debugging, and validating of the model results using a fifth river reach as a testing region.

The model has been further improved for Basin-wide water extent detection from remotely sensed images and Basin-wide water depth estimation using the state-of-art methods and best available digital elevation model (DEM). The latest version of Multi-Index Method (MIM V2.0) has implemented better cloud cover detection, better wetland mapping and consolidated mask files. Tests have been done to ensure the best spatial match between the Landsat MIM and Sentinel-2 MIM to create a seamless water extent product. The project team also collaborated with Geoscience Australia to improve the identification of water under vegetation using an innovative dynamic threshold that accounts for the additional shortwave infrared reflectance caused by the presence of tree canopies over floodwater.

The project team is in the process of publishing the next version of the maximum flood water depth for the MDB:

- Using the latest updated DEM data with integration of bathymetry for large lakes and main river channels
- Using better water extent mapping with MIM V2
- incorporation of Sentinel-2 data
- providing monthly estimates (rather than two-monthly) from 2016.

Additionally, the project team analysed the history of flood inundation in the Basin and explored its connection to current and future climates. They quantitatively assessed inundation frequency and trends over 35 years (1988–2022), and characterised this 35-year perspective of inundation using modelled runoff and compared it with a historical 123-year period (1900-2022) and future climate change projections. The results have been summarised in a journal paper currently under review.

This project is being undertaken in close partnership with the MDBA, which is actively engaging with other key stakeholders, particularly the CEWH and Basin States. The project team has collaborated with the MDBA to establish the datasets, including bathymetry for large lakes and river channels.

Enhancing river operation outcomes using water forecasts and optimisation (RQ8a)

This project aims to demonstrate how water forecasts can inform river operation decision-making in the Murray–Darling Basin, e.g. decisions on dam releases and environmental water delivery. During 2023-24, the project team worked on completing case study 2 (Producing forecast of event streamflow volume to support CEWO decision-making on environmental water delivery to the Narran Lakes) and commencing case study 3 (Understanding how seasonal forecast inflow to Hume and Dartmouth reservoirs can inform dam filling and airspace management during wet conditions).

Case study 2 seeks to understand how best to produce forecasts of streamflow event volumes to support the CEWH decision-making related to the delivery of environmental water to the Narran Lakes in the northern Basin. The project has assessed the value of two forecasting products, a bespoke hydrological forecasting model for the Condamine-Balonne River to the St. George gauge, that was established during Year 2, and the use of the Bureau of Meteorology's Australian Water Outlook (AWO) seasonal forecast product. Improvements in the skill of the bespoke forecasting model have been made by using SILO, rather than Australian Gridded Climate Data (AGCD), rainfall forcing and refining the model calibration strategy. AWO hindcasts were verified and subsequently post-processed to reduce forecast bias and improve skill.

Overall evaluation indicates that the bespoke model produces the most skilful forecast to lead times of up to 15 days, which is commensurate with the CEWH decision-making time

frames. The AWO, even when post-processed, offer little skill. The key conclusion from the case study is that a tailored forecasting system is required to produce forecasts with sufficient skill to support CEWH decision-making.

Case study 3 seeks to understand how sub-seasonal to annual forecasts inflows to Hume and Dartmouth Reservoirs can inform dam filling and airspace management during wet conditions. The case study is working closely with MDBA river operators to ensure a common understanding of current decision-making practice and how forecasts may assist. The case study has commenced with long-range forecasting models being developed for three reservoir inflow time series, Hume Natural inflow, Hume Unregulated inflow and Dartmouth inflow. Models to forecast monthly inflow to lead times of 12 months have been developed and an archive of forecasts extending from 1981 to 2023 established. Forecast verification results indicate there is skill in monthly totals and accumulations to lead times of 12 months, with skill tending to decrease with lead time. The next steps will be to compare the forecasts to the output of the existing decision support tool that estimates minimum inflow according to a 'serially correlated minimum inflow'

Groundwater as an adaptation to current water resources management (RQ8b)

This project is improving understanding of causality of a decreasing trend in groundwater levels using machine learning methods and assessing the potential for managed aquifer recharge (MAR). The covariates considered for causal attribution include groundwater extraction, rainfall and evapotranspiration. The proof-of-concept analysis of causal attribution using a trained and tested neural network model was completed and the results published in a journal paper (Fu et al, 2023) demonstrating the applicability of the approach.

Groundwater level data at the monthly temporal resolution for the SDL units was evaluated for availability and suitability for trend analysis. Four SDLs (Lower Namoi Alluvium (GS29), Lower Murrumbidgee Deep Alluvium (GS28b), Goulburn-Murray: Sedimentary Plain (GS8c) and Goulburn-Murray: Shepparton Irrigation Region (GS8a)) have been selected for the causal attribution analysis based on data availability.

The groundwater level trend analysis was used to interpolate trend surfaces, rather than surfaces based on static point-in-time or exceedance probability analysis. A stochastic spatial screening framework was also introduced to account for uncertainty and to estimate storage capacity in unconfined and confined aquifer conditions. A financial cost assessment methodology that accounts for uncertainty was developed to estimate costs of MAR using infiltration basins and injection wells. The spatial assessment of MAR potential will be used to develop one or more conceptual MAR site configurations. Implementation strategies will be discussed with respect to recent research on possible frameworks and policy settings.

Drivers of northern Basin hydrology (RQ-H)

The objective of this project is to understand the influence of climate and catchment processes on runoff in the northern Basin. Research in 2023-24 has focused on four key activity areas:

1. **Changes in weather systems and rainfall characteristics affecting runoff.** Attributions of rainfall anomaly (seasonal and monthly rainfall, extreme rainfall, dry and wet spell-lengths) to the long-term changes (1979 to 2015) in weather systems have been characterised and assessed.
2. **Analysis of observed hydroclimate data and remotely sensed data to characterise and quantify non-stationarity.** Non-stationarity in 136 unimpaired catchments in the Basin was assessed by analysing rainfall-streamflow data and using statistical tests to characterise temporal changes in the rainfall-runoff relationship. Catchments were classified as whether they experienced non-stationarity, and if they do, whether they have recovered post-drought and the magnitudes of change quantified. The main drivers of change have been assessed, including the role of climate (from Activity 1), vegetation (using remotely sensed evapotranspiration and leaf area index data) and other landscape dynamics (farm dams, surface-groundwater interactions, changes in total water storage from gravity measurements).
3. **Adapting hydrological models.** To enhance understanding of the processes in Activity 2 on hydrological non-stationarity, and hence to better quantify the drivers of the hydrological changes in the catchments, hydrological models have been adapted to include processes related to farm dams and vegetation dynamics. On-farm storage and monthly leaf area index from multiple satellite observations are used to drive the model, in addition to conventional climate inputs. The model is applied to the 136 Hydrologic Reference Station (HRS) catchments in the Basin. Sensitivity analysis and scenario modelling are being carried out to quantify the contributions of climate, vegetation and land use change on key hydrological variables.
4. **Mapping and assessing changes in irrigation.** Independently of the other activities, the role of irrigation is being assessed by mapping main irrigated areas in the Basin (using AI/ML techniques) and assessing their water use and change in cropping systems since 2000. To assess irrigation characteristics over time, Self-Organising-Maps (SOM) have been produced for main irrigated areas in the MDB during years with different surface water allocations. These SOMs have been assigned to land cover types (including major crop types, orchards, and assessing if these are irrigated) and used to train a (deep or shallow) neural network to produce land cover characteristics in an area covering the Murrumbidgee-Lachlan valleys, focusing on irrigated crops and overall water use. Verification data (crop areas from ABARES, ABS and industry publications) have been collated and will be used to assess the produced maps.

Case Studies

RQ7 Improving floodplain inundation and volume prediction to inform water resources planning and environmental watering

The two-monthly maximum water extent and depth datasets developed in the project is the best of its kind in the MDB, and has been used to model critical environmental factors, such as habitat availability, waterbird breeding grounds and groundwater recharge zones. By accurately tracking water extent, we can understand how different wetland ecosystems respond to fluctuating water levels, which is crucial for the conservation of aquatic habitats and biodiversity.

The project combined the floodplain inundation dataset with rainfall-runoff modelling and showed that floodplain inundation in the past 35 years in the MDB has been more frequent than the century-long baseline. Despite this, there has been considerable challenges in sustaining floodplain inundation for ecosystem outcomes. On a positive note, the study also showed that floodplain inundation frequency under climate change in the MDB is likely to be like the baseline (and not necessary decrease like projections for water resources), due to more intense extreme rainfall compensating for drier antecedent catchment conditions.

The project also developed a daily floodplain inundation and water balance model, through process conceptualisation and parameterisation, establishing relationships between streamflow hydrograph and satellite data, and validated against hydrodynamic model simulations. The floodplain model can be used to assess how changes in streamflow from climate variability and change, or water resource management, or e-watering decisions, affect floodplain inundation outcomes.

The knowledge, datasets, and models developed in Project RQ7 are used in many other projects and are informing Sustainable Yields modelling and Basin Plan review.

RQ8b Groundwater as an adaptation to current water resources management

The groundwater project in RQ8b showed an overall long-term decline in groundwater levels in most key alluvial aquifers in the MDB. Regional-scale analyses of groundwater resilience, stress and sustainability indicators revealed that half of the management areas assessed showed one or more issues. Analyses using Explainable Artificial Intelligence methods indicate that the declining groundwater level trends are driven by groundwater resource development combined with a drying climate.

Despite the above, groundwater currently represents only 12% of total water use in the MDB. There is potential to use groundwater as an adaptation to a drying climate, particularly when managed conjunctively with surface water. MD-WERP research completed an assessment of managed aquifer recharge (MAR) potential across the MDB and identified prospective sites in some of the main alluvial systems. Preliminary economic analysis indicates that MAR can potentially be implemented cost effectively to deliver multiple benefits.

The knowledge, tools and datasets developed in Project RQ8b are used in other projects, as well as informing Basin water management.

Pathway to Impact

Outputs from the hydrology theme over the first three years include 10 datasets, 20 technical reports, 15 journal papers and 20 conference abstracts. Five journal articles were published in 2023-24, and two journal articles were submitted for peer review The research was presented at the 25th International Congress on Modelling and Simulation (MODSIM2023) and AGU Chapman Conference on Remote Sensing of the Water Cycle (see Appendix 2 – List of Journal Publications).

There has been significant and sustained external engagements in all five projects, largely with MDBA technical experts, CEWH environmental water managers, and other MD-WERP researchers (particularly in the climate adaptation theme). Research from this theme has been presented and discussed in the MDBA and Basin States Modelling Advisory Group meetings. The third annual Hydrology Theme workshop was held over two days in May 2024. The workshop provided insight into the progress and insights made in each of the Hydrology research projects and provided an opportunity for collaboration between projects as well as the Theme 1 research and the MDBA. The ongoing relationship between the research consortium and MDBA technical staff continues to mature and become a realised benefit for the program.

There have been many engagements through meetings and workshops with stakeholders including MDBA river operators, CEWH, Queensland Department of Regional Development, Manufacturing and Water, Queensland Department of Environment and Science, Bureau of Meteorology and SunWater. This has led to the development of the two application case studies to demonstrate opportunities for water forecasts to inform decision making to support river operation and environmental watering.

In addition, there has been ongoing communication and engagement with the MDBA river operators (RQ8a), regular monthly meetings with MDBA groundwater experts to report on progress, coordinate data needs/access and discuss MD-WERP research (RQ8b), and presentations to the MDBA's Groundwater Advisory Panel in August 2023 and March 2024.

Theme 3: Environmental Outcomes

A healthy Basin relies on healthy ecosystems. However, parts of the Basin face a challenging future: severe droughts and extreme ecological events (e.g. algal blooms, fish kills) highlight the significant challenges in managing Basin ecosystems. Drought conditions associated with fish kills are likely to become more common in some parts of the Basin, and increasing water scarcity will require careful prioritisation of which environmental assets to protect. Climate change and land use in managing Basin ecosystems are central to this research.

This research theme seeks to improve our understanding of how rivers, wetlands and water-dependent species will respond to future environmental conditions (Table 4). It will:

- produce a better understanding of how reduced water availability affects the abundance of aquatic life
- help identify areas of high priority conservation value, and to inform management and conservation of the Basin rivers and ecological assets
- examine how fish populations may respond to the changing climate
- map surface water and waterhole connections to determine flow-related changes in fish habitat along the Lower Darling channel
- collate a data atlas of environmental and socio-economic values.

Table 4. Summary of key research questions (RQ), outputs and outcomes for Theme 3: Environmental Outcomes.

Key questions	Key outputs and outcomes
RQ9. What are the low flow needs of the environment? RQ10. How can floodplain flow volumes, components, and inundation prediction be improved to support environmental watering and water resources planning? RQ11. How can adaptation through enhanced river operations and water resources management improve water outcomes?	Improved understanding of low flow requirements of the Basin's environmental assets and values to inform water planning and management, particularly under a changing climate. Prioritisation of environmental assets, values and functions for targeted water management and complementary measures to sustain and restore their conservation values. Development of predictive models to better understand the spatial distribution of environmental assets and values, how they respond over time to water management, and the risks to future population and ecosystem sustainability from ecosystem stress.

