SEQUANA
WATER ENVIRONMENT ENERGY

RECONFIGURATION FEASIBILITY STUDY

TECHNICAL ASSESSMENT REPORT

OFFICIAL

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ACKNOWLEDGEMENT

Sequana acknowledges the Traditional Owners of Country throughout Australia and pays respect to and recognises the contribution from their Elders past and present.

RECONFIGURATION FEASIBILITY STUDY

REVISION CONTROL

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EXECUTIVE SUMMARY

OVERVIEW

The Broken River System (Broken System) in Northern Victoria is crucial for sustaining a vibrant agricultural sector and local community. However, the average yearly water inflows to the Broken System have significantly decreased over the past few decades. This decline presents substantial challenges to maintaining sustainable water usage practices within the system.

In response to emerging challenges, a community-initiated review of the sustainability of the system was conducted between 2020 and 2022. One of the recommendations from the review was that a Feasibility Study into system reconfiguration be undertaken, which was subsequently commissioned for completion from 2023 to 2024. This report details the technical analysis undertaken to support the study findings and outcomes.

BACKGROUND TO THE FEASIBILITY STUDY

In 2019, community members and irrigators called for a review of the sustainability of the Broken System, given the low or zero opening allocations to entitlements and changes which had occurred since the decommissioning of Lake Mokoan in 2008.

The Broken System Review was completed between 2020 and 2022. In its recommendations to the Victorian Minister for Water, the Review's Project Steering Group articulated the ongoing challenges for entitlement holders in the region and recommended that a study into system reconfiguration options – including fundamental changes to the irrigation footprint – must be done first, to support the community to plan for reduced water availability in the future.

Commencing in early 2023, the Broken Reconfiguration Feasibility Study (BRFS) was overseen by a consultative committee appointed through an Expression of Interest (EoI) process. The study's primary goal was to identify and assess feasible options for reconfiguring the Broken System. Reconfiguration options were then tested with the community and evaluated based on success criteria developed in conjunction with the Consultative Committee (CC) at the beginning of the study.

PRINCIPLES AND CRITERIA DEVELOPMENT

The process for developing the set of project principles and success criteria to guide the Study involved a collaborative critical analysis of the System values and the future needs of the community. These elements provided a framework for how the project would be conducted and became the basis for evaluating the viability of proposed options as the project progressed.

Through the establishment of the criteria, it was determined that the success of reconfiguration options would depend on their alignment with the following:

- Achieve Multiple Benefits
- Create Change
- Future Ready
- Community Acceptance
- Value for Money

COMMUNITY ENGAGEMENT

Throughout the course of the Study, the community was invited to make contributions and share their insights to aid in the development of the reconfiguration options. A variety of methods were used to ensure community members were given opportunities to engage with the Study in the manner that best suited them. The engagement activities undertaken include:

- Five Consultative Committee meetings.
- Individual property visits with 70 customers.
- Eight face-to-face community workshops.
- An online information session, which was recorded and made available for access.
- A dedicated Study website.
- Publication of Committee Meeting Summaries, workshop presentations and other updates as the project progressed.
- A map-based and transparent online feedback forum, where all comments were visible to the public. Thirty-two submissions were made prior to the completion of this report.
- An engagement survey where 40 responses were received.
- Information stands at public events.

This inclusive engagement strategy allowed for representation of the broader community perspectives, enriched the decision-making process and helped to develop well-informed and widely supported solutions. The engagement activities collectively resulted in representation from 60% of the entitlement held in the system.

OPTION AND SCENARIO ASSESSMENT

During the early stages of the engagement program, stakeholders were encouraged to nominate reconfiguration options for consideration. This led to the identification of 22 individual options for review. A preliminary assessment of the initial option list was undertaken to confirm alignment with the criteria, and shortlist the options with the best prospects for achieving the objectives.

Following the preliminary assessment, it became evident that the potential benefits could be enhanced in combination with other options. Furthermore, the benefits for some options were more likely to be achieved in certain locations. This led to the development of a set of *Scenarios* to advance to the detailed assessment process.

The Scenarios developed in consultation with the committee were:

- **Scenario 1 –** Do nothing (Bookend to understand opportunity range).
- **Scenario 2 –** Transition out of irrigation (whole system) (unlikely to be an outcome however required as a basis for comparison).
- **Scenario 3 –** Remove or reconnect all services in Zone 5.
- **Scenario 4 –** Remove or reconnect all services in Zone 3.
- **Scenario 5 –** Mokoan Pipeline supply channel efficiency improvements.
- **Scenario 6 –** Systemwide initiatives (Voluntary entitlement purchase plus support for landowners to adapt to a drying climate).
- **Scenario 7 –** Improved D&S supply security.
- **Scenario 8 –** A combination of Scenarios 3, 4, 6 and 7.
- **Scenario 9 –** Extended combination Scenario including Scenarios 5 and 8, with the removal or reconnection of all services in Zone 4 also added.

After the Scenarios were established, multiple technical assessments were carried out to verify their feasibility and alignment with the success criteria.

1 INTRODUCTION

1.1 OVERVIEW

The Broken River System (Broken System) in Northern Victoria sustains a vital agricultural sector and local community. Nonetheless, there has been a significant decrease in the average yearly water inflows to the Broken System over the past few decades. This decline poses significant challenges to maintaining current water usage practices sustainably within the system. As a result, it's imperative to collaborate with the affected community to explore how to effectively manage the System in the face of reduced inflows, especially amid a drying climate.

The Department of Energy, Environment, and Climate Action (DEECA) has emphasised the necessity of gaining a better understanding of the community's needs and expectations concerning future water usage in the Broken System. This endeavour aims to develop a Feasibility Study that identifies potential strategies, allowing the local community to adapt to decreased water availability, while ensuring a sustainable future. The process of identifying and assessing these strategies will involve engaging constructively with communities, utilising reliable data and robust methodologies to achieve comprehensive outcomes that benefit the entire system and support regional communities.

1.2 BACKGROUND TO THE FEASIBILITY STUDY

In December 2019, the Victorian Minister for Water initiated an evaluation of the regulated Broken River System due to the distinctive challenges confronting communities reliant on it. Given the gradual decline in the reliability of water inflows, compounded by anticipated further impact in a drier climate, the review aimed to thoroughly assess the Broken System's status. The primary objective was to ascertain if any modifications were necessary to ensure its ongoing resilience and sustainability.

After conducting an extensive engagement initiative and undertaking a technical evaluation of prevailing conditions, the findings and recommendations of the review were released for public input in mid-2022. This comprehensive review resulted in the formulation of seven recommendations aimed at enhancing the system's operation and utilisation. This Technical Assessment forms a component of the feasibility study, initiated in response to Recommendation 7:

"Proposal 7 – A feasibility study of how the Broken System could be reconfigured should be done – including the potential for a reduced irrigation footprint - so that the local community can understand long-term options for the future of the valley with reduced water availability".

1.3 PURPOSE AND SCOPE OF THE TECHNICAL ASSESSMENT

The purpose of the detailed technical report is to compile the various critical elements, such as:

- The process and methodology employed to pinpoint and evaluate reconfiguration options within the Broken River System. This delves into the comprehensive process, incorporating research methodologies, consultation approaches, validation techniques, and underlying assumptions that guided the entire assessment.
- The considered options and the feasibility of the options considered for reconfiguration within the Broken River System. Each option's feasibility is thoroughly evaluated, providing a clear rationale for determining their viability or infeasibility. This rationale draws upon a systematic analysis of each option's potential impacts, benefits, and challenges.
- The developed risk assessment framework specifically devised for this project. It elucidates the methodology, criteria, and tools utilised to assess and mitigate risks associated with the reconfiguration options under consideration.
- The outcomes of the technical risk assessment derived from the technical component of the risk assessment. This highlights the identified risks, their potential consequences, likelihood, and proposed mitigation strategies, offering a comprehensive view of the risk landscape associated with the proposed reconfiguration options.
- The additional unforeseen benefits and opportunities that surfaced during the technical investigation. These include interfaces with existing systems and alternative uses of resources that arise from the reconfiguration or risk mitigation strategies.

In summary, the technical assessment aims to compile a comprehensive report that outlines the methodology, options considered, their feasibility, risk assessment framework, outcomes of risk assessment, and any supplementary benefits or opportunities identified through the investigation. This holistic document serves to inform decision-making and chart a path forward for the sustainable management of the Broken River System.

1.4 BROKEN RIVER ZONES

In order to properly assess the range of opportunities across the system, the Study area is divided into five separate zones, as depicted in Figure 1. A zone-based approach recognises the different geological characteristics, usage patterns, and physical limitations that influence the effectiveness of potential solutions. For instance, the lower reaches of the Broken System run parallel to an irrigation district and piped Domestic & Stock (D&S) supply. In that part of the region, the potential to resupply properties from a more reliable source may prove to be viable. This opportunity is not available in the upper region, as there are no viable resupply sources in close proximity.

Further benefits from adopting a zone-based approach include:

- Supports a targeted resource management approach, increasing the efficiency of proposed interventions.
- Focuses any required environmental impact assessment to the specific areas of change, allowing for a more accurate representation of future conditions.
- Localised and relevant community engagement that enables stakeholders to participate in discussions and provide input into matters that directly impact their Zone.

- Provides an opportunity to package a combination of different options tailored to the needs of the Zone. The packaging of options may lead to Scenarios where benefits

  re enhanced, and in some cases made viable where they may not have been if delivered as a stand-alone option.

For the purpose of this study, zones in the Broken System were designated based on common geographical conditions and by the location of river structures. The five zones assigned within the project area, are:

Zone 1. Broken River from Lake Nillahcootie to Lake Benalla.

Zone 2. Broken River from Lake Benalla to Casey's Weir, including entitlement holders connected to the Mokan Pipeline system.

Zone 3. Broken Creek from Casey's Weir to Waggarandall Weir.

Zone 4. Broken River from Casey's Weir to Gowangardie Weir.

Zone 5. Broken River from Gowangardie Weir to the confluence with the Goulburn River.

Figure 1: Broken System Reconfiguration Zones

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2 PRINCIPLES AND CRITERIA DEVELOPMENT

A documented set of guiding project principles and success criteria plays a critical role in the completion of the Feasibility Study by providing a clear framework, direction, and criteria for evaluating the viability and success of the proposed options moving forward. Project principles help articulate the fundamental values and objectives guiding the feasibility study. They provide a clear statement of the project's purpose, mission, and overarching goals, ensuring that all stakeholders understand the fundamental principles driving the study. Furthermore, clearly defined project principles help align the study with the expectations and needs of various stakeholders, including investors, community members, regulatory bodies, and project team members. This alignment is crucial for gaining support and minimising conflicts throughout the feasibility study process.

Ensuring the principles and success criteria are well defined at the beginning of the project also assists as a decision-making framework, providing a set of criteria against which project options and decisions can be evaluated. This ensures that the evaluation framework used to access the options is consistent with the project's underlying principles and objectives.

2.1 DEVELOPMENT PROCESS

The development process of the project success criteria and project principles involved a structured approach to ensure comprehensive input and consensus among Consultative Committee members, agency representatives and the project team. The following is a breakdown of the method used:

- The project team commenced by creating an initial set of guiding principles. These principles were shaped by discussions held in the first Consultative Committee (CC) meeting and were based around principles used on recent projects of similar nature and scope.

- In the second CC meeting, CC members reviewed and provided input into the development of the principles, in conjunction with the project success criteria.

- Through these iterative discussions and refinements, the CC collaborated to reach consensus on the guiding principles and success criteria. The final list of project principles and success criteria was confirmed after incorporating the feedback, suggestions, and considerations from both committee meetings. This ensured that the guiding principles accurately reflected the collective insights, expertise, and perspectives of the stakeholders involved.

By following this method, the project team facilitated an inclusive and iterative process that allowed for the development of project success criteria and principles through collaboration with consultative committee ultimately fostering an ownership and alignment among the involved parties.

2.2 PROJECT PRINCIPLES

2.2.1 Sustainability

The project is committed to promoting sustainable water use and river operations practices. We will prioritise reconfiguration solutions that enhance the long-term health and resilience of the river ecosystem, considering environmental, social, and economic factors.

2.2.2 Stakeholder Engagement

We recognise the importance of engaging and involving all relevant stakeholders throughout the Feasibility Study. We will seek input and feedback from Entitlement Holders, Traditional Owners, local communities, government agencies, environmental organisations, and other interested parties to ensure a comprehensive and inclusive decision-making process. Our communication methods will be adapted to meet the diverse needs of stakeholders, taking into account the degree of impact changes may have on different community members.

2.2.3 Transparent Communication

We are committed to maintaining transparent and open communication throughout the project. We will provide regular updates, share findings, and engage in meaningful dialogue with stakeholders, ensuring that information is accessible and understandable to all interested parties. So that expectations remain realistic, we will provide honest advice about the likelihood, uncertainties, known constraints, and potential timing of options under examination.

2.2.4 Technical Rigour

The Feasibility Study will be conducted with a strong emphasis on technical rigour. We will incorporate and build on the assessments produced during previous investigations. We will employ reliable data collection methods, accurate analysis techniques, and robust modelling tools to evaluate the potential impacts and benefits of various reconfiguration scenarios.

2.2.5 Integrated Approach

We will take an integrated approach, considering the interconnectedness of different aspects related to river use. This will involve examining ecological impacts, recreational opportunities, economic implications, cultural significance, and regulatory requirements to develop a comprehensive understanding of the project's feasibility.

2.2.6 Commitment to Best Practice

We will strive to deliver the Study in a manner that sets the standard for future projects of this nature. Lessons learned from similar projects will be taken into account to create efficiencies wherever possible.

2.2.7 Adaptive Management

Recognising the dynamic nature of river systems and communities, we will embrace an adaptive management approach. This approach allows for ongoing monitoring and evaluation of the reconfiguration strategies and their outcomes, enabling us to make necessary adjustments and improvements as new information becomes available.

2.2.8 Diversity and Inclusion

We embrace diversity and inclusion at every stage of our study. Recognising the richness that diverse perspectives bring, we are committed to ensuring that all voices, irrespective of gender, race, ethnicity, age, ability, or any other defining characteristic, are heard and respected.

2.2.9 Equity

We are committed to ensuring that the benefits and impacts of the system reconfiguration are distributed fairly among all stakeholders and provide equitable access and benefits for all involved parties.

Alignment

We are committed to ensuring that our reconfiguration strategies and recommendations are fully aligned with the water resource management strategies and policies of the Victorian Government, as well as the Commonwealth Water Act and Basin Plan where applicable.

Cost-effectiveness

Our study will evaluate the cost-effectiveness of different reconfiguration options. We will strive to identify solutions that provide the greatest benefits in relation to their costs, ensuring efficient allocation of resources and maximising the return on investment.