Key outputs and outcomes for the environmental outcomes theme

- Improved understanding of low flow requirements of the Basin's environmental assets and values to inform water planning and management, particularly under a changing climate.
- Prioritisation of environmental assets, values and functions for targeted water management and complementary measures to sustain and restore their conservation values.
- Development of predictive models to better understand the spatial distribution of environmental assets and values, how they respond over time to water management, and the risks to future population and ecosystem sustainability from ecosystem stress.

Progress and Achievements

Theme 3 has made a lot of progress in Year 3, with four projects completed. The EUAG feedback on the final project reports have been positive about the quality and value of the research. In addition, *RQ9.3b Maintaining Barkandji fish traps and their cultural values* restarted after a significant pause. It will provide an important contribution to First Nations-led research and documentation of important cultural values.

At the end of 2023-24 there were 25 key deliverables, of which:

- 17 key deliverables have been completed, with 11 of these in Year 3 (2023-24)
- 8 key deliverables are on track to be completed in Year 4.

Drivers of ecological resilience and persistence during low and cease-to-flow conditions in the northern Murray–Darling Basin (RQ9.1)

Field work for this project has been significantly delayed due to persistent high flows in the Barwon-Darling into early 2023. Field sampling was undertaken in November 2023 and February/March 2024. Sampling focused on small fish (seine nets and bait traps), freshwater mussels and/or river snails, and crustaceans (*Macrobrachium* – seine, bait traps and dip nets). Physical data on habitat complexity and riparian vegetation structure and health was also collected. Analysis of the field data is currently underway and will be completed early in Year 4.

A draft manuscript 'Predicting the resilience of riverine biota to low flows' has been submitted to Freshwater Biology and is in review.

Forecasting risks to fish and their available habitat from low flows and hypoxia (RQ9.2)

The project has adapted a three-dimensional hydrodynamic-water quality model to two sites: Lower Culgoa River and Burtundy, below the Menindee Lakes. Model outputs are being calibrated to measurements using variables of water temperature, dissolved oxygen,

chlorophyll and nutrients. These variables will be used to explore available fish habitat under a variety of flow conditions including connected and disconnected waterholes. The final report is on track for completion in early 2024-25.

Maintaining Barkandji fish traps and their cultural value (RQ9.3b)

This project was paused for 12 months and has now restarted. There is now some risk that it might not be able to fully complete one aspect of the project (maintenance of the fish traps) within the final 12 months of the program, given the time it may take to obtain permissions for this work. However, this will not undermine the remainder (and majority) of the project. The project team will monitor progress and review the maintenance feasibility mid project and can adapt the project to maximise data collection and monitoring of the current fish traps.

A data atlas for conservation prioritisation (RQ10.1)

This project was completed in Year 3 with the final deliverable accepted in December 2023. To uphold the fundamental principles of transparency and reproducibility, this project developed a series of spatial geodatabases that consolidate data required for RQ10.2.

This project aimed to create specialised geodatabases for a Gap Analysis, Vulnerability Assessment, and Conservation Prioritisation Plans, complemented by a comprehensive user guide to ensure reproducibility, repeatability, and transparency. Each data layer is accompanied by detailed metadata, providing a solid foundation for future work.

The project followed a systematic approach, beginning with stakeholder consultations to identify critical data needs. Data collection, transformation, and spatial analysis were conducted using a range of technologies and methods. This resulted in the compilation of approximately 600 data layers, encompassing raw and processed datasets, spatial analysis results, specific climate velocity data for the MDB, and layers tailored for Marxan prioritisation analysis.

The project's significant achievements include:

- A series of specialised geodatabases for a Gap Analysis, Vulnerability Assessment, and Conservation Prioritisation Plans, accompanied by a comprehensive user guide for reproducibility, repeatability and transparency and transparency.
- Detailed metadata for each data layer, enhancing the foundation for future research and decision-making.
- A successful peer-review process with positive feedback and acknowledgement of the usefulness of the databases.
- Collaborative efforts with RQ14.1, ensuring data consistency across projects and facilitating greater reproducibility in future research.

The user guide aims to assist users in accessing data within the spatial geodatabase and conducting analysis effectively. Its purpose is to provide step-by-step instructions and guidance for users to navigate and utilise the data for their analytical needs.

As the database is a compilation of existing datasets, each data layer has its own Intellectual Property and licence agreements. Given this complexity, the spatial geodatabase is housed on the MDBA server for internal use but has not been made publicly available.

Evaluating protection gaps and conservation prioritisation (RQ10.2)

The input data layers and results of the prioritisation analyses have been added to the RQ10.1 Data Atlas and the gap analysis report is complete. The gap analysis report will be published with the final report and datasets, due in July 2024.

The 'Conservation Prioritisation for the Murray-Darling Basin: Representation Gap Analysis and Vulnerability Assessment' report presents the key findings from a comprehensive evaluation of representation gaps for high conservation value aquatic species, ecosystems and habitats (biodiversity assets) in the Murray–Darling Basin. The study aimed to assess the protection status of biodiversity assets within existing conservation measures and identify gaps that require urgent attention. The analysis focused on the representation of biodiversity assets, the correlation between asset size and protection, and a vulnerability assessment of assets to climate change. The results provide valuable insights for prioritising conservation efforts and guiding future management decisions.

Part 1: Representation Gap Analysis

The Murray–Darling Basin demonstrates low protection, with 14% of the area falling within existing protected areas, Key Biodiversity Areas (KBA), or Ramsar wetlands. Additionally, 24% of the Basin is potentially waterable, and 4% falls into both protected and waterable categories. The study found a significant correlation between biodiversity asset size and protection, with larger assets exhibiting higher representation within protected areas, KBA, or Ramsar wetlands.

Certain biodiversity asset types showed better representation within conservation measures. Wetlands classified as Directory of Important Wetlands in Australia (DIWA) demonstrated relatively higher representation compared to other asset types. The overall protection equality metric (PE) for Important Wetlands (DIWA) was 0.55, indicating a low to average level of protection equality. Specific wetland types, such as streams and transition streams classified under Australian National Aquatic Ecosystems (ANAE) framework, were poorly represented in the Basin.

Specific catchments were identified with varying levels of representation. The Condamine catchment exhibited the lowest representation, despite its significant species richness, particularly reptiles and mammals. Ecological Communities of National Significance exhibited low representation, with only 16% of likely to occur classes being adequately protected.

Catchments such as Hamilton, Murrumbidgee, and Upper Murray demonstrated relatively higher representation, while the Otway and Lake Frome catchments lacked designated protected and managed areas.

Furthermore, there are major representation gaps across most of the Basin, particularly in the Condamine, Border Rivers, and Macquarie catchments, which had minimal to no representation within protected areas, KBA, or Ramsar wetlands. The assessment highlighted the Mid-Murray catchment as having the highest proportion (60-80%) of potentially waterable area, followed by the Condamine, Murrumbidgee, and Goulburn-Loddon catchments (20-40%).

ANAE wetland classes, particularly permanent stream systems, were significantly underrepresented within protected areas, KBA, or Ramsar wetlands. While 68% of important wetlands (DIWA) were represented within conservation measures, several wetlands remained unprotected or inadequately represented.

These findings emphasise the need for targeted conservation efforts to address the representation gaps and enhance the protection of important biodiversity assets within the Murray-Darling Basin. The detailed analysis, maps, and metrics provided in this study offer valuable tools for informed decision-making, assisting stakeholders in prioritising conservation and management strategies. Access to the interactive map developed on Google Earth Engine further facilitates the use of these findings in future conservation initiatives and sustainable management practices in the region.

Part 2: Vulnerability Analysis

The vulnerability of biodiversity assets to climate change within the MDB were assessed using Climate Velocity as an indicator. Climate velocity layers, derived from reliable gridded datasets for monthly mean temperatures and precipitation, were obtained and analysed. The analysis focused on understanding the projected shifts in climate conditions across the landscape in terms of kilometres per year (km/yr).

The findings highlighted areas where significant climate shifts are expected to occur. And identified biodiversity assets within these regions that are likely to experience notable climate changes. For example, the Darling River floodplain vegetation is projected to undergo average changes in mean monthly temperature ranging from 3.43 to 3.99 km/year and mean monthly precipitation ranging from 3.21 to 5.16 km/year.

This vulnerability analysis provides valuable insights into the potential impacts of climate change on biodiversity assets within the MDB. The results can guide future conservation efforts and inform management strategies aimed at mitigating the risks associated with climate change. This information provides a vital insight that will be utilised as a penalty layer in the Basin-wide prioritisation analysis that will follow on from this study.

Developing a First Nations perspective on conservation planning (RQ10.3)

This project was put on hold in 2022-23 pending further consultation with First Nations groups. It was subsequently decided by the research team to not pursue this project and it was removed from the Theme 3 contract in March 2024.

Spatially explicit population models for fish in the Barwon-Darling river system (RQ11.1)

This project was completed in Year 3 with the final report accepted in May 2024 with publication planned in Year 4. It has developed a spatially explicit dynamic fish population model to assess the population viability of four freshwater fish species (Murray cod, Golden perch, Bony bream and Common carp) of the Darling (Baaka) River under hydrological conditions observed in the past ~40 years. This model combines information on hydrology and waterhole persistence with estimates of fish survival and recruitment to model long-term population trends. By analysing the persistence characteristics of riverine waterholes during cease to flow events and simulating multiple future hydrological conditions we found key drivers of population viability across the Darling (Baaka) River.

The results show that two large bodied long-lived species, Golden perch and Murray cod, are at risk of local extinction under multiple future scenarios. These model predictions are reinforced by analyses of population age-structure, which shows that average rates of population growth within the system are well below replacement. An absence of the youngest year classes in high abundance is a notable feature of the Murray cod populations in the Darling (Baaka), particularly upstream of the Main weir at Menindee. This indicates a recruitment bottleneck for the species.

Parameterising stochastic population models with these data in addition to comparison of vital rates to populations elsewhere in the Murray–Darling Basin for the species show that populations in the Darling (Baaka) are at a high risk of extinction over very short time periods if antecedent cease to flow conditions persist or intensify.

Among the recommendations for future management of the system, flow delivery that aims to alleviate local pressures on populations including prolonged cease to flow events and waterhole turn over would assist in the persistence of populations in the waterholes across the river above the Main weir. Additionally, implementing greater fish passage solutions has been identified as an important step to allow fish dispersal across the system. This would allow dispersal of high density populations of individuals in the river section where these significant fish kill events have occurred, between Weir 32 and the Main weir at Menindee.

The Menindee Lakes act as an important nursery habitat for freshwater fish species, and a major source population for the Darling (Baaka) that is largely restricted from contributing to the meta population of the catchment. The metapopulation model supports the contention that barriers at Menindee, and upstream, have a large effect on upstream population sizes. While the population model has thus far only been used to explore a limited range of

scenarios, the development of a quantitative tool that can explicitly test the long-term population outcomes of alternative future management scenarios provides an important complement to existing river modelling capability.

Predicting changes to the persistence and connectivity of in-channel aquatic habitat in the lower Darling River (RQ11.2)

This project is near complete with the final report due to be submitted in July 2024. The final stages of work have included determining waterbody persistence and connectivity, and relating them to flow and rainfall data using a regression model. This model has then been used to predict changes to the persistence and connectivity under wet and dry modelled flow scenarios. Mapping of waterbody persistence and connectivity is in progress. Further detail on the progress of the project is provided in the case study.

Predicting change in floodplain habitat availability at the Basin scale (RQ11.3)

This project was completed in Year 3 with the final report accepted in January 2024 and published in March 2024.

This project identified relationships between flow and inundation extent at a Basin scale and used them to predict inundation under different flow scenarios. This study was not mechanistic and could not explicitly identify the processes behind floodplain inundation. However, the empirical results are of conceptual interest, and can inform fine scale studies for the effective delivery of environmental flows, in addition to other flows.

The spatial and temporal distribution of inundation was mapped in two key floodplain habitat types (River Red Gum Forest and Lignum shrub land habitat) from the ANAE classification scheme using inundation data derived from Landsat imagery. The relationships between these floodplain habitat types and flow, rainfall and broad scale catchment variables were quantified using a gradient boosting decision tree algorithm. This helped to determine the spatial and temporal factors that predict floodplain inundation throughout the Basin. This information was then used to predict how different floodplain habitat types may respond to changes in flow under three different flow scenarios (a flow scenario under a dry climate, a flow scenario under a wet climate and flows that would occur under a without development (WOD) scenario).

The models developed had a relatively high level of predictive accuracy and showed that flow was an important predictor of inundation, however it was not the only determinate, and other factors such as catchment characteristics, rainfall and anthropogenic disturbance were also important for predicting floodplain inundation. This suggests that other catchment level variables, some of which cannot be readily altered, should be considered when managing flow for floodplain inundation.