Risk Assessment and Mitigation

We will conduct a thorough risk assessment, identifying potential risks associated with the proposed reconfiguration strategies. Based on this assessment, we will develop appropriate mitigation measures to minimise negative impacts and enhance the overall success and sustainability of the project.

Regulatory Compliance

The Feasibility Study will adhere to all applicable laws and regulations related to water resource management and environmental protection in Victoria. We will work closely with relevant authorities to ensure that our recommendations align with legal requirements and regulatory processes.

Privacy Protection and Information Confidentiality

We are firmly committed to safeguarding the privacy of all stakeholders and maintaining the confidentiality of information shared or obtained during the study. All data, insights, and communications will be handled with the utmost discretion, ensuring that sensitive information is not disclosed or misused.

Ethical Considerations

We will conduct the feasibility study with the utmost ethical considerations. We will respect the rights and interests of all stakeholders.

2.3 SUCCESS CRITERIA

2.3.1 Criterion 1: Diligence

At its completion, the Feasibility Study will have investigated the merits of identified reconfiguration opportunities in the Broken Basin within the bounds of the study scope. This criterion will be deemed to have been satisfied once the final report is endorsed by the Consultative Committee (CC) and Project Oversight Group (POG).

2.3.2 Criterion 2: Comprehensive Stakeholder Engagement

The Study should be conducted in a manner that provides key stakeholders, as identified in the Project Delivery Plan, with an opportunity to:

- Review information gathered for the study.
- Provide input and feedback throughout the study period.
- Be communicated with in a manner that best fits their individual circumstances.
- Participate in identifying and selecting which options to pursue.
- Contribute to the study findings and recommendations.

The successful achievement of this criterion will be established through acceptance of the extent and quality of stakeholder engagement by the CC.

2.3.3 Criterion 3: Impact Neutrality or Positivity

The study will evaluate the potential impacts of each reconfiguration option on:

- Socio-economic conditions.
- The environment.
- Cultural heritage values.
- Flood protection.
- Emergency response.

Including provisions to offset impacts, the success of this criteria will be the demonstration of an overall net neutral or positive outcome for adopting recommendations.

2.3.4 Criterion 4: Community Acceptance

The study will aim to strike a balance between different stakeholder interests in order to elicit majority support from the wider Broken System community. Taking any constraints into account, recommendations will be tailored to align with identified community priorities. The success of this criterion will be demonstrated through CC acceptance of the final recommendations.

2.3.5 Criterion 5: Technical Assessment

Technical assessments relied upon in the final report will be undertaken by suitably experienced and qualified agents. The assessments will be supported by reliable and accurate data and will adhere to a high standard of technical rigour. The success of this aspect would be reflected in the depth and detail of the technical findings. The CC will demonstrate confidence in the technical work and findings.

2.3.6 Criterion 6: Value for Money

The economic viability of recommended reconfiguration options is a key consideration for the Study. All effort will be made to provide an estimate of the likely cost and expected benefits for each option examined including clear assumptions and basis for estimates. Where possible, comparisons against other water industry and environmental projects should be drawn upon to ensure recommendations are within anticipated and acceptable limits. Success for this criterion will be established through acceptance by the CC and POG of the cost benefit methodology, assumptions and analysis.

2.3.7 Criterion 7: Recommendations are Appropriate and Implementable

The final report will provide a holistic and objective view of potential changes to Broken System water use arrangements. Each recommendation will align with the study objectives, will accord with the defined principles, will be proportionate and will include a clear pathway to full implementation. The intent of Terms of Reference for the CC will be reflected in the content of the final report to safeguard the validity of any endorsement the CC provides. This criterion will be deemed to have been satisfied once the final report is endorsed by the CC and POG.

2.3.8 Criterion 8: Legal and Regulatory Compliance

The feasibility of each option will be examined against the framework of existing regulations to ensure chosen options can be implemented without legal barriers. The criteria will be deemed to have been met upon acceptance of the final report by the project sponsor.

2.4 ASSESSMENT CRITERIA

The initial assessment criteria was developed using the above success criteria and project principles. The criteria used to conduct the preliminary assessment of the initial options is shown below:

Sustainable irrigation sector future

Does the option offer a pathway to support investment in productive irrigated agriculture?

D&S Supplies

Is the options capable of providing for secure, year-round access to water for D&S and urban needs?

Environmental values

To what extent does the option protect or enhance the environmental values of the Broken River?

Social

Does the option support social values including recreational fishing and passive enjoyment of the river?

Cultural

Does the option support indigenous cultural values and outcomes?

Robustness

Is the option robust, adaptable and capable of delivering benefits under potential future climate change?

2.4.1 Risks

What is the ability of each option to mitigate and manage major risk issues that could limit or prevent the achievement of agreed objectives?

Value for Money

Is the option affordable and represent value for money to project funders and to water users, and expected to be able to attract the necessary funding?

Community Acceptance

Is the option consistent with stakeholder aspirations and likely to achieve support from the community?

Regulatory and policy alignment

Are the options consistent with government strategy and polices, and expected to be able to comply with relevant regulatory provisions (including water legislation and planning approvals etc.)?

Impacts and benefits

Is the distribution of benefits or impacts between the involved parties likely to be judged as fair and reasonable overall?

3 INITIAL COMMUNITY ENGAGEMENT

3.1 STRATEGY FOR COMMUNITY ENGAGEMENT

Community engagement is vital for ensuring that the project is responsive, sustainable, and effective. It not only enhances the project's success but also promotes inclusivity, empowerment, and long-term positive outcomes for the community as a whole. The initial engagement strategy involved:

- Attending three public events.
- Participating in three face-to-face invited workshops.
- Conducting three face-to-face drop-in sessions.
- Hosting one online session, recorded and uploaded for access.
- Communicating with the community via phone calls, SMS, and emails.
- Utilising newspaper advertisements and media releases.
- Posting on social media with reminders.
- Launching a social pin-point on the BRFS web-page.

The community engagement was structured to cater for a wide range of differing levels of understanding and knowledge bases. This structure was implemented to ensure all community members could utilise these sessions, supporting new users with little to no understanding of the System, to tenured customers with a clear image of what success in the System looks like to them.

Community members were given the opportunity to indicate their own picture of success and were encouraged to provide their own inputs of potential options to be analysed and considered by the project team.

3.2 PARTICIPATION AND FEEDBACK

The community engagement aimed to reach as many local community members and Broken System customers as possible. A summary of the involved parties who, attended sessions, were contacted via phone or email, or were seen at public events is as follows:

- D&S Syndicates,
- Private Pipeline Co-ops,
- Permanent Planting Irrigators,
- Traditional Owners,
- Ecologists,
- CC EOI applicants,
- GMW customers (contacted via email and SMS),
- BRFS contact list (contacted via email and phone), and
- Those who were made aware of engagement activities via local newspapers and / or social media.

The community drop-in sessions provided a thorough opportunity for attendees to input their individual options and success criteria, with an additional four options added to the list that had previously been developed with the CC. This was on top of many other suggestions seen in the sessions which were already existing on the options list, which affirmed that these options were correctly considered. Below is a summary of consistent themes heard at the community engagement sessions, particularly focussed on the important items for consideration by the project team:

- Assess options within the context of modern and efficient farming practices.
- Consider development and changes in land use.
- Evaluate infrastructure feasibility, including storages and pipelines.
- Address system exit issues comprehensively.
- Explore HRWS transfer rules and trade opportunities.
- Seek advice from GMW and maintain strong GMW involvement in the project.
- Prioritise certainty for Domestic & Stock (D&S) supply.
- Emphasise the critical importance of timely allocation and certainty.
- Recognise and differentiate between private and commercial irrigators.