In terms of flow delivery, the results suggested that less skew in a hydrograph resulted in increased floodplain inundation, indicating that environmental flows should focus on

delivering small to medium flows to increase floodplain inundation, thereby decreasing the skew in the hydrograph. However, the occurrence of small to medium flows will need to be context dependent, as in some areas of the Basin increased hydrograph stability can create sub-optimal habitat conditions.

When assessed at the contracted catchment level, patterns of inundation change emerged, suggesting that climate change and water development, including dams, weirs and extraction, may have a disproportional impact on different areas of Basin. The models predicted a reduction in inundation extent in the northwest of the Basin under a dry climate flow scenario, while under a WOD flow scenario inundation extent in the northwest increased. This result suggests that floodplains in the northwest of the Basin may be at risk of habitat loss under a drying climate, and that water development in this region may have a deleterious impact on floodplain habitat availability.

The models developed for this project are a relatively fast and effective way to predict floodplain inundation in different habitat types at the Basin scale. The models are applicable across different catchment management objectives including initiatives such as "Assessing Vulnerability for use in Determining Basin-scale Environmental Watering Priorities" (Commonwealth of Australia, 2023) and other large scale environmental water planning initiatives such as the Enhanced Environmental Water Delivery Project (EEWD) (Department of Environment and Water 2023).

Limitations associated with the current study include inundation being modelled at relatively course temporal and spatial scale and the modelled flow data used to model inundation being only available to 2009. Further, only inundation extent was modelled, not depth or duration. However, the models developed can be updated with relative ease when new data becomes available.

Four key messages emerge from the results of this study which can be used to inform finer scale studies for the effective delivery of flows throughout the Murray–Darling Basin.

1. While important, flow is not the only determinate of floodplain inundation. Physical catchment characteristics, alongside levels of anthropogenic disturbance, are also important predictors of floodplain inundation. This suggests that environmental flow planning should occur within the context of the surrounding catchment.
    a. By influencing the skew of the hydrograph, alterations to flows in the mid-low hydrograph may have a large impact on floodplain inundation.
2. Floodplain ecosystems in the northwest of the Basin may be at risk of habitat loss under a dry climate flow scenario.
3. Catchment development including dams, weirs and water extraction has a large effect on floodplain inundation, however the effects of catchment development on floodplain inundation may differ between the north and the south of the Basin.

Assessing future vulnerability of species and ecological communities (RQ11.4)

This project was completed in Year 3 with the final report 'Habitat Suitability Modelling of Fish, Aquatic Invertebrates and Riparian Plants in the Murray Darling Basin' accepted in March 2024 and published in June 2024. A web-based data portal (ShinyApp) has also been developed to view and download results. The MDBA data team is working with the Theme Lead and Project Lead to make the portal publicly available. Details of this project and the outputs are provided in the case study below.

Case Studies

RQ 11.2 Predicting changes to the persistence and connectivity of in-channel aquatic habitat in the lower Darling (Baaka) River

This project examines the role of persistent surface water habitats in the Murray-Darling Basin, essential for aquatic life during dry periods, which have increased since pre-development times. These habitats, called refuges, depend on adequate water flow to maintain quality and connectivity, preventing harmful temperature and oxygen levels that can cause fish deaths, such as those seen in the Darling River near Menindee.

The Sustainable Rivers Audit rated many Basin areas, including the Darling River, as poor due to climatic conditions and water use for agriculture. This project aimed to identify and analyse these refuges in the Darling River (Louth to Menindee) using 35 years of Landsat satellite images and graph theory to map and assess connectivity. This method highlighted key habitats vital for fish movement and dispersal.

Connectivity varied throughout the river: upper segments showed seasonal changes, middle segments had both stable and fluctuating habitats, and lower segments were more consistent in water coverage. The central region contained important habitats acting as hubs for ecological activity. Connectivity was influenced by the distance between habitats, with more isolated areas being less connected.

Weirs played a crucial role in maintaining water levels and connectivity, with upstream areas showing better water persistence, while downstream areas were often isolated. Flow levels were the most significant predictor of connectivity, with climate trends and rainfall also significant. Future climate models suggested that wetter conditions would slightly increase connectivity, whereas drier conditions would reduce it.

Using logistic regression, the study predicted the connectivity of nine selected water bodies, showing that higher flows are needed to connect isolated habitats. The outcomes of this project will benefit river management by forecasting connectivity under different flow scenarios. The study emphasized the ecological importance of these habitats in the Darling River and the need for effective flow management to sustain them.

A report which details the long-term persistence and connectivity of in-channel refuge waterbodies in the Darling River was published on the MD-WERP website in December 2024.

RQ 11.4 Assessing future vulnerability of species and ecological communities

This project sought to understand current and future distributions of key animals and plants in the Murray Darling Basin. The study combined contemporary survey records of fish, invertebrate and plant species with information on climate, land-use, catchment physiography and river hydrology to model current habitat suitability for various species throughout the Basin. The study also included future hydro-climatic scenarios which were used to predict distributions of these same fish, invertebrate and plants species under dry, medium and wet future climates. Such scenario-based analysis can help prioritise options for water management and complementary works (e.g., refuge restoration/creation) to meet the physical and functional habitat requirements of plant and animal communities in a changing climate.

The outputs from this project included habitat suitability models for 32 fish, 123 aquatic invertebrate, 419 riparian plant species. An analysis of changes in distribution in response to future climate scenarios revealed a broad range of predicted responses, with some 'winners' and some 'losers' – i.e. species whose range may expand or contract respectively. Among the fish and plants, winners tended to be invasive species, whereas among invertebrates many groups were modelled to be tolerant of a range of conditions, and even expand habitat in some cases. Suitable habitats for plants strongly associated with rivers and wetlands were predicted to decrease in spatial extent under future climates.

As noted above, the main output of this project was a series of maps of current and future habitat suitability estimates for fish, invertebrates, and plants throughout the MDB. To make these results more accessible, a web-based data portal (ShinyApp) has been developed, which can be used to view and download results for the Basin as a whole or for individual catchments. Additionally, a report has been published on the MD-WERP website.

The outcomes of this project will benefit catchment management in the Murray-Darling Basin at a whole of Basin scale. It is anticipated that these results will be useful in guiding future planning that considers the effects of climate change on basin ecosystems and biodiversity.

Pathway to Impact

The project teams presented updates on projects 9.1, 9.2, 10.2, 11.1 and 11.2 to the Theme 3 EUAG on 29 April 2024. The EUAG has also reviewed and provided feedback on several reports prior to their formal submission.

The final reports for *RQ11.3 Predicting change in floodplain habitat availability at the Basin scale* and *RQ11.4 Assessing future vulnerability of species and ecological communities* were published on the MD-WERP website.

A draft manuscript 'Predicting the resilience of riverine biota to low flows' was submitted to Freshwater Biology in June 2024 and is under review.

RQ10.1 has developed a comprehensive collection of spatially-explicit biophysical and socio-economic datasets that will inform RQ10.2. Collaborative efforts with RQ14.1 has ensured data consistency across projects and facilitated greater reproducibility in future research.

- **Benefit**: Conservation prioritisation.
- **Realisation description**:
    - Compiled spatial layers of assets, functions, and values in the MDB to inform a gap analysis, vulnerability assessment, and conservation prioritisation analyses.
- **Program objectives supported by the benefit**:
    - 1. Invest in applied research that delivers better informed environmental water management decisions by Commonwealth agencies and improved outcomes for communities.
    - 2. Maximise value to water reform and management from investment.
- 4. Facilitate adoption of research by advancing cooperation between users and researchers.
- **Target date for full benefit realisation**: 2023.
- **Current status**: Realised.

Theme 4: Social, Economic and Cultural Outcomes

People rely on healthy ecosystems for their wellbeing and survival. Degraded landscapes and waterways affect the social, emotional, physical and financial health of people and communities. Theme 4 focuses on the social, economic and cultural benefits of river health, and research questions, summary of outputs and outcomes can be found in Table 5.

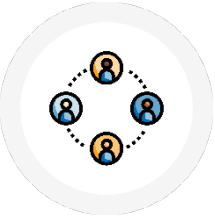

Table 5. Summary of key research questions (RQ), outputs and outcomes for Theme 4: Social, Economic and Cultural Outcomes.

Key questions	Key outputs and outcomes
RQ12. What is the relationship between the condition of the riverine ecosystem and social, economic and cultural values? RQ13. What are the cultural, economic and social outcomes for First Nations people and how can they be improved? RQ14. How can communities adapt to and be more resilient to a future with less water? What makes a community more resilient and adaptable to a future with less water?	Improved understanding of the value of healthy river ecosystems to mental health and cultural wellbeing of people and communities, and to recreation and tourism in the Basin. Identified First Nations aspirations, access to and use of water, developed water action plans and designed a real-world water delivery process. Improved understanding of First Nations' knowledge of water and perspectives on the relationship between water access, agency, self-determination and wellbeing. A new basin-wide social and biophysical data platform that will enhance research. New social mapping of community pathways for resilience, and production of 'story maps' to increase understanding of how communities navigate change.

Key outputs and outcomes for the social, economic and cultural theme

- Improved understanding of recreation and tourism in the Basin, and the relationship with riverine ecosystem health.
- Improved understanding and incorporation of First Nations peoples' science and knowledges of water management and caring for Country; and including perspectives on their relationship between water access, agency, self-determination and wellbeing.
- A new Basin-wide social and biophysical data platform that will enhance research.
- New social mapping of community pathways for resilience, and production of 'story maps' to increase understanding of how communities navigate change.

Progress and Achievements

Overall, Theme 4 has made significant progress in 2023-24, after a delayed start for some projects, including disruption for RQ14.2 and 14.3 around the study sites. These issues have been resolved and research is progressing very well. Two projects were completed and two First Nations projects commenced. At the end of 2023-24 there were 44 key deliverables, of which:

- 15 key deliverables have been completed, all in Year 3 (2023-24)
- 11 key deliverables are on track to be completed in Year 4
- 13 key deliverables are due to commence and be completed in 2024-25
- 5 key deliverables are delayed.

The mental health benefits from improvement to riverine ecosystem health (RQ12.1)

The focus in 2023-24 has been on developing the community survey questions, data collection and analysis. The survey was slightly delayed however this was so it could be incorporated into the University of Canberra's Regional Wellbeing Survey, giving access to a much larger sample base. There were around 6000 respondents across the Basin. While there was some delay in accessing the data, the final report is anticipated to be submitted by the end of 2024.

The recreational and tourism value of healthy rivers (RQ12.2)

In July 2023 the Governing Panel approved extension components to this project:

- Extension A: Expanded investigations with user-generated photo-post data from Flickr providing a more detailed understanding of the response of visitors to environmental conditions and improve understanding of the economic benefits from visitors to recreational sites.
- Extension B: Quantifying additional economic activity from condition improvements at birdwatching sites – including impact of environmental watering at key sites – using user-generated bird sighting data from eBird Australia.

The expanded scope will help quantify the impact of riparian condition and environmental water management on visitation-linked economic activity via user-generated visitation data. For relatively little cost, extending the original research will result in significant enhancement of our understanding of the recreational and tourism value of healthy rivers and provide deeper insights into visitation rates and characteristics or tourism – building the evidence base for future tourism and recreation research.

The project team has made excellent progress with significant new and rich data from the bird watching community that is expected to add to the empirical understanding of the relationship between recreation tourism and a healthy river system.

During the year, opportunities for further analysis arose. An additional dataset was constructed in which individual sub-catchments ('contributing catchments' in Australian Hydro GeoFabric terminology) are the individual units of analysis. The new dataset draws on remotely sensed data processed by the MDBA and Griffith Univeristy which reports the percentage of each sub-catchment that is 'wet' (i.e. inundated) in each month between March 2013 and March 2019. These 'wet area' data provide a proxy metric of riparian condition, in addition to the NDVi 'green-ness' metric of broader landscape condition which had been constructed previously.

This further analysis required an extension to the deliverable due dates to consolidate the modelling and reflect on similarities and differences regarding which factors influence

visitation rates in the different River Regions across the Basin. Some of the differences are likely to be systematic and others idiosyncratic.

First Nations water-based outcomes in the southern Basin (RQ13.1)

In October 2023, MLDRIN notified La Trobe University that it would be withdrawing from RQ13.1. On the advice of the La Trobe University Consortia Director, the Governing Panel agreed to not proceed with this project in recognition that the ICIP for the project's design rests with MLDRIN. It was also agreed that the unspent funds budgeted for this project would be quarantined for tactical projects to be scoped directly by the researchers and the MDBA through existing relationships and networks with First Nations peoples.

First Nations water-based outcomes in the northern Basin (RQ13.2)

This project was formally removed from the Program as two alternative northern Basin projects were endorsed by the Governing Panel. Both projects are the outcome of a considerable amount of work in a tight time frame and promise some substantial First Nations' led knowledge creation.

Winanga-Li Gunimaa – Incorporating Cultural Values into Environmental Flows (RQ13.2a)

This project is an indigenous engagement project led by the University of Canberra and Macquarie University at Gingham Wetland in the Gwydir region, involving Gomeroi/Kamilaroi Traditional Owners. It was endorsed by the Governing Panel in December 2023.

The project is designed to investigate and improve engagement and knowledge sharing, as well as improve knowledge of hydrological, cultural, and biotic outcomes, as well as opportunities for indigenous self-determination in water management. The project aims to:

- develop and document engagement strategies to enable successful two-way knowledge exchange that can inform a water delivery event
- assess the linkages between cultural and environmental benefits of this planned water release, including hydrological, biotic and cultural engagement
- reflect and analyse indigenous self-determination in natural resource management
- highlight potential pathways for greater opportunities for First Nations access to and management of Basin water.

Application of this project as a case study in demonstrating the on-ground value of knowledge sharing and transdisciplinary study will facilitate evidence-based policy development and decision making for both state and federal government agencies.

The team held the first project planning meeting on 15 March 2024 with the co-designed project plan on track for delivery in early 2024-25.

Wetland Grasses, Ancient Grains, and Indigenous Food Production (RQ13.2b)

This project was endorsed by the Governing Panel in April 2024 and is being led by Sydney University and Griffith University. It builds on native grains research being undertaken by the University of Sydney. The project aims to:

- document Indigenous knowledge of grains and cultural practices of grain harvesting and food production through interviews with elders in the northern Basin (including Moree, Mungindi, Narrabri)
- examine records (explorer, settler and scientific) for reports of Indigenous grain harvesting and food production
- document the effect of changing flow regimes and reduced water, or other process, such as tilling, on native wetland grasses in the project area by interviewing Indigenous and other experts
- describe the response of First Nations to native grass and wetland restoration projects, the impact on well-being and other effects
- obtain legal advice on the Indigenous Cultural and Intellectual Property issues associated with commercialisation of native grasses, including naming rights and benefit sharing
- facilitate a learning exchange between Kerrie Saunders, Bruce Pascoe and Dr Angela Pattison who are researching the potential for native grasses and First Nations' knowledge to contribute to Australian food production
- promote the value of native grasslands and Indigenous knowledge (cultural, agricultural, environmental) through the production of booklets and leaflets for cultural tours, schools, farmers etc.

The first deliverable is a Written advice by Indigenous IP specialists on the broader ICIP considerations around commercialisation of Indigenous ethnobotanical knowledge. The purpose of this advice is to provide guidance to First Nations people interested in native grass restoration and commercialisation on disseminating cultural knowledge.

Basin-wide socio-economic, socio-demographic and biophysical data platform (RQ14.1)

This project has been completed with the data platform, included data, software scripts for spatial geometry conversion and a detailed User Guide accepted in January 2024. The final deliverables were:

- RQ14.1.1 – original data layers as a GeoDatabase
- RQ14.1.2 – data platform provided as a GeoDatabase
    - holds the data layers used in and produced by the RQ12.2 Visitation Rate Analysis
- RQ14.1.3 – examples of maps and data, to illustrate variation in socio-demographic and socio-economic conditions across the Basin and through time

- Spatial Geometry Conversion software script and Geodatabase which holds the data layers used in and produced by Spatial Geometry Conversions
- maps and table folder – are shown as examples of spatial geometry data conversion tables and maps that can be plotted for MDBA spatial geometries.

In addition, a Geodatabase User Guide has been created to explain how the spatial data sets can be accessed, along with geoprocessing steps involved in data production, and instructions for running the ABS Geometry Conversion script tool.

Pathways to community resilience (RQ14.2)

Despite some initial delays with the community focus groups (due to the slower than expected uptake of focus group opportunities and delays in gaining ethics approval for First Nations consultation), good progress has been made on this project. Community focus groups have been completed in two of the three case study communities (Griffith and Loxton) and initiated in the third case study location of Bourke. Bourke has recently replaced Walgett as the third case study site due to broader concerns relating to First Nations representation in the northern Basin.

The online youth component has been delayed somewhat but progress has been made. Over 30 organisations have been contacted whose work has relevance to youth groups and/or engaged directly with youth. Further discussions with organisations, e.g. Landcare NSW and MDBA communication lead have been had, with the aim of scaling the survey results across the Basin. This has included also several discussions with youth and the online survey component and Miro Whiteboard to collect answers. Part of the barriers for finishing the survey and Miro Board has been finding the youth (16-25) participants. While many organisations recognise this age group as a significant data gap in their work in the Basin, less contacts and networks have been established that would have resulted in broader participation. New contacts and groups were established in April-May 2024.

Navigating change (RQ14.3)

First Nations engagement with Loxton and Griffith has been complex and slower than expected, with delays possibly linked to the Voice to Parliament referendum lead up and outcome. Negotiations with First Nations also led to some delays with interviews in Loxton and Bourke. Negotiations continue with the Loxton community. For Bourke, these have now been resolved and preparations are underway for interviews to be conducted. Interviews at Griffith have now been completed.

Understanding the water cultures of the MDB (RQ14.4)

The overarching objective of this project (2021-2023) was to supplement a project titled Water Cultures of the MDB, which was funded by the Australian Research Council in 2020 (SR200200322).

The aim of the ARC project (and hence the component funded by the MDBA) is to investigate the ways that attitudes, norms, beliefs, and practices relating to water have developed across three regions of the Basin – Mildura, the Murrumbidgee, and the Lower Darling.

There are no discrete MD-WERP deliverables for this project, and the ARC project is not due to be completed until May 2025 due to delays incurred by travel restrictions during the COVID-19 pandemic affecting the commencement of negotiations with communities and the field work.

A research article focussing on three white men who were critical to saving Hattah Lakes was published in Australian Historical Studies in April 2024.

Case Studies

RQ14.3 Navigating Change: The value of oral history in capturing lived experiences of environmental change and social responses to it

With most interviews complete in Bourke, the interim analysis reveals the value of oral histories. When individuals reflect on their relationships with their communities, environment, and the Murray-Darling Basin, their narratives provide colour and richness. Uniquely personal stories bring to life the results of quantitative studies that have been used to understand communities across the Basin. These communities are, after all, made up of and defined by the human experiences of community members past, present, and future. Oral history offers a window into the lived experiences of these communities.

Population declines in Bourke

Since the 1990s, when water buybacks and years of drought left Bourke's horticultural and agricultural industries struggling, the Shire's population has been in steady decline. In 2001, the Australian Bureau of Statistics recorded the Bourke Shire's population as 3,964 people. In 2021, it was just 2,389.

The oral history interviews undertaken as part of WERP 14.3 Navigating Change reveal the meaning of this rapid drop in population for the community and individual residents. Not only has this decline impacted local industry, the economy, and services, but individuals have lost life-long friends, businesses, social networks, and opportunities to connect with one another.

Loss of social connection

For most interviewees, a critical impact of environmental and policy changes over time has been the steady decline of Bourke's population. When asked what it was like to be part of the Bourke community, one couple admitted that they weren't entirely sure as those they had been closest to in Bourke had left following the Millennium Drought. Bourke is now just a "government town", or "service town" several interviewees reflected. People come and go. "There's a lot less social connection" one man told us.

The constant fluctuation in Bourke's population left one couple reluctant to make new connections as "people come, roughly do their three years and move on and you build good relationships and some really good people come and you have your friends and then … [they] end up leaving". "Once people leave it's hard to get them back", a Council member explained.

This decline has affected social cohesion as, many described, Bourke used to be a "zinging", "thriving", and "dynamic" place. However, "all the people with zing in them left town" after the Millennium Drought, one man stated. "Good people … just packed up and left, walked out", another told us regretfully.

Among those who left were vital labourers and skilled workers, but also volunteers, members of community groups, and sports clubs. In the 1990s, Bourke's rugby union club fielded two teams. It attracted ample players, volunteers, and sponsors. Now, several people explained with disappointment, Bourke's and Brewarrina's rugby union clubs have had to amalgamate to field one team. Several of the town's volunteer organisations have gone under. And events that bring the community together – such as the Back O' Bourke Stampede and Bourke Show – have been frequently postponed as volunteers and sponsors are in short supply. "There's just not the population base to support a lot of that sort of activity" anymore, one woman explained.

While Bourke's population decline can be gleaned from statistics, the everyday consequences of that decline are powerfully revealed by people's stories, captured in oral history interviews.

RQ12.1 The Mental Health Benefits of Waterways in the Murray-Darling Basin

The Murray-Darling Basin (MDB) is one of Australia's most significant environmental and economic regions, supporting communities through agriculture, recreation, and tourism. It also has the potential to support the mental well-being of the community via the provision of healthy waterways. Recent studies have established a growing body of evidence linking nature exposure to improved mental well-being, with specific research indicating that visits to freshwater ecosystems can enhance mental health, elevate mood, and reduce stress. Of the few studies specifically targeting riparian areas, most found that healthy waterways tend to lead to better mental health outcomes than those in poor condition.

This case study explores the relationship between waterway visits, activities, connection to nature, and mental well-being in Australia's Murray-Darling Basin. By examining how interactions with waterways influence mental health outcomes, this research provides valuable insights into the public health benefits of maintaining healthy aquatic ecosystems.

Focus groups were conducted in the MDB to determine the types of activities residents undertake at waterways. This showed that people report visiting waterways for four main reasons: recreation (e.g., fishing, swimming), social gatherings (e.g., family events), connection to place (e.g., caring for Country), and wildlife or art appreciation. The project then surveyed 1,160 residents across the MDB to investigate how individual characteristics, such as socio-demographic factors, nature connectedness, and the frequency of visits to waterways and activities, influence mental well-being. The study had the following objectives:

- Understand the individual characteristics of people (e.g., socio-demographics, connection to nature) linked to usage of waterways.
- Understand the direct relationship between using waterways for activities and people's mental well-being.
- Determine what mediates the relationship between people, recreational activities in waterways, and mental well-being benefits.

The study confirmed that MDB residents who regularly visit waterways report significantly better mental well-being than those who do not. This relationship depends on individual attitudes toward nature, perceived importance of waterways, and the types of activities conducted during visits.

People's self-reported nature connectedness also plays a key role in mediating the flow of mental well-being benefits from visiting waterways. This study showed that residents who report high nature connectedness in general also perceive waterways as important for feeling happy, rested, and mentally restored.

Socio-demographic factors, including age, education, and employment status, were found to impact the frequency of visits and the type of activities undertaken. Younger participants, women, and those with higher education levels were more likely to visit waterways and report positive mental health outcomes.

The findings of this study have significant implications for both public health and environmental management:

- Mental Health Promotion: Given the growing global concern over mental health, promoting access to and engagement with natural environments, particularly waterways, could be a valuable strategy for improving mental well-being in the MDB.
- Environmental Conservation: Policies that enhance the accessibility of waterways and ensure their environmental health could have far-reaching benefits for the mental health of local populations.
- Recreational Planning: Encouraging a diverse range of recreational and social activities near waterways could maximize the mental health benefits for different demographic groups.
- Education and Awareness: Programs that foster nature connectedness and raise awareness about the mental health benefits of waterway interactions could amplify positive outcomes.

Project RQ12.1 provides robust evidence supporting the mental health benefits of interacting with waterways in the MDB. Frequent visits, coupled with high nature connectedness, significantly improve mental well-being, underscoring the need for integrated policies that prioritize both environmental conservation and public health. As the Murray-Darling Basin continues to face environmental challenges, this research highlights the critical role of healthy waterways in supporting the well-being of its communities.

Pathway to Impact

The theme continued to engage with the MDBA Social and Economic Community of Practice as the Theme 4 End User Advisory Group.

The researchers for *RQ14.2 Pathways to community resilience* presented at the ABARES Outlook Conference in March 2024 with a presentation titled 'Values Matter – Recognising the 'Intangible' in Landscape Policy Decisions'. Presentations on this research have also been given to the District Council of Loxton Waikerie and Region 9 of the Murray Darling Association.[3]

Maps and info-graphics developed from the *RQ14.1 Data Platform* will provide useful entry points for MDBA and agency discussions with Basin communities around topics such as water literacy, emergent understandings of the importance and value of water in all its forms, and the multiple pathways through which improvements in the condition of rivers, lakes, wetlands and floodplains can enhance mental health and increase economic activity. Full realisation of benefits from this project will continue over the next 1-2 years.

- **Benefit**: Social capital.
- **Realisation description**:
    - Organisation of broad range of data sources and indicators into social capital subsets for ease of analysis and reporting conditions related to social wellbeing.
- **Program objectives supported by the benefit**:
    - 1. Invest in applied research that delivers better informed environmental water management decisions by Commonwealth agencies and improved outcomes for communities.
    - 2. Maximise value to water reform and management from investment.
- **Target date for full benefit realisation**: 2026.
- **Current status**: In progress.

RQ14.4 *Understanding the water cultures of the MDB* has published a journal article and researchers presented at the 'Riverhood Symposium: Histories across time, place and waters' in April 2024 at Harvard University, USA. Griffith University hosts the Murray–Darling Basin Water Cultures Network has appointed 3 research assistants.