4 OPTIONS IDENTIFICATION

4.1 DATA COLLECTION AND ANALYSIS

Informed by the evidence compiled in the previous project stage, ‘Understanding the issues’, potential reconfiguration opportunities across the Broken System were accessed to determine what changes were technically feasible to make and what the outcomes of those changes would have been in terms of System operation, access to water, and other technical requirements identified through project research and planning.

This work forms the major technical component of the Study as presented in this report. The options were identified drawing on the knowledge and experience in Victoria’s water entitlement framework, catchment hydrology, irrigation infrastructure operation and maintenance, and other relevant technical disciplines. The assessments established the outcomes for the Broken System and its components in the short, medium, and long terms, to inform the analysis of the social, environmental, and economic outcomes of the options in the next stage of the project.

4.2 IDENTIFICATION OF RECONFIGURATION OPTIONS

In order to identify a broad set of potential options, which when combined or applied individually to the project area would support the objectives of the BRFS, the process to identify an initial ‘long-list’ of options included:

- A four-hour workshop which included key members from DEECA, GMW and the Project Team who were able to utilise their existing industry and regional knowledge and experience to identify an initial suite of options.

- The Consultative Committee (meeting #2) utilised an open discussion which allowed all members the opportunity to identify potential options with the advantage of their system, area and industry knowledge.

- A series of community drop-in sessions commenced on the 21 November 2023, providing the broader community with the opportunity to identify any key options that should be factored into the BRFS.

- The result of which was a final ‘long-list’ of options, used as the basis for initial assessment.

5 EVALUATION FRAMEWORK

5.1 FRAMEWORK OVERVIEW

The assessment framework has been crafted to offer a methodical and transparent approach in evaluating the various reconfiguration scenarios aimed at reconfiguring the Broken System. This framework enables the systematic evaluation of scenarios through a quadruple bottom-line approach, ensuring a consistent consideration of both negative and positive social, cultural, environmental, and economic impacts and advantages.

As a decision support tool, this framework equips the project with essential information necessary for assessment of different scenarios. Feasibility for the scenarios under the Study hinges on their evaluation against specific criteria, ultimately relying on endorsement by both the POG and the CC. This endorsement consolidates the feedback garnered throughout the community co-design process.

The evaluation framework prepared by Alluvium Consulting Australia (Alluvium) can be found below in Attachment 1.

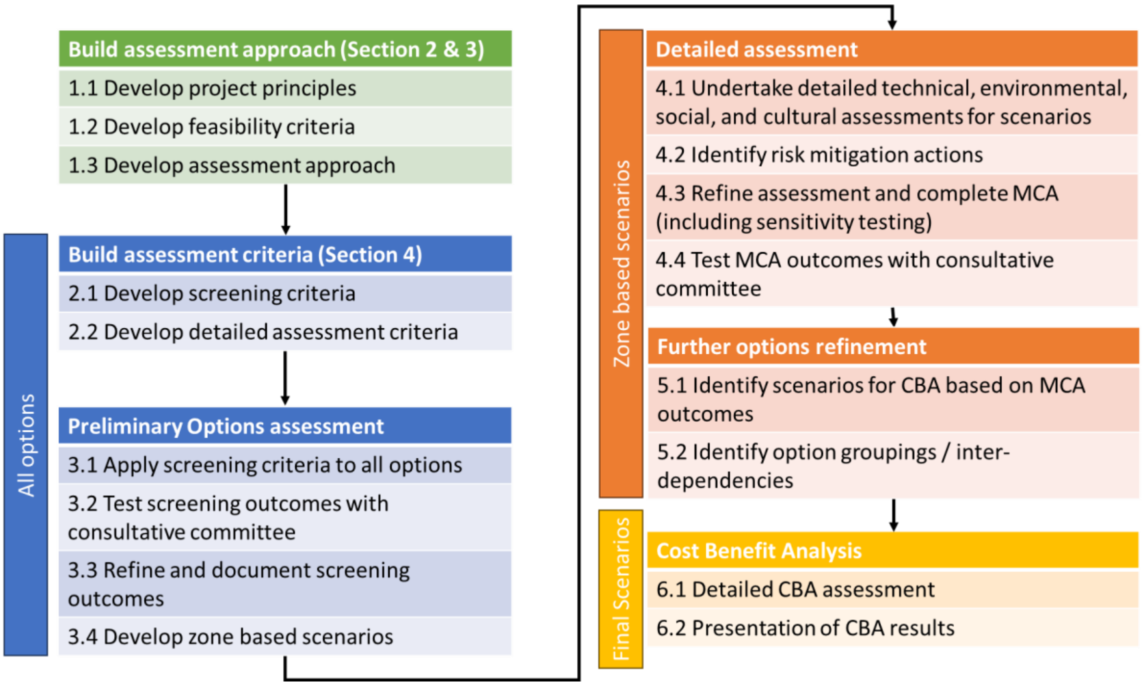
5.2 FRAMEWORK DEVELOPMENT

The framework was developed in a Multi Criteria Assessment (MCA) format to allow for the broad range of feasibility criteria and project principles to be considered through one clear and transparent process.

Community consultation during the development and application of the framework will be critical to ensure that the outcomes align with the aspirations of the key stakeholders and to allow for the outcomes to receive broad community support.

The framework was applied in a multi-stage approach to ensure effort was not invested undertaking detailed assessment of scenarios that were unlikely to be feasible, or do not meet the requirements of the project principles. The multi-stage approach is shown in Figure 2.

Figure 2: Assessment Framework Development



5.3 ASSESSMENT CRITERIA

The preliminary assessment criteria were developed to examine specific risks. The assessment scale allowed for the negative impacts (or disbenefits) and the positive impacts (benefits) to be captured where applicable. Each round of assessment included a step that looked at options for mitigating any negative impacts. The options for mitigating the negative impacts were presented at part of each assessment step and scored as part of the detailed options evaluation process. Where a risk mitigation action was found to have an overall benefit to the proposed scenario, it was included in a refined version of the scenario. Where a risk mitigation measure was found to have an overall negative benefit to the proposed scenario, it was not included in the refined version of the scenario. The criteria is shown below is Table 1 and is also previously reflected in Section 2.4.

Table 1: Assessment Criteria

Category	Criteria
Project Objective	**Sustainable irrigation sector future**: Does the option offer a pathway to support productive irrigated agriculture?
Project Objective	**D&S Supplies**: Are the options capable of providing for secure, year-round access to water for D&S and urban needs?
Environmental	**Environmental values**: To what extent does the option protect or enhance the environmental values of the Broken River system?
Social	**Social**: Does the option support social values, including recreational fishing and passive enjoyment of the river system?

Cultural	**Cultural**: Does the option support Traditional Owner cultural values and self-determination?
Robustness	**Robustness**: Is the option robust, adaptable and capable delivering benefits under potential future climate change?
Risk	**Risks**: What is the ability of each option to mitigate and manage major risk issues that could limit or prevent achievement of success criteria?
Economic	**Value for Money**: Is the option affordable and represents value for money to project funders and to water users, and expected to be able to attract the necessary funding?
Project Objective	**Community Acceptance**: Is the option consistent with stakeholder aspirations and likely to achieve support from the community?
Project Objective	**Regulatory and policy alignment**: Is the option consistent with government strategy and polices, and expected to be able to comply with relevant regulatory provisions (including water legislation and planning approvals etc.)?
Economic	**Impacts and benefits**: Is the distribution of benefits or impacts between the involved parties likely to be judged as fair and reasonable overall?