The pathway to impact and benefits realised for RQ14.4 will continue over the next 12 months or more as the ARC project concludes.

[3] Murray Darling Association Region 9 member councils: Carrathool Shire Council, Hay Shire Council, Lockhart Shire Council, Murrumbidgee Council, Wagga Wagga City Council, Narrandera Shire Council, Leeton Shire Council and Griffith City Council.

- **Benefit**: Improved understanding of the formation and evolution of cultural values relating to water.
- **Realisation description**:
- The MDB Water Cultures Network and the Chief Investigators have stimulated discussions about the social and cultural significance of water to the diverse communities of the Basin. They have conversed with regional communities, academics and policy makers through interviews, academic presentations and Network interactions.
    - Publication of book and several journal articles.
- **Program objectives supported by the benefit**:
    - 1. Invest in applied research that delivers better informed environmental water management decisions by Commonwealth agencies and improved outcomes for communities.
    - 3. Leverage co-investment with research providers and key stakeholders.
- 4. Facilitate adoption of research by advancing cooperation between users and researchers.
- **Target date for full benefit realisation**: May 2025.
- **Current status**: In progress.

6. Progress of Tactical Projects

MD-WERP is supporting the Australian Government to address emerging and high priority issues in the Murray–Darling Basin by investing in practical, short-term (6-12 months) projects in water management, river operations and Basin Plan implementation. The projects are being delivered by a range of research and delivery partners.

The Tactical Investment Stream allows the Australian Government to respond to short-term knowledge needs during the life of the MD-WERP. The projects are usually carried out 'in-house' by Australian Government partners, or in partnership, and if necessary, the whole project may be contracted to another supplier. The initial approach for tactical investment involved a broad call for submissions across Australian Government partners. The governance and process has been streamlined to ensure projects are aligned with the overarching objectives of the MD-WERP.

Four tactical projects were in progress during 2023-24, with component B of TP12 completed.

The following tactical project deliverables were published on the MD-WERP website:

- Final report for TP09 Foraging habitats for colonial nesting waterbirds in the Murray–Darling Basin.
- Final report for TP13 Knowledge synthesis of the latest science on Blue-green algae (BGA) and an assessment of whether algal blooms are becoming more frequent or severe.

The animated videos developed as part of *TP12 Riverbank stability and erosion* component B were presented at the MD-WERP Annual Symposium 2024.

TP12. Riverbank Stability and Erosion

This tactical investment stream project will help address increasing community concern and negative media relating to bank erosion along the River Murray. The project has 3 components:

- **A.** Desktop synthesis of bank condition and the scientific knowledge of the influences on erosion within the different reaches of the river and major anabranches from the confluence with the Swampy Plains River at the upper end of the system to the Murray Mouth. This is an internal report to inform development of the public communication material. Completed in 2022-23.
- **B.** Preparation of communication material for communities to help with positive engagement and increased understanding of the complexity of the erosion issue.
- **C.** Scoping of a strategic plan for monitoring erosion along the River Murray to fill the knowledge gaps and/or to address community concerns and support understanding of the issue with robust, fit-for-purpose information.

Progress and Achievements

Animate Your Science (AYS) produced two animated videos and one infographic to effectively communicate the complexities of erosion along the River Murray. The project included videos which were presented at the Annual Symposium 2024. Revision of the River Murray erosion information on the MDBA website was underway based on the desktop synthesis and communication materials developed by this project.

Procurement also commenced for the final component to develop a strategic plan for monitoring erosion along the River Murray. Based on quotes received, the project team submitted a Project Variation Request (PVR) for additional budget to the Governing Panel for consideration. The Panel approved the PVR at meeting 21 in June 2024.

TP17. Operational Ranges of the River Murray Fishways

This project will boost understanding of the operational ranges of the River Murray fishways in relation to flow and level. While it is known that variability in weir pool levels can impact the operational performance of fishways, the relationship between operations and fish passage (i.e. weir pool levels and which fish passage is impeded and optimised respectively) is not well understood.

It is anticipated that the project deliverables will be used by agencies to:

- ensure transparency and robustness of decision-making in managing river system operations
- inform trade-off decisions for annual weir pool variability planning and implementation
- inform referrals by river operators, on behalf of Basin government agencies, to New South Wales DPI Fisheries to seek approvals for temporarily impeding fish passage during a proposed Weir Pool Manipulation (WPM) event
- evaluate river level variability impacts on fishway performance, including proposed WPM trials
- inform Sustainable Diversion Limit Adjustment Mechanism (SDLAM) projects and supply shortfall strategies
- prioritise knowledge gaps and their criticality to fishway performance
- determine whether future investment in investigation of expansion of the operational range of fishways is warranted.

Progress and Achievements

The project team commenced the procurement process in October 2023 and in February 2024 GHD was contracted to deliver this project with the key deliverables:

- Final report summarising the review and assessment of fishway performance and operational limits across the expected hydrologic flow range for the Joint Venture River Murray fishways, followed by the characterisation of fishway conditions and effectiveness for proposed WPM levels across the expected hydrologic flow range.
- Development of operational guidance notes that detail lock/weir operation relative to fishway operational limits with respect to real time measurements of Tail Water Level and Head Water Level.
- Presentation at the conclusion of the project outlining key findings and outcomes from the final report and operation guidance notes to the MDBA and invited stakeholders.

The project was due for completion in June 2024, however an extension to 30 August 2024 was requested due to progress being stalled by a combination of staffing, obtaining key information from stakeholders for GHD to undertake the modelling and analysis, and resourcing bottlenecks. The PVR was approved in June 2024.

TP18. Enhancing local fish communities on Country by utilising natural managed waterbodies as nursery ponds for native fish

This tactical project aims to recover two species of native threatened fish – silver perch and golden perch by adding hatchery reared fish (fingerlings) to selected wetlands. These key

wetlands will act as fish nurseries with the aid of water for the environment, to recreate natural flooded wetlands, stimulating what would have happened naturally as part of fish breeding cycles. The project will examine how native fish move through the Murray–Darling Basin and improve collective understanding of how fish respond to different management efforts, such as the delivery of water for the environment in wetlands.

The need for this project is driven by the fact that over one hundred native fish species are listed under the Environment Protection and Biodiversity (EPBC) Act 1999 as critically endangered or endangered. Their abundance and distribution have been severely impacted by the way we have modified waterways over the last 150 years including loss of wetland connectivity. Prior to European settlement, flooded wetlands provided critical nursery habitat for many species of native fish, this ecological function has unfortunately been compromised or lost. The last decade has seen major losses of native fish because of declining water quality and flows, bushfires and blackwater related flooding. The death of millions of fish in the lower Darling River in recent years has prompted community outcry that more needs to be done to protect our native fish. Researchers suggest native fish populations are around 10% of their original biomass with some native fish now locally extinct in the wild.

Simultaneously Traditional Owners to the lands and waters of the Murray-Darling Basin have also been displaced from Country with the arrival of European settlement, resulting in loss of family ties and kinship and connection to language, storey-telling and cultural practices. First Nations people have a wealth of science and knowledge that has been passed down through generations and a lot can be learnt from their wisdom in how to care for and manage Country. As we move forward to a shared and collaborative approach for managing water and biodiversity of the Murray–Darling Basin, it is imperative that we listen and learn from First Nations.

This specific project is therefore unique as it is co-developed by the Victorian Fisheries Authority and the First People of the Millewa Mallee Aboriginal Corporation (FPMMAC) and aims to combine First Nations science and knowledge with modern fisheries science. Additional project support is also being provided from Catchment Management Authorities, the Victorian Environmental Water Holder, academic researchers, the Murray-Darling Basin Authority and other relevant agencies.

The FPMMAC River Rangers are involved to help monitor the performance of stocked fish and in December 2024 a visit to Arcadia fish hatchery will involve tailored training in the classroom and on Country and encourage the sharing of First Nations science and knowledge into how the fish will be managed. There is potential scope to also integrate traditional fish net weaving and put the nets to use, but this will depend on the time aligning and at this stage is not confirmed.

On-Country stakeholder meetings will be held to select three specific wetlands in northern Victoria that would be suitable to host juvenile fish. Early into 2025, hatchery fish will be

stocked in each wetland and FFMMAC will monitor the fish and water quality until maturity, before liberating them to adjoining waterways; to help rebuild native fish populations within the Murray-Darling Basin.

Overall, this project will significantly progress our understanding of how to best utilise wetlands for stock enhancement of threatened native fish. It will also build awareness, skills, and confidence in First Nations people to lead native fish stock enhancement projects in the future.

Progress and Achievements

This tactical project proposal was approved by the Governing Panel at meeting 20b in April 2024 and the contract between MDBA and VFA executed in early July 2024.

TP19. A rapid-assessment tool for hydrological indicators

Hydrological modelling, and the interpretation of this modelling through metrics and indicators, is core to the MDBA's Basin Plan activities. This modelling allows for a range of future scenarios (and their social-cultural-environmental-economic impacts) to be explored for policy and planning purposes, and to be communicated to a wide range of audiences to demonstrate that a proposed policy setting has a robust underlying evidence base.

The project will develop a rapid assessment tool that can extend the Climate Adaptation Toolkit being developed in Theme 1, while delivering to short-term needs of the MDBA. The tool will allow a rapid exploration of a wide range of any desired future hydrological patterns. The input-output relationships will be based on existing hydrological model scenarios, hence they will inherit the existing scientific robustness and established multi-jurisdictional support but will not be bound by existing time constraints of detailed modelling approaches. This capability was a vital component of the development of the Basin Plan, the subsequent SDL adjustment and Northern Basin Review, and will be central to the Basin Plan Review in 2026 and ongoing Basin Plan implementation activities beyond 2026.

Progress and Achievements

This tactical project proposal was provisionally endorsed by the Governing Panel at meeting 20b in April 2024 subject to confirmation of the Program budget forecast. The project was subsequently approved to proceed by the Governing Panel and a contract was established in June 2024 between CSIRO and MDBA to deliver the project by April 2025.

7. Communication, Adoption, Transparency and Engagement

MD-WERP has continued to build awareness of the program and develop pathways towards adoption. The CATE work program began to ramp up in 2023 with a considerable increase in the number of deliverables ready for publishing, improving the Program's web content, holding the 2023 symposium, planning and holding the 2024 symposium, and procuring a CATE delivery partner (Table 6).

Table 64. CATE actions completed in 2023-24.

Opportunity	Tactic type	When
MD-WERP Annual Symposium	Face-to-face and virtual (communication, adoptions, transparency, engagement)	July
MD-WERP symposium wrap up	Summary of MD-WERP symposium published on MD-WERP webpage (Engagement and communication)	September
MD-WERP symposium video on LinkedIn – Overall	Video summarising the symposium (Engagement and transparency)	September
MD-WERP symposium video on LinkedIn	Interview with Andrew McConville (Engagement and transparency)	September
MD-WERP symposium video on LinkedIn	Interview with Rob Vertessy (Engagement and transparency)	September
MD-WERP symposium video on LinkedIn	Interview with David Post (Engagement and transparency)	September
Theme 4 Community of Practice	Thematic end user advisory group meeting (engagement and adoption)	September
MD-WERP symposium video on linked in	Interview with Nick Bond (Engagement and transparency)	October
Theme 1 EUAG	Thematic end user advisory group meeting (engagement and adoption)	October
Macquarie hydroclimate case study workshop	Workshop between researchers, NSW state government and MDBA staff to discuss climate adaptation options to be considered within the case study (engagement and adoption)	October
Theme 1 Traditional Owner engagement on country with the NTS Corp	For T1.SI6 *Report outlining method and outcomes of a shared understanding of the impacts of climate change on Cultural Values* (engagement and communication)	October
Publication of MD-WERP symposium posters	24 posters published on the MD-WERP website (transparency)	October
Publication of MD-WERP symposium presentation	Waterbirds presentation published on the MD-WERP website (transparency)	October
List of journal articles and conference presentations added to MD-WERP website	List of all peer-reviewed journal articles produced from the program so far added to the MD-WERP website (transparency)	October

Opportunity	Tactic type	When
Theme 2 EUAG	Thematic end user advisory group meeting (engagement and adoption)	December
MD-WERP SLT workshop	Social-cultural-environmental-economic impacts of climate change for low flows and cease-to-flows (engagement, adoption)	January
MD-WERP Get Involved webpage	Theme 1 peer reviewed journal article published (transparency and engagement)	February
MD-WERP Get Involved webpage	Six deliverable reports published (engagement, transparency and adoption)	March
MD-WERP Get Involved webpage	MD-WERP eNewsletter #5 published (communication and engagement)	March
MD-WERP website	Transition from Get Involved to MDBA (communication, transparency, engagement)	May
MD-WERP Annual Symposium	Showcase latest in MD-WERP research with Basin communities, web presence and promotion, special edition newsletter (communication, engagement, transparency, adoption)	June
Publication of deliverables	Release of technical reports (engagement, transparency, adoption)	June

Annual Symposium 2023

On 19-20 July 2023, the MD-WERP held its second annual symposium at the Canberra Rex Hotel, and online. The strategic aims of the 2023 event were to focus on sharing and discussing the research conducted so far, as well as developing a shared understanding on how we can capitalise on and use this research.

More than 170 people attended the event over the 2 days (130 in person, 40 online). The symposium dinner was attended by 116 people. A breakdown of attendees by stakeholder group is at Table 7.

High-level speakers included:

- Authority Chair, Sir Angus Houston (MDBA) – Roadmap to the 2026 Basin Plan Review
- A/g Division Head Water Policy (DCCEEW), Marcus Finn – priorities for Australian Government water policy.
- Sheryl Hedges, First Nations Water Policy Branch Manager (DCCEEW) – the approach to First Nations knowledge and science.
- Grace Mang, A/g General Manager Strategy & Integration (MDBA) – detail on the focus and journey to the Basin Plan Review.
- Deranie Jackson, A/g General Manager Science Acquisition (MDBA) – overview and update on the MD-WERP.

- Commonwealth and Consortium theme leads – overview of their strategic research focussing on the outcomes expected and links to government needs (Commonwealth lead) and outputs expected from the research (Consortium lead).
- Associate Prof. Emily O'Gorman (Macquarie University) – dinner guest speaker.

Table 7. Summary of attendees at the 2023 symposium.

Stakeholders
Governing Panel
Authority
Commonwealth partners (involved directly in MD-WERP) DCCEEW, CEWH and MDBA
Consortium partners (including Commonwealth) CSIRO, La Trobe University, Griffith University, Alluvium Consulting, eWater, Deakin University, and MLDRIN
Tactical project leads
End User Advisory Groups (involved directly in MD–WERP) MDBA, DCCEEW, CEWH, BOM, QLD, NSW, ACT, VIC, SA, ANU, Uni of Canberra, Watertrust
Other Commonwealth staff (not directly involved in MD-WERP) DCCEEW, CEWH, MDBA, ABARES, AFF
Jurisdictional staff (not directly involved in MD-WERP) NSW, SA, Vic
Science influencers ACSEES, OneBasin CRC, Goyder Institute, Watertrust, ANU

The 2023 symposium featured interactive poster sessions for 25 strategic research projects. The sessions enabled attendees to engage with individual research projects and researchers. Attendees were asked to consider benefits, barriers and opportunities to adopting the research outputs in their work. Online attendees had a (prewarned) reduced experience due to the nature of the poster format.

Two completed tactical research projects – TP09 Waterbird Foraging Habitats Identification and Prioritisation, and TP13 Synthesis of Blue-green algae bloom knowledge & analysis of recent trends in the Murray-Darling Basin – were presented and followed by a collective Q&A session that was very engaging and showed high levels of interest in the projects.

A post-event survey was distributed on Survey Monkey. The majority of responses were very positive about the format and content of the symposium with 92% saying the event met their expectations. Researchers and end-users across all themes enjoyed the opportunities to collaborate, network and share knowledge. The poster sessions were a great way to get everyone talking and interacting, with the overall symposium being an excellent opportunity for engagement, making connections and improving attendees understanding of the range of MD-WERP research projects.

Attendees also enjoyed the opportunity to ask questions of Program leaders during the Governing Panel Q&A session, and several survey responses noted that the Slido format enabled a transparent, democratic process of question asking and answering.

Suggestions for improvements for the 2024 Symposium included:

- focus on linking research outcomes to policy and defining pathways to enable this
- giving attendees more time to sit with and reflect on research before asking about benefits, risks and opportunities
- greater diversity in panel discussions and in leadership roles within MD-WERP
- greater focus on communication of program aims and outputs external to program.

Annual Symposium 2024

The MD-WERP Annual Symposium 2024 was held on Friday the 21 June at the Commercial Club Albury. The symposium was held in conjunction with the MDBA River Reflections conference and was open to the general public. The symposium theme was 'Knowledge of the collective to shape a way forward' and focussed on community engagement while demonstrating research and adoption to audiences beyond MD-WERP researchers and government policy advisors.

Overall, the event was warmly received and professionally delivered. The event had 185 attendees (both in person and virtually). Key presentations included:

- Prof. Rob Vertessy, MD-WERP Governing Panel Chair – contribution of MD-WERP to collective wisdom and the utility of research outcomes beyond the life of the program.
- Andrew McConville, Chief Executive, MDBA – how science supports and informs policy development and helps us understand what the potential consequences of a decision may be.
- Rachel Connell, Division Head Water Policy, DCCEEW – Australian Government priorities.
- Prof. Lauren Rickards, Director of La Trobe Climate Change Adaptation Lab, La Trobe University – Climate change adaptation and social change
- Commonwealth and Consortium theme leads – overview of strategic research focussing on benefits and adoption.
- Tactical project leads – communicating riverbank erosion, water bird foraging habitats, enhancing local fish communities on Country.
- MD-WERP Governing Panel Q&A

A modified interactive poster session with researchers (for 12 strategic research projects) was held in response to feedback from 2023. Online attendees were taken on a livestream 'watch & listen' of discussions at the posters, however the poster session was only 1 hour in duration due to the 2024 symposium being a much shorter event than previous years.

Feedback from participants indicated that they were happy with the speakers and the panel discussion, however felt the poster session was too brief and in some instances the delivery

of content by presenters too complicated. Online participants were very impressed with the livestream poster session and believed it went a long way in explaining the purpose and outcome of the research to the online audience.

The 2024 MD-WERP Symposium met almost all communication objectives (Table 8). The objectives not met were due to the inability to measure the outcomes.

Table 8. 2024 symposium communications objectives and what was achieved

Objective	Achievement
The Symposium attracts positive media attention – stories about the Symposium are published/broadcast	**Water, environment research unveiled** Southern Riverina News • Newspaper • 26 Jun 2024, 12:00 am Progress of research that will benefit the basin and its communities for years to come has been shared at the third annual symposium of the Murray-Darling Water and Environment Research Program. 2085602125_20250626.pdf (isentia.com) **Rob Vertessy interview with Flow FM's Country View Point program.** Flow FM broadcast area covers regional SA, Vic and southern NSW, with new sites recently online in the Murray-Darling basin catchment area. The interview aired Monday July 8th during the second hour of the Country Viewpoint program. **OpEd from Andrew McConville**
Website traffic	**Webpages** Google Analytics 4 (GA4) web stats for Symposium 2024 from 19 June to 4 July 2024: • Landing page for Symposium 2024 - 579 hits, users spend on average 25 sec • Video livestream page - 197 users watching on average 2 min 49 • Total of 389 PDF downloads of posters. **Livestream** Approximately 80 participants at most times. Peaked at 120 participants at one point. **Newsroom articles** 2024 Science Symposium highlights collaboration and research progress – 147 views. **Media release** Water and environment research unveiled at Basin science symposium – 98 views.
Symposium attendees are positive about the outcomes/ achievements of the event	**Responses to feedback survey:** Overall, how would you rate your experience at the MD-WERP Science Symposium 2024? 4.15/5
Social media traffic	**WERP Symposium livestream** 12/6: 9% engagement **LinkedIn WERP Symposium** 20/6: 4.7% engagement **Facebook Symposium solstice**: 5.8% engagement (Any engagement rate higher than 5% is considered very high).
End-users have a greater understanding of how the Basin Plan is being delivered and the	The 'mock symposium' held the week before helped to ensure accessibility of language and messaging, and linkages to the BPR and the MD-WERP generally.

Objective	Achievement
benefits of programs such as MD–WERP.	**Responses to feedback survey:** Did the Science Symposium provide you with a better understanding of the research being undertaken by the Murray Darling Water, Environment and Research Project? 4.42/5 How did you find the interactive poster session with the researchers? 4.06/5 Do you believe the research presented in the posters reflects concerns you have for the Basin's future? Yes 28, No 3
Increased awareness of MD-WERP and interaction with broader MDBA	**Responses to feedback survey:** Strategic research themes: Climate adaptation, Hydrology, Environmental outcomes, Social and economic outcomes 4.09/5

Communication and Transparency

Fourteen strategic research and tactical research deliverables were published on the MD-WERP Get Involved website in 2023-24 (Table 9). The recordings from both the 2023 and 2024 MD-WERP Symposiums and posters were also published on the website.

Table 9. MD-WERPdeliverables published in 2023-24.

Investment stream	Project	Deliverable title	2023-24 quarter published
STRATEGIC RESEARCH			
1. Climate Adaptation	Foundational Science (FS)	T1.FS3 Assessing the sensitivity of water resources in the Murray-Darling to fire and climate change	Q3
	Showcasing Adaptability and Pilots (SA)	T1.SA1 Technical paper describing the system for classification of adaptation options and adaptation investigations	Q2
	Synthesis and Implementation (SI)	T1.SI1 Report outlining framework for Basin-wide monitoring and management	Q2
	Science Applications and Assessment Toolkit (TK)	T1.TK4 Values & vulnerabilities report	Q2
2. Hydrology	RQ6. Enhancing low flow prediction to support water resources planning	T2.6.4. RQ6 – Progress towards enhancing low flow predictions	Q3
	RQ7. How can floodplain flow volumes, components, and inundation prediction be improved to support environmental watering and water resources planning?	T2.7.4 Description and metadata for two-monthly maximum flood water extent and depth for the Murray-Darling Basin	Q3

Investment stream	Project	Deliverable title	2023-24 quarter published
	RQ8a. Enhancing river operation outcomes using forecasts and optimisation	T2.8a.4 Insights into forecast-informed operation of the Hume Dam release	Q3
	RQ8b. Groundwater as an adaptation to current water resources management	T2.8b.3 Scripts and tools developed for trend and cluster analysis, GDE analysis, salinity mapping and time series analysis	Q3
		T2.8b.4 Groundwater as an adaptation option to current water resources management	Q4
	RQ-H. Impact of hydrological non-stationarity and changing catchment conditions on runoff in the northern Basin	T2.H.2 Summary report – Hydroclimate and catchment processes impacting runoff in the northern Murray–Darling Basin	Q4
3. Environmental Outcomes	RQ11.3. Predicting change in floodplain aquatic habitat availability at the Basin scale	T3.11.3.3 Predicting change in floodplain habitat availability at the Basin scale: Final report	Q3
	RQ11.4 Assessing future vulnerability of species and ecological communities	Habitat Suitability Modelling of Fish, Aquatic Invertebrates and Riparian Plants in the Murray–Darling Basin	Q4
TACTICAL PROJECTS			
	TP09. Waterbirds Foraging Habitat	Foraging Habitats for Colonial Nesting Waterbirds in the Murray–Darling Basin	Q2
	TP13. Knowledge synthesis of the latest science on Blue-green algae (BGA) and an assessment of whether algal blooms are becoming more frequent or severe	Synthesis of Blue Green Algae (Cyanobacteria) bloom knowledge and analysis of recent trends in the MDB	Q2

Website traffic continued to be high, with 3400 unique visitors from July to mid-October and 2000 unique visitors from December to mid-March. The top unique downloads over this period were:

- Annual Symposium agenda (269 downloads)
- Annual Progress Update 2021-22 (158 downloads)
- Research prospectus 2020 (156 downloads)
- Edition 4 newsletter (137 downloads)
- Program governance (132 downloads)
- T1.FS3 Assessing the sensitivity of water resources in the Murray-Darling to fire and climate change (155 downloads)

- T3.11.3.3 Predicting change in floodplain habitat availability at the Basin scale: Final report (133 downloads)
- T2.6.4 RQ6 – Progress towards enhancing low flow predictions (103 downloads)
- T1.SA1 Technical paper describing the system for classification of adaptation options and adaptation investigations (95 downloads)
- TP09 Waterbirds Foraging Habitat (89 downloads).

Edition #5 of the MD-WERP e-newsletter was released in March 2024. It was distributed to more than 200 stakeholders including the Governing Panel, Research Consortium, tactical project leads and end user advisory groups. The newsletter was also published on the MDBA website. The newsletter content focused on reports and peer reviewed journal articles published since the May 2023 newsletter, spotlighted the waterbird foraging habitat tactical project, a wrap-up of the 2023 symposium, and a look ahead over the next few months.

Engagement and Adoption

The Engagement and Adoption Plan, which identifies objectives and opportunities to facilitate adoption of research outputs by end users, is being reviewed to better reflect the current status of the Program. The Program Engagement and Adoption action plan is being updated for 2024-25 – identifying events/activities, primary audiences, engagement objectives, methods and measures of success.

Commonwealth theme leads and coordinators have reviewed the benefits realisation maps, new capabilities and barriers to adoption ensuring they are still current/relevant and updating as needed. This has been completed for Themes 1, 2 and 3 and is currently being finalised with Theme 4. From this, a benefits management approach will be developed to define benefits management actions and benefits reviews that will be established to ensure that the project and program outcomes are achieved and confirm the benefits are realised[4]. A part of this includes tracking engagement and mapping MDBA's use of the research.