6 PRELIMINARY OPTIONS ASSESSMENT

6.1 EVALUATION PROCESS

In the preliminary assessment, a total of 22 individual options underwent review, each evaluated against the 11 criteria outlined in the rubric. The assessment process also included consideration for the 'level of confidence' associated with each option. Qualitative evaluations were conducted to shortlist the most promising options based on their merits. Ultimately, a comprehensive summary encapsulated the outcomes derived from this preliminary assessment.

6.2 SUMMARY OF ASSESSMENT RESULTS

Each option was individually assessed with a qualitative final assessment as to whether the option was likely to offer suitable outcomes across a range of criteria. The outcome of the preliminary assessment for each option is shown below in Tables 2 and 3 and a detailed assessment for each option is provided in Attachment 2 below. The numbers assigned to each option reflect the option number shown in the detailed assessment.

Table 2: Shortlisted Options

Potential to offer system-wide benefits	Provides benefits to specific customers	Provides benefits to existing Irrigation customers only	Provides benefits to existing D&S customers only
18 - Water entitlement (HRWS and/or LRWS purchase). % 'retired', % environmental, % cultural.	9 - East bound Irrigation pipeline from East Goulburn Main.	15 - Supported market correction.	1 - Secure access to the first 2 ML of water used each season for D&S purposes.
14 - Supported transition to 'dry-land' agriculture.	11 - Transfer Broken demand to the Goulburn system for properties inside the SIA.	21- Provide more opportunities for trading allocation out of the Broken System.	3 - D&S reserve. Utilise Cosgrove savings.
13 - On-Farm Storage.	5 - Connection to alternate D&S schemes.	22- Fund a Whole Farm Plan and business planning program to support irrigation to dry-land transitions.	4 - Explore options for increasing groundwater access for D&S.
19 - Decommissioning of Infrastructure. e.g. Gowangardie Weir.			

Table 3: Options that were not shortlisted

Potential to offer system-wide benefits	Provides benefits to specific customers	Provides benefits to existing Irrigation customers only	Provides benefits to existing D&S customers only
7 - Access to / enhance the Winton wetlands as a storage for Mokoan pipeline supply.	17 - Targeted water entitlement purchase and return to the environment.		2 - Align D&S use with Section 8 conditions i.e. 24/7 D&S use.
10 - Pipeline from other regulated			6 - D&S scheme with local off-

systems (e.g. Eildon or Ovens) into the Broken, upstream of Nillahcootie.			stream storage.
12 - Create ability to access unregulated flows early in the season.			
16 - Water entitlement purchase and retirement of entitlement solely to improve system reliability.			
8 - Managed Aquifer Recharge.			

6.3 SHORTLISTED OPTIONS

The shortlisted options along with a description of the option are shown below in Table 4.

Table 4: Shortlisted Options with description

Shortlisted Option	Aim	What's Involved
Water entitlement (HRWS and/or LRWS purchase). % 'retired', % environmental, % cultural	To reduce the demand on the Broken System through retirement while still providing positive environmental outcomes.	Purchasing of targeted users water entitlement with the intention of retirement of a percentage of the allocation whilst also returning a percent to the environmental water allocation.
Supported transition to 'dry-land' agriculture	To reduce the demand on the Broken System. To enable productive agriculture to continue without the reliance on the full water allocation.	Voluntary change of traditional practises to allow sustainable agriculture to continue without the reliance of water from the system.
On-Farm Storage	To provide additional water allocation reliability and security for both Irrigation and D&S security.	Constructing on-farm dams for individual properties up to the size of their allocation. The on-farm dams would be filled whilst there is allocation available.

Decommissioning of Infrastructure. e.g. Gowangardie Weir	To support native fish migration and other environmental objectives.	Removal of weir structure/s. Augmentation of existing private pumps.
East bound Irrigation pipeline from East Goulburn Main	To reduce a portion of the Broken System demand by using an alternate irrigation water source. Provide greater irrigation reliability to a portion of the system irrigators.	Construction of a pipeline from the East Goulburn Main channel. Customers would need to follow the rules and regulations of the Goulburn system.
Transfer Broken demand to the Goulburn system for properties inside the SIA.	To reduce or supplement a portion of the Broken demand by using an alternate water source. Provide greater reliability to users inside the Shepparton Irrigation Area.	Transfer of customers from Broken System to Goulburn System. Construction of required infrastructure i.e. pipelines and pumps.
Connection to alternate D&S schemes	To provide a more reliable D&S supply source for customers in close proximity to existing piped networks.	Extensions to the existing pipelines, with tapping points for reconnected Broken System users. Connecting properties will need to install complementary on-farm infrastructure in line with the Tungamah terms of use, including tank storage. Purchase of Goulburn 1A entitlement.
Supported market correction	To assist users, utilise existing tools available. To allow users to transfer out their entitlement if not being used and allow users to gain additional allocation if needed.	Users purchasing additional water entitlements so they still have enough allocation in years of 50% allocation. Waiving of fees such as transfer fees or stamp duty etc.
Provide more opportunities for trading allocation out of the Broken System	Provide improved income generation opportunities for entitlement holders.	Review of trading rules to develop a more dynamic trade rule, with larger volumes able to be traded out.
Fund a Whole Farm Plan and business planning program to	Arm Entitlement Holders with the best available knowledge on how	Funding to be set aside for Broken System irrigators to join the WFP program.

support irrigation to dry-land transitions.	to manage water on farm efficiently.	Farm designers engaged to survey and consult with irrigators. Irrigators implement efficiency improvements.
Secure access to first 2 ML of water used each season for D&S purposes.	To provide immediate access to D&S water at the beginning of a new season, regardless of the seasonal allocation.	Potentially involves mitigation measures to offset impact, e.g. relinquishing 3ML HRWS to gain more secure access for 2ML.
D&S reserve. Utilise Cosgrove savings	To improve the likelihood of D&S being available to users at the beginning of a new season.	Approximately 400 ML of HRWS from the 830 ML secured through the Cosgrove Project (currently held by GMW) credited to a special reserve.
Explore options for increasing groundwater access for D&S	To enhance security of access to D&S water for properties near a groundwater source.	Licensing and installation of groundwater bores to supplement D&S supply.

7 DEMAND MODELLING

Modelling was undertaken to provide a better understanding of system losses and of system performance under a range of reconfiguration scenarios. Performance was also tested under future climate and full demand. The GSM REALM model was used for this assessment. The modelling was prepared by Hydrology and Risk Consulting (HARC).

7.1 BASE CASE MODEL UPDATES

There had previously been scenario modelling to support the Broken Review in 2021 and investigation into a Broken D&S Reserve in 2023. The base case model from 2023 was adopted as a starting point for this project and key model settings reviewed. A number of changes were made to the base case model for this project including:

- Explicitly represent D&S demand (2 ML/yr per customer) in each reach.
- Split lower Broken reach and water shares upstream and downstream of Gowangardie weir to accommodate Broken Reconfiguration zones.
- Set Shepparton WWD demand to zero as this is now supplied from Cosgrove pipeline.
- Set demand of Tungamah urban to zero as this is not currently being used by North East Water.

Settings for carryover, Inter Valley Trade (IVT) and the Broken Creek loss provision were reviewed but not updated.