First Nations Engagement

Northern Basin

The MD-WERP consortia continued engaging with individual Nations in the northern Basin. As a result, several new projects commenced in 2023-24 with the: Barkandji Nation (RQ9.3); Gomeroi Traditional Owners (RQ13.2a and RQ13.2b); and a Native Title Applicant Group in

[4] It is important to note that while some benefits may be realised during the Program, in most cases, many or all of the benefits will be realised after the Program is completed. The benefits management approach will document how and when post-program reviews should occur and who is responsible and accountable for them.

the Macquarie catchment representing the Ngemba, Ngiuampaa, Wangaaypuwan and Wayilwan Nations (SI).

An important principle has been to recognise and respect cultural safety in research design and collaboration with First Nations, which is essential for building trust and ensuring meaningful engagement. A critical aspect of this is honouring timelines and the timing of projects, which may be influenced by cultural events and other factors, which may differ from conventional academic timelines. By demonstrating flexibility, patience, and respect for these differences, researchers are able to foster a more inclusive and respectful partnership that supports both the integrity of the research and the well-being of the community.

Southern Basin

Regretfully, MLDRIN withdrew from RQ13.1 (Activities 1 and 2) in November 2023 after ongoing efforts by La Trobe University to progress the contract negotiations. An update from MLDRIN at the MD-WERP Science Leadership Team meeting in September 2023 noted frustrations with DCCEEW being unwilling to fund RQ13.1 Activities 3 and 4, and reiterated that the four activities for RQ13.1 are a package and the lack of resourcing is a major issue. An open invitation stands for MLDRIN to meet with the Governing Panel to discuss any concerns with how MLDRIN has been engaged with and involved in the Program.

Respecting that the ICIP for RQ13.1 rested with MLDRIN, the Governing Panel agreed to change the First Nations engagement approach in the southern Basin to replicate the northern Basin. To manage the risk of co-design and implementation in the remaining timeframe for MD-WERP, principles for alternative/tactical-style First Nations projects in the southern Basin were adopted:

- the project must meet MD-WERP objectives
- projects are initiated and led by First Nations leaders, involve direct engagement with one or a small number of Nations and are based in Country, not Basin wide
- projects build on existing relationships between the leader and Nations and/or springboard off other projects already in train with strong First Nation relationships
- the contracting body must meet governance standards and have proven delivery capability
- the opportunity to develop projects is shared among First Nations leaders in the consulted group
- the project must be able to be contracted by mid-2024 for completion by 30 June 2025.

Opportunities for participation in the MD-WERP were provided to additional First Nations groups. As a result, *TP18 Enhancing local fish communities on Country by utilising natural managed waterbodies as nursery ponds for native fish* has commenced and another tactical-style project proposal is being developed by the Yorta Yorta Nation Aboriginal Corporation.

End User Advisory Groups (EUAG)

Forming strong links between researchers and end users is a crucial component of the program. Each of the 4 strategic research themes has an EUAG, with members spanning Australian Government and all Basin state jurisdiction policy makers and researchers (Appendix 4 – End User Advisory Group membership). These 4 groups draw on a broad range of end user perspectives, expertise and experiences. They create opportunities for policy makers and researchers to allow for ongoing co-design and feedback on the research.

The EUAGs are also vital for research impact – being involved throughout the program will ensure that key users of the research are ready to adopt and apply the new knowledge as soon as it becomes available.

The Climate Adaptation theme continued its strong engagement between the Consortium and the MDBA across all projects. Two meetings held by the Climate Adaptation End User Advisory Group (EUAG) provided valuable feedback on project output and emerging project activities. Additionally, there were focussed meetings and workshops with collaborator organisations on individual projects and activities. All project deliverables are being reviewed by the EUAG before submission.

The Hydrology theme End User Advisory Group (EUAG) received an update of the research projects in mid-December 2023 including a briefing on how the hydrology MD-WERP research mapped towards Basin Plan Review intent. The EUAG are keen to understand the connection between the research coming through and how the work can be utilised over the next few years to answer policy questions. It is expected that the theme engagement with the EUAG will continue to increase over the next 12 months as the research program produces products that will inform or influence broader policy work across the Basin.

There have also been a number of meetings with the Environmental Outcomes theme EUAG, including with individual members who have in some cases provided additional data and advice to support the projects (e.g. RQ11.1). A number of presentations on finalised research have also been given.

The Theme 4 CoP met twice in 2023-24, with the focus more on providing a forum to share knowledge and future work in economic and social research / policy / programs. Topics included Social Impact Assessment and the benefits it provides to the Basin Plan Review social and economic research, and Justice, Equity and Fairness in water policy and management.

CATE delivery partner

In March 2024, the Governing Panel agreed to engaging an external CATE delivery partner, recognising MDBAs limited experience and capability in engagement and adoption practices

for research and science. An Approach to Market was issued in April 2024 for the following services:

- Research integration for policy exploration – facilitate cross-theme workshops to encourage knowledge sharing and generate ideas for integrating research outcomes to develop a 'working box' for policy exploration purposes.
- Science translation/communication – develop the technical synthesis science narrative to support science to policy translation and as a foundation for general communications; build on research integration by synthesising research outputs to develop a narrative for target audiences (i.e. key recommendations or findings for policy makers).
- End-user engagement and adoption – advise on how to best activate end-user engagement and championing and, assist in end-user agencies transitioning from interested observers to active users of the research.

Elysium EPL, sub-contracting to Water Technology, was contracted in early July 2024 and has commenced development of a detailed workplan.

8. Monitoring, Evaluation, Reporting and Improvement

The MD-WERP Monitoring, Evaluation, Reporting and Improvement (MERI) Plan sets out roles and responsibilities and guides the approach to the monitoring, evaluation, and reporting to inform continuous improvement of the Program. This includes 6-monthly progress reports from each strategic research theme, and the Program to deliver two evaluations:

- a health check on the effectiveness of the program to date (2023 mid-term evaluation)
- a full and final program evaluation at the end of the program term (2025 end of term evaluation).

Mid-Term Evaluation

The MERI Plan states the mid-term evaluation (MTE) is to provide an assessment of the Program's achievements against the Key Evaluation Questions relating to the efficiency and effectiveness of the program, with the outcomes being used to inform program improvement and to demonstrate program successes.[5]

[5] KEQ1: To what extent was the program implemented in an efficient manner?
KEQ2: To what extent have program activities and outputs effectively supported the achievement of program outcomes?

The MTE was conducted by independent evaluators Professor Barry Hart and Dr Rhonda Butcher from July to November 2023. The MTE is constructive and formative in nature where possible with the intent to assisting in improving Program processes where appropriate.

The MTE sought to answer 6 evaluation question set by the Governing Panel using the following program level process indicators: governance processes; program design and planning (co-design activities); program implementation (collaboration, project management, communications and engagement); outputs and outcomes (progress, likely outcomes/impacts) (see Appendix 6 – Summary of Mid-Term Evaluation Findings). This evaluation has not reviewed in any detail the actual research projects being undertaken, but rather focused on high level program processes. Detailed review of the research will be a task for the end of program evaluation of MD-WERP.

The independent evaluators reviewed numerous program artefacts and semi-structured interviews with 33 key stakeholders including representatives of: Governing Panel; Executive Leadership Team; Science Leadership Team; Implementation Team; Commonwealth theme leads; Consortium leads and Theme leads; Policy end-users; First Nations; and End-User Advisory Groups.

Evaluative Judgement

The MD-WERP is of significant value and merit. Overall, the processes used to conceive, design and implement the Program are largely effective and efficient. Program documentation is comprehensive, thorough, and mostly effective in providing a good description of the planning and implementation of the Program. Governance processes, including operation of the Program structure and Program management, are moderately effective to effective. The co-design activities were largely appropriate, with some exceptions, and collaboration is considered to be largely effective although improved interaction with the EUAGs is needed.

Overall clarity on what is being delivered needs some work, again mostly with the end users. Most of the research is on track, with a few exceptions, however the packaging of the outputs for adoption needs to be addressed further. Realisation of benefits is a work in progress, but requires detail on how benefits will be measured, and when they will be assessed as being delivered.

9. Program Administration

The program has complex, multi-layered governance involving government and non-government organisations. This requires thorough communication and collaboration between all players. Program administration is managed by the MDBA to support delivery of the program. Budget, systems, reporting, secretariat duties and overarching contract management are delivered by the MD-WERP Implementation Team.

The administrative focus in 2023–24 has been:

- drafting papers and secretariate support for 5 Governing Panel meetings, 4 out-of-session Governing Panel meetings and 5 Executive Leadership Team meetings
- reviewing and uplift of reporting templates, workorders, deliverable and financial trackers, and program risks and issues management plan
- finalisation of project variation tolerances and new templates to clearly document project variation requests and approvals
- drafting, execution and variation of strategic research workorders
- managing the mid-term evaluation and implementing the Governing Panels' responses (see Monitoring, Evaluation, Reporting and Improvement)
- commencing planning for the end of program evaluation process
- regular (weekly or fortnightly) meetings with strategic research themes
- supporting tactical project leads
- recruitment and onboarding of new Program Manager (September 2023), Engagement and Adoption Lead (March 2024) and Science Outreach Officer (May 2025)
- supporting CATE activities including procurement of CATE delivery partner, symposium planning and delivery, web content management
- negotiation of a variation to milestone 6 of the MoU (executed in July 2024).

10. Governance

Successfully delivering a 5-year cross-agency program requires a robust framework of authority and accountability applied by the different levels of governance to ensure that the research creates value, and the investment delivers against Australian Government objectives.

The MD-WERP governance structure remains as agreed in 2020–21 (Figure 1), although the value of the Commonwealth Advisory Team (CAT) as a formal group is pending further discussion.

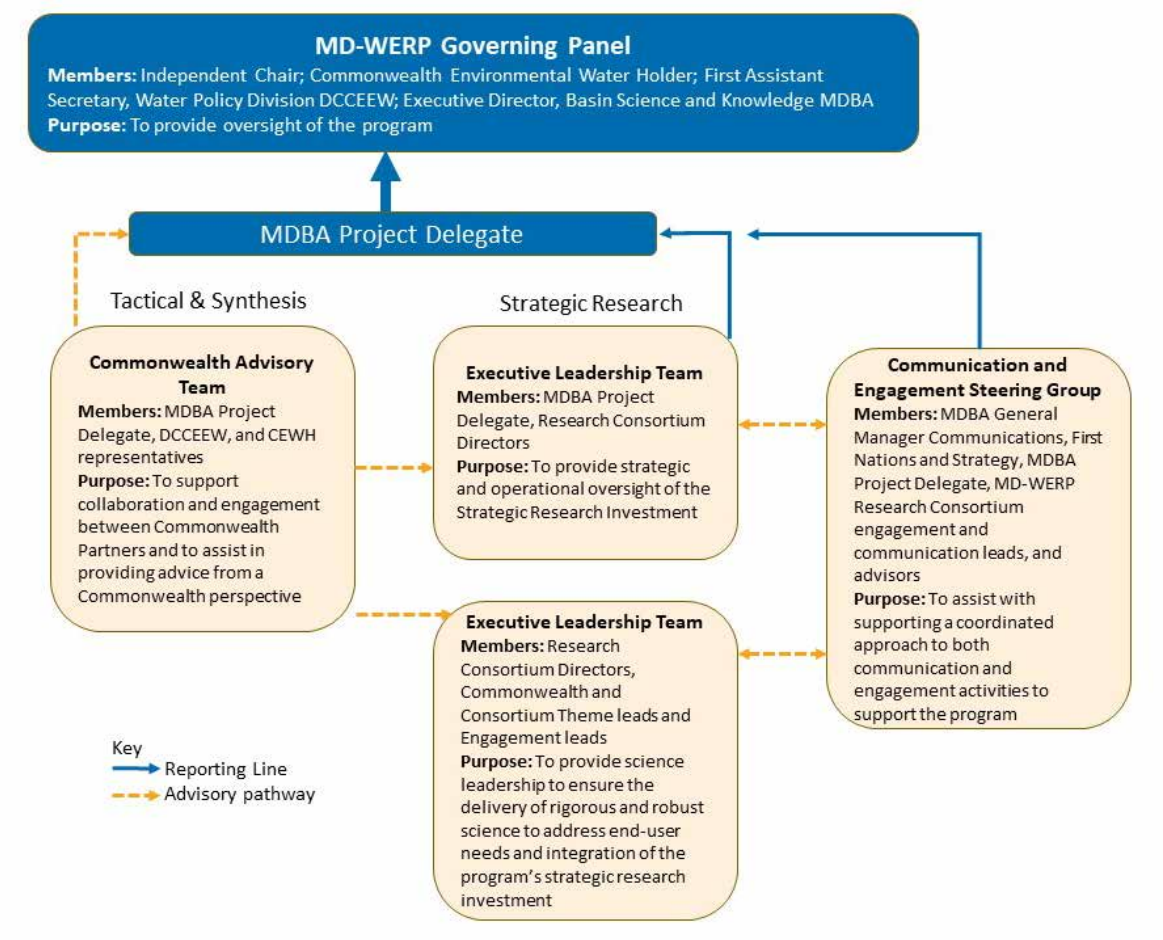

Figure 1. MD-WERP governance structure as at 30 June 2024.