7.2 MODELLING RESULTS

In addition to System reliability, the water resources model was also designed to support comparison against the base case for the following key elements:

- September and February allocation (reliability) - % time exceeded.
- Historic climate cases – Reproducing the allocation in any given year based on system parameters and applying historic inflows.
- System operating losses by reach.
- % of unrestricted demands satisfied.

This information is significant in assessing the potential benefits of system reconfiguration scenarios as it allows quantification of key parameters including:

- Benefits to overall System reliability.
- Benefits to early (September) allocations.
- Reduction in overall system operating losses.
- Environmental flow assumptions.

The model included assumptions on how recovered water would be reapportioned to the environment and System reliability improvements. Changes to System losses and reliability were modelled based on 50% of recovered water provided to the environment, and 50% retired for reliability improvement.

Note: This does not preclude the return of water to Traditional Owners for self-determined purposes. DEECA will engage with Traditional Owners on their aspirations for water return and water management in the development of a Business Case, should this study result in one.

The environmental flow demands included in the model are based on the assumed future use of environmental water informed by the existing flow studies and discussions with GBCMA and GMW. An underlying assumption for the existing environmental flow studies is that various reaches (of the Broken River and Broken Creek) are operated to service irrigation demands in the System. If these demands were to change and the river was to be operated without these operational considerations different environmental flow demands may result. A new flow study would be required to investigate how the system could operate without the current operational demands and therefore overall environmental objective and associated flow demands over the year. It is proposed that the flow study review be undertaken as part of the detailed business case.

Scenario 1 is the baseline case used to compare current conditions to subsequent reconfiguration scenarios. For Scenario 1, the baseline model is updated to include a range of possible changes to future reliability.

Modelling for Scenario 1 includes assessment of available data to show historical and projected reliability for:

- Historical (utilises historic water usage only)

- Historical, full demand (assumes water use is equal to water entitlement)
- The period Post 1975 (scales historic inflows to match the post-1975 climate using decile scaling)
- The period Post 1997 (scales historic inflows to match the post-1997 climate using decile scaling)
- 2040 high-impact climate change (adjusts future inflows based on climate change forecasts)
- 2065 high-impact climate change (adjusts future inflows based on climate change forecasts).

Figure 3 shows the level of system reliability (February allocation - % time exceeded) under the base case scenario representing a reliability of 100% allocation in:

- 84 years out of 100 under 'historical' conditions; and
- 48 years out of 100 under the 2065 high climate change.

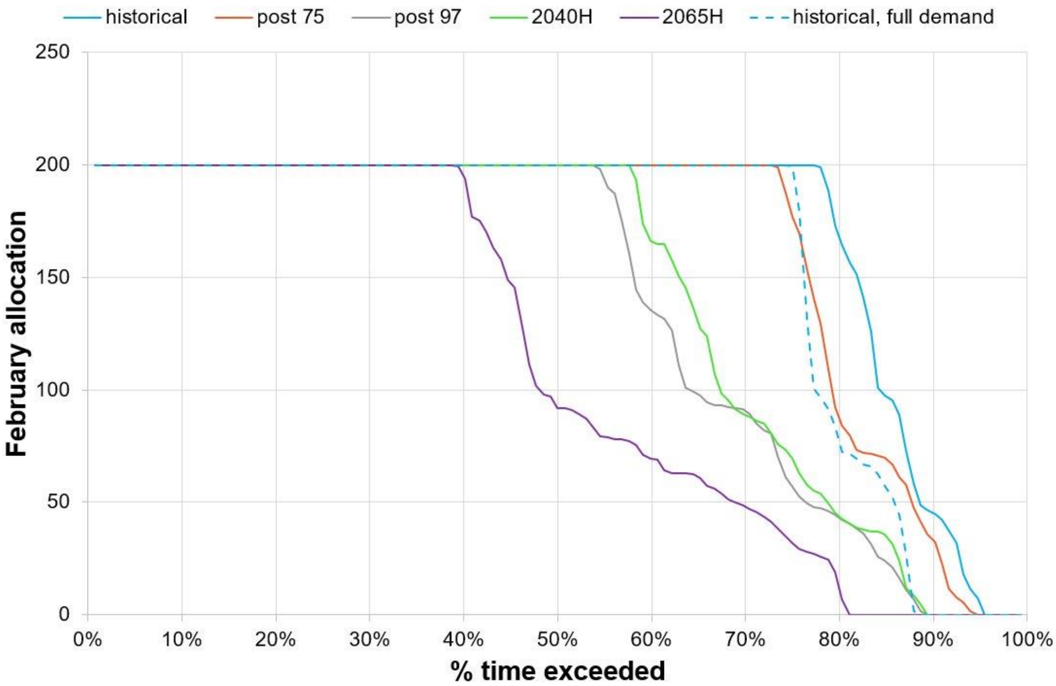


Figure 3: February allocation reliability for scenario 1 (base case) with future climate and full demand scenarios Note that 100 allocation (y-axis) represents 100% allocation of HRWS and 200 represents 100% allocation of both HRWS and LRWS.

Whilst all Scenarios were modelled and compared to the base case results, Scenario 9 presented the most significant improvement to early season reliability and thus the results of this Scenario are presented below. Compared with the base case, the implementation of Scenario 9 would result in an improvement in both September and February allocations (as shown in Table 5 below), with full season allocation going up by 9%. In this scenario environmental water holdings in the system would increase by 5,303 ML HRWS and 506 ML LRWS increasing the total from 647 ML to approximately 6,456 ML.

Table 5: Indicative results for scenario 9 (measured against the base case)

Metric	Baseline (current)	Scenario results
Full season reliability (100% HRWS allocation by February)	84%	93%
Early season reliability (100% HRWS allocation by September)	2%	94%

Figure 4 to Figure 7 below show the modelled changes in reliability for September and February compared to the base case if recovered shares are distributed equally between the environment and improvements to reliability (retired shares).