Governing Panel

The program is overseen by a Governing Panel, which reports to the Australian Government Minister responsible for Water. The Governing Panel consists of an independent Chair, DCCEEW First Assistant Secretary for Water Policy/Reform Division, the statutory position of the CEWH, and MDBA Executive Director of Basin Science and Knowledge (Figure 1).

The Governing Panel met 5 times during 2023–24 (Table 20) and 4 times out of session (Table 21). Key decisions included:

- endorsed the 2023-24 strategic research work orders
- endorsed the new Project Variation Requests (PVR) process
- approved the MD-WERP Mid-Term Evaluation Report and Governing Panel response
- agreed to the CATE investment proposal including contracting an external delivery partner
- approved 2 new tactical projects
- agreed to recommendations for the End of Program Evaluation process based on Recommendation 7 of the mid-term evaluation
- approved the MD-WERP Annual Report 2022-23 for submission to DCCEEW

- endorsed 2024 symposium proposal
- approved First Nations strategic research project under RQ13.2.

Executive Leadership Team (ELT)

The ELT provides recommendations on investments and/or opportunities, and oversight on progress reporting, including escalation of program risks. The ELT members are the MDBA MD-WERP Project Delegate (General Manager, Science Acquisition), CSIRO Research Consortium lead and La Trobe University Research Consortium lead.

The Chair position rotates between members for each meeting and the MD-WERP Implementation Team provides secretariat support. The Executive Leadership Team met 5 times during 2023–24 (Table 22) and predominantly discussed:

- First Nations engagement
- deliverables for publication
- synthesis and integration of MD-WERP deliverables
- mid-term evaluation recommendations
- outcomes of the 2023 Symposium and planning for 2024 Symposium.

Science Leadership Team

The MD-WERP Science Leadership Team (SLT) is a multidisciplinary team comprised of researchers, Australian Government end users, First Nations representatives and engagement specialists. The SLT provides science thought leadership to ensure the delivery of rigorous and robust science to address end user needs and integration of the program's strategic research investment. The SLT is led by the Research Consortium and met 4 times in 2023–24 (4 July 2023; 12 September 2023; 12 December 2023; 3 April 2024) to discuss the research activities across the 4 themes.

Communication and Engagement Steering Group

The Communication and Engagement Steering Group only met once in 2023-24. This was largely due to the staffing issues outlined above. The Group met in April 2024 to discuss:

- revising the Terms of Reference, in particular core and advisory members of the group
- updating the CATE Framework and subordinate plans as per the mid-term evaluation recommendations
- procurement of the CATE delivery partners
- the 2024 Annual Symposium planning
- the website transition from Get Involved to MDBA.

11. Financial Summary

Budget, both actual and forecast to Program close, is on track within the $20 million funding allocation. A total of $2,506,754 was spent in 2023-24 (Table 10), taking the total Program expenditure to $12,322,369. The Consortia invested $1,501,358 as FTE in-kind contribution, equivalent to 60% of the Australian Government cash investment for 2023-24.

Table10. 2023-24 actual expenditure (GST exclusive) as at 30 June 2024.

Funding stream	Expense	Actuals
Strategic	Theme 1. Climate Adaptation 2022-23 Work Order	$640,965
	Theme 1. Climate Adaptation 2023-24 Work Order	-
	Theme 2. Hydrology 2023-24 Work Order	$418,300
	Theme 3. Environmental Outcomes 2022-23 Work Order	$343,254
	Theme 3. Environmental Outcomes 2023-24 Work Order	$72,264
	Theme 4. Social, Economic and Cultural Outcomes 2022-23 Work Order	$203,334
	Theme 4. Social, Economic and Cultural Outcomes 2023-24 Work Order	$155,050
	TOTAL	**$1,833,167**
Tactical	TP17. Operational ranges of the River Murray fishways	$38,122
	TP12b. Synthesis of current knowledge on bank erosion along the River Murray	$24,805
	TOTAL	**$62,927**
CATE	2023 MD-WERP Annual Symposium	$45,788
	2024 MD-WERP Annual Symposium	$5,203
	Salaries	$54,828
	Travel	$3,268
	TOTAL	**$109,087**
Administration	Governing Panel Chair	$25,156
	Mid-Term Evaluation	$71,660
	Salaries (including contractors)	$398,785
	Travel	$2,910
	Other	$3,063
	TOTAL	**$501,574**
	Program Total	**$2,506,754**

Appendix 1 – Program Glossary

Term	Definition
Adoption	The uptake of information, concepts, tools or practices (innovations) that have been generated predominantly through research.
Advisory Committee on Social, Environmental and Economic Sciences (ACSEES)	The MDBA's independent scientific advisory body comprising 8 committee members focused on delivering advice on Basin Plan implementation and the broader scientific context of the MDBA's work, including environmental watering, First Nations, adaptive management, climate change and the monitoring and evaluation of Basin Plan outcomes.
Chair	Independent Chair who provides strategic oversight of the program and leads the MD–WERP Governing Panel.
Co-design	Purposely designed to include end users throughout the life of the program to ensure it maintains its relevance.
Commonwealth Advisory Team (CAT)	A group established to support collaboration and engagement between Australian Government Partners and to assist in providing advice from a Commonwealth perspective.
Commonwealth and Engagement Steering Group	A group established to assist with supporting a coordinated approach to both communication and engagement activities to support MD–WERP.
Communication, Adoption, Transparency and Engagement Framework	A framework developed to guide the development of all communications, engagement, transparency and adoption activities; it outlines expectations at program and project/thematic level.
Commonwealth Environmental Water Holder (CEWH)	The CEWH is an independent statutory position established under the *Water Act 2007* to manage the Australian Government's water entitlements in the Murray–Darling Basin. The CEWH leads, and is supported by, the Environmental Water and Aquatic Ecosystems Division of DCCEEW. The Division supports the CEWH to deliver water across the Basin to meet environmental priorities and targets set out under the Basin Plan.
Australian Government Partners	A collaboration between Australian Government agencies to help deliver the program, comprising the MDBA, the CEWH, and DCCEEW.
Department of Climate Change, Energy, the Environment and Water (DCCEEW)	Australian Government department partnering in the research program with the MDBA and CEWH.
End Users	Individuals, groups and organisations for whom the findings and outputs of MD–WERP will have direct relevance and consequences to their work programs.

Term	Definition
End User Advisory Groups (EUAGs)	Established to assist in developing a shared vision for the research program, including impact pathways, research questions and connected teams. Groups are comprised of ends-users from the Australian Government (DCCEEW, CEWH, MDBA), state governments and the research sector who have an interest or expertise in a particular research stream.
Evaluation	Systematic determination of the quality or value of something. Evaluation will be used to determine the value of the program and its activities. Formative evaluation through the life of the program will inform ongoing improvements, with summative evaluation being conducted to capture the overall worth of the program at its closure.
Executive Leadership Team (ELT)	A leadership group comprising the MDBA Project Delegate, and Research Consortium leads to provide strategic and operational oversight of the Strategic Research Investment.
Get Involved	The MDBA's stakeholder engagement website which hosts the MD–WERP program webpages. *https://getinvolved.mdba.gov.au/MD–WERP*
Governing Panel	An executive leadership group established to provide strategic oversight of the program, comprising an independent Chair, the Commonwealth Environmental Water Holder, Head of Division of the Water Policy Division (DCCEEW), and Executive Director of Basin Science and Knowledge (MDBA).
Impact Pathway	Outlines the key inputs, activities, outputs and expected outcomes and impacts for each research theme and the relevant research questions in ensuring the research continues to be used and developed by others after the four-year program.
Knowledge Prospectus	Identifies 14 priority research questions across the 4 themes of Climate Adaptation, Hydrology, Environment, and Social, Cultural and Economic. It was developed in 2020 through an independent consultative process involving a range of participants including the Basin governments, academia and the community.
Monitoring	Observing or checking the progress of something over a period of time. In the context of MD–WERP, monitoring may include performance monitoring or operational monitoring depending on the question it is being used to address. Monitoring will inform evaluation and reporting.
Murray–Darling Basin Authority (MDBA)	Responsible for administering the program, in collaboration with Australian Government Partners, DCCEEW and CEWH, Basin stakeholders, and the Research Consortium.
MDBA Delegate	MDBA Executive Director, Basin Science and Knowledge, responsible for the program. Provides strategic guidance and leadership and oversees budget allocation, program investments, research design, and monitoring, evaluation and reporting.
MDBA Project Delegate	MDBA General Manager, Science Acquisition, responsible for administering the program with the support of the MD–WERP Implementation Team.

Term	Definition
Murray–Darling Water and Environment Research Program (MD–WERP)	A 5-year (2021–25), $20 million Australian Government funded research program designed to help inform water and environment management decisions, which will improve outcomes for the Basin and its communities.
MD–WERP Implementation Team	Provides support to the MDBA Project Delegate in administering the program by managing the program administration, program streams, providing secretariat support, and engaging with key stakeholders and program partners.
Memorandum of Understanding (MoU)	Funding for MD–WERP is provided under a Memorandum of Understanding between DCCEEW and the MDBA. The MDBA administers the program under the guidance of the MD–WERP Governing Panel.
Monitoring, Evaluation, Reporting and Improvement (MERI) Framework	Outlines the rationale, scope and approach for monitoring and evaluating the activities carried out under MD–WERP, the reporting activities and feedback loops for program improvement.
Murray Lower Darling Rivers Indigenous Nations (MLDRIN)	A confederation formed in 1998 of First Nations from the southern part of the Basin. It comprises representatives of the Barapa, Dhudhuroa, Dja Dja Wurrung, Latji, Maraura, Mutti Mutti, Nari, Ngarrindjeri, Ngaywang, Ngintait, Ngunawal, Nyeri, Tatti Tatti, Taungurung, Wadi, Wamba Wamba, Waywurru, Wegi, Wergaia, Wiradjuri, Wolgalu, Wotjabaluk, Yaitmathang and Yita.
Northern Basin Aboriginal Nations (NBAN)	A confederation formed in April 2010 that comprises First Nations from the northern part of the Basin. It comprises Traditional Owner nominated representatives from the Barunggam, Bidjara, Bigambul, Budjiti, Euahlayi, Githabul, Gomeroi, Gunggari, Gwamu (Kooma), Jarowair, Kambuwal, Kunja, Kwiambul, Mandandanji, Mardigan, Murrawarri, Ngemba, Ngiyampaa, Wailwan and Wakka Nations.
Reporting	Giving an account of something that has been observed, heard, done or investigated. Reporting will be used to track risks and disseminate monitoring and evaluation findings. Reporting will feed into ongoing improvement of activities and broader evaluation of the program. Reporting plays a critical role in ensuring transparency.
Research Consortium	Comprised of CSIRO and La Trobe University, each with additional collaborators, to lead and deliver the strategic research stream of the program over 4 themes: climate adaptation, hydrology, environmental outcomes, and social, economic and cultural outcomes.
Research Implementation Plan (RIP)	An outline of the research questions to be answered and the research planning for how these questions will be answered, including a defined impact pathway to outline the key inputs, activities, outputs and expected outcomes and impacts for each theme and the relevant research questions.
Research Theme	Four themes that form the strategic research stream of the program including: 1) climate adaptation 2) hydrology, 3) environmental outcomes and 4) social, economic and cultural outcomes.

Term	Definition
Research Question	A set of agreed research questions identified by the *Knowledge Prospectus* across the 4 research themes that have clear links to priority knowledge gaps and critical user needs.
Science Leadership Team (SLT)	A group established to provide science leadership to ensure the delivery of rigorous and robust science to address end-user needs and integration of the program's research investment.
Strategic Research Investment	One of 4 program streams involving a collaboration between the Australian Government and the Research Consortium to co-design, co-invest and deliver applied research across 4 themes. The strategic research component of the program will invest in priority research needs to improve the long-term management of the Murray–Darling Basin.
Streams	Four program funding streams that comprise MD–WERP including 1) Strategic Research 2) Tactical Investments 3) Communications, Engagement and Adoption, and 4) Administration.
Sustainable Rural Water Use and Infrastructure Program	The Sustainable Rural Water Use and Infrastructure Program (SRWUIP) is a national program investing in rural water use, management and efficiency, including improved water knowledge and market reform, and water purchase for the environment. SRWUIP funding is managed by DCCEEW. Funding for the MD–WERP is provided by DCCEEW from SRWUIP Bill 1.
Synthesis Activities	Creation of explainer products and activities that bring together information from across the program and communicate new and existing science for a variety of audiences.
Tactical Investment	Delivery of short-term and responsive outputs to assist decision and policy makers on water management, river operations and Basin Plan implementation.
Theme Team	Comprising an MDBA Theme Lead and Theme Coordinator to oversee and support the strategic research investment of the program on behalf of the Commonwealth Partners, and to liaise with the EUAGs in the co-design, monitoring, evaluation and adoption of the research.