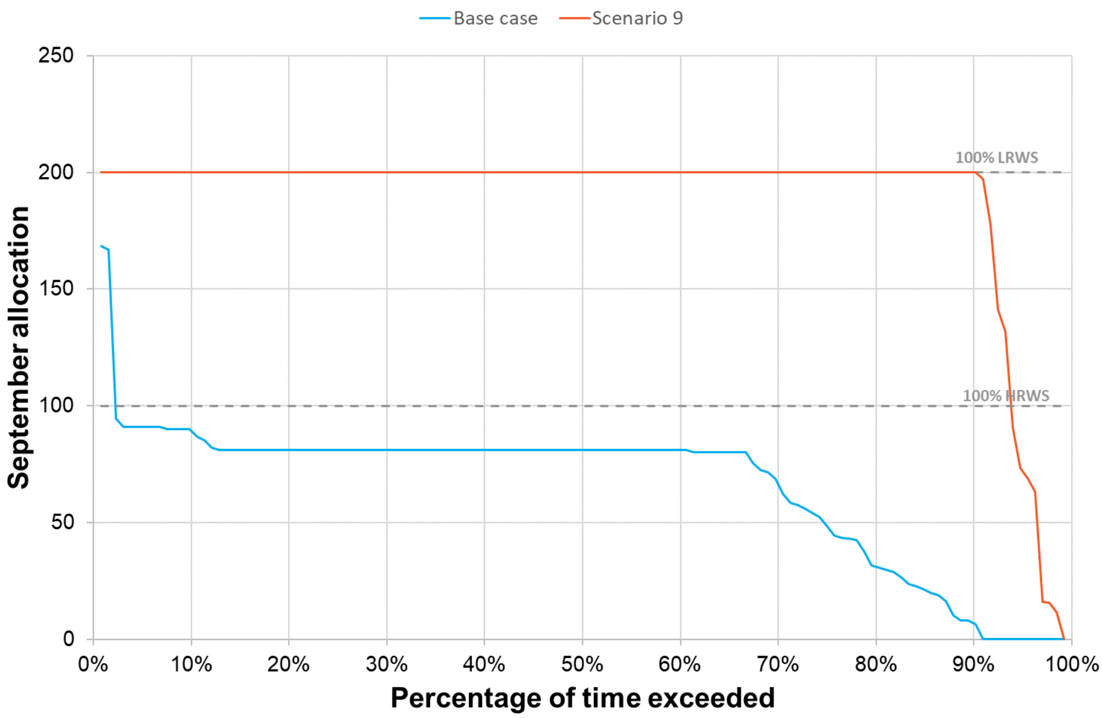


Figure 4: September allocation reliability for Scenario 9

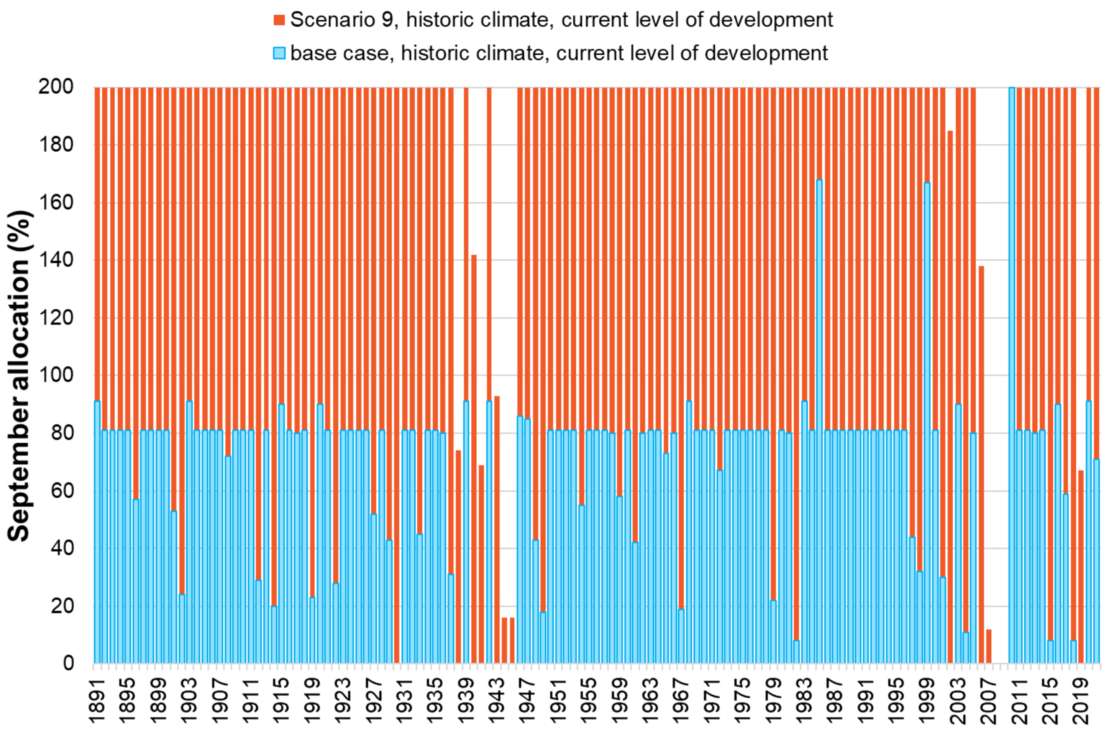


Figure 5: Modelled historical allocation under Scenario 9

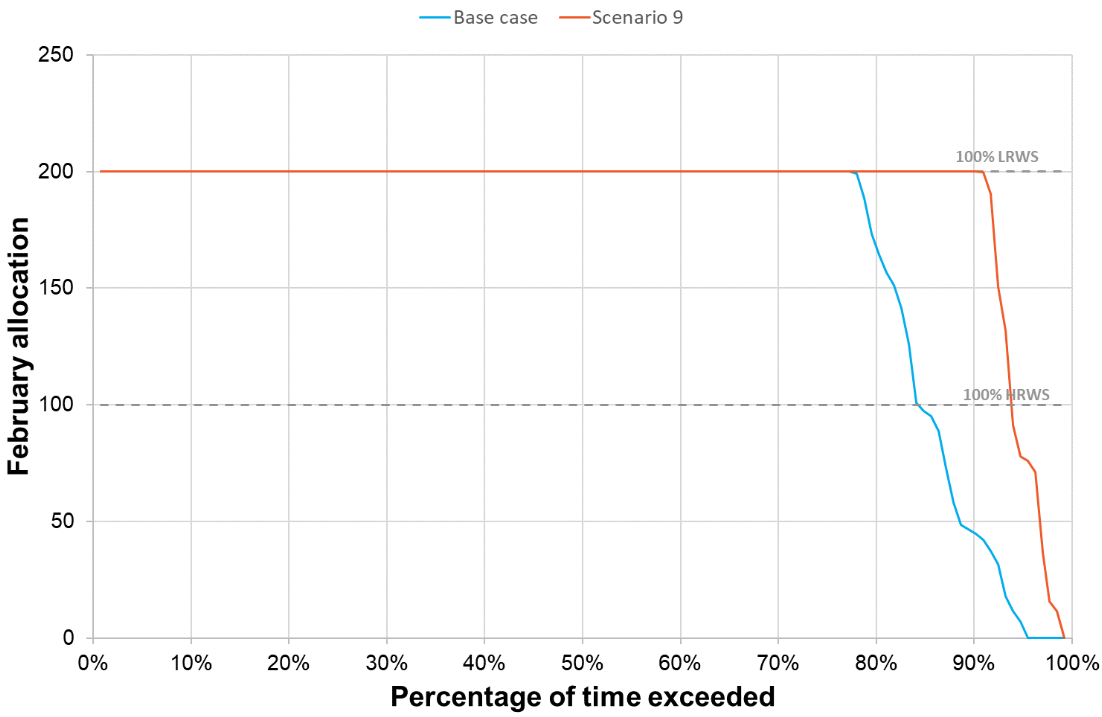


Figure 6: February allocation reliability for Scenario 9

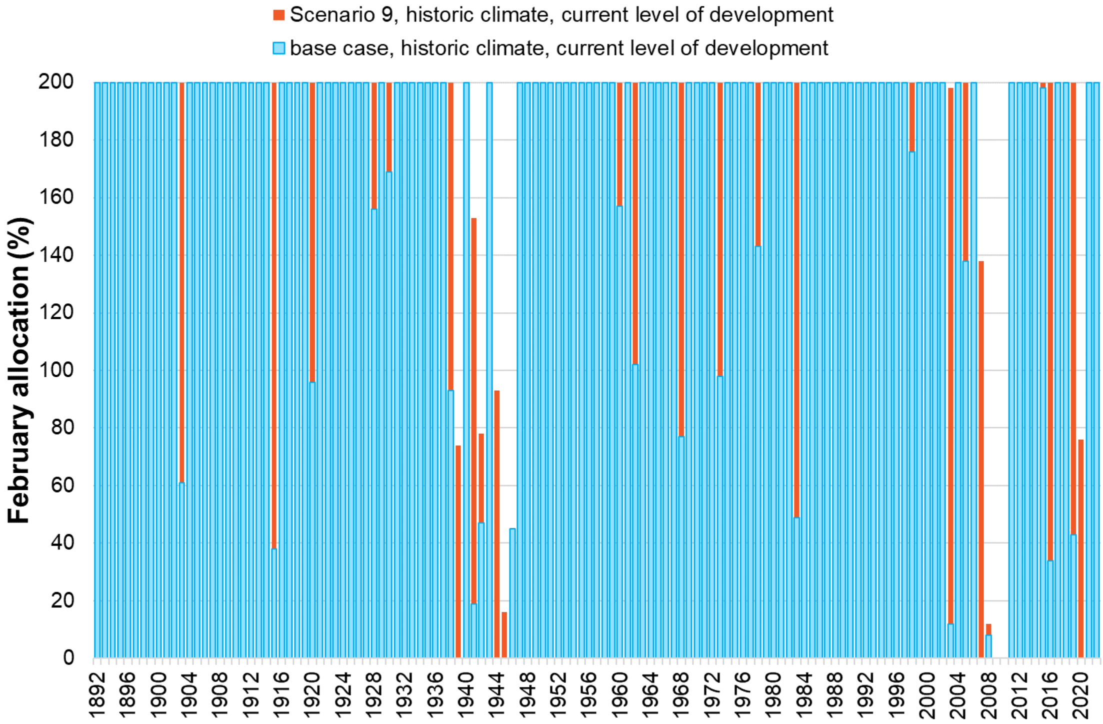


Figure 7: Modelled historical allocation under Scenario 9

The full modelling results, including the modelled effects for all Scenarios, and report prepared by HARC is shown below in Attachment 3.

8 RECONFIGURATION SCENARIO ASSESSMENT

Following endorsement of the suite of preliminary options, the project team held a workshop held with DEECA and GMW to develop the scenarios using the shortlisted options. The options were assessed to determine how they could be most successfully applied (either in combination or individually) to the 5 identified zones in the project area. Generally, the Scenarios required the combination of multiple options to achieve of potential solution that contributes to the desired BRFS outcomes. This included an assessment of technical considerations, such as water availability, water demand, and potential infrastructure locations and sizes.

The resulting Reconfiguration Scenarios were subject to detailed evaluation:

1. Do nothing (*Bookend to understand opportunity range*).
2. Transition out of irrigation (whole district) (*Bookend to understand opportunity range*).
3. Remove or reconnect all services in Zone 5.
4. Remove or reconnect all services in Zone 3.
5. Mokoan Pipeline supply channel efficiency improvements.
6. Systemwide initiatives.
7. Secure access to D&D water.
8. A combination of the above Scenarios.
9. An extended combination Scenario including Scenarios 5 and 8, as well as including ‘Remove or reconnect all services’ in Zone 4.

8.1 SCENARIO ASSESSMENT CRITERIA

The assessment criteria was developed to examine the packaged Scenarios. The assessment scale allowed for the negative impacts (or disbenefits) and the positive impacts (benefits) to be captured where applicable. Each round of assessment included a step that looked at options for mitigating any negative impacts. The options for mitigating the negative impacts were included in each assessment step and scored as part of the detailed evaluation process.

The detailed assessment stage of the assessment framework required input from expert analysis, and the community to assess each scenario. The criteria in this phase of the evaluation was built on the screening process and aligned with the project principles and government policy direction.

The criteria for the detailed assessment was included in the MCA for all categories excluding the economic criteria. The economic criteria are addressed in Section 9 Cost Benefit Analysis.

Note: In accordance with Traditional Owner advice, the MCA does not include an assessment of impact on cultural values. The important task of working with Traditional Owners to provide input into future planning will continue as a part of the business case development.

This assessment considered the following key elements as shown in Table 6.

The criteria in this phase of the evaluation build on the preliminary assessment criteria, as shown previously in Table 1 and Section 2.4. A draft set of assessment criteria were presented to the Consultative Committee and its feedback was included through the refinement and addition of some criteria.

Table 6: MCA Assessment criteria

Number	Category	Criteria
PO1	**Project Objective**	**Sustainable irrigation sector future**: Reliability of water supply for High Reliability Water Shares.
PO2	**Project Objective**	**Sustainable irrigation sector future**: Reliability of water supply Low Reliability Water Shares.
Rob1	**Robustness to future uncertainty**	**Delivers value under projected future climate change:** Reliability of supply of HRWSs under a high climate change future.
Rob2	**Robustness to future uncertainty**	**Delivers value under a range of future water use scenarios:** Reliability of supply for HRWS under a demand scenario that represents full SDL demand.
Ris1	**Risk**	**Risk of unintended consequences:** Scan of risks that have not been captured in other MCA criteria.
Env1	**Environmental**	**Environmental values**: To what extent does the option protect or enhance the environmental values of the Broken River system.

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Number	Category	Criteria
Env2	Environmental	**Support of environmental values under future high climate change projection**: To what extent does the option protect or enhance the environmental values of the Broken River system in a high climate change future.
Soc1	Social	**Change to recreational, amenity and social connection outcomes**: The impact of each option on the recreational, amenity and social connections values of the study area.
Soc2	Social	**Wellbeing and social cohesion:** How does the scenario impact on the mental and physical wellbeing of the local community and aspects of liveability.
Eco1	Economic	**Value for money – capital costs**: comparison of the capital cost of the project on a costs per ML saved basis between the different scenarios.
Eco2	Economic	**Value for money - Project operating and maintenance costs:** comparison of the operating and maintenance costs per ML of water saved across the different scenarios.
Eco3	Economic	**Economic impacts and benefits:** comparison of the economic impacts or benefits associated with the changed water availability and agricultural use for each scenario.

8.2 MULTI-CRITERIA ANALYSIS

The assessment framework is centred around the application of a multi-criteria analysis (MCA).

MCA is a decision support tool that was developed as part of a field of study called “operations research”, where decision makers assess multiple options across a range of decision factors (reasons or considerations) that may have different and inconsistent assessment measures, including non-monetary valuation. MCA has been adopted for environmental management, as it is invaluable in assessing unique elements of a project that do not include financial components. Put simply, it is valuable as a technique for “comparing apples and oranges”.

When applied with care, consistency and transparency, an MCA provides a structured framework for comparing options. Weightings are applied to each of the categories of objectives to reflect their relative importance to decision-makers and stakeholders. Under each objective, there are typically a number of assessment criteria. These criteria are also typically weighted within the objective to reflect their relative importance. The assessments against each criterion can be based upon either the outputs of previous technical analysis (e.g. a hydrological model), or use a semi-qualitative approach based on expert discussion and/or community engagement. This approach enables different considerations to be incorporated into the same framework of options evaluation.

8.2.1 MCA WEIGHTINGS

As part of an MCA assessment, weightings are given to each category to represent its importance to the decision-making process. Given this project is a feasibility study with limited engagement with the broader community there was little guidance on the level of importance the community would place on one category over another. Therefore, it was considered appropriate to apply equal weightings of 20% each to the categories related to the environmental, social and economic categories, as these are direct impacts of the scenarios. The robustness to future uncertainty and risk categories have been given a combined weighting of 15% as the key assumptions within these categories are less certain. For example, the increase in demand to SDL level of demand would require a significant increase in the water use in the catchment. The category weightings applied to the MCA assessment are shown in Table 7.

Table 7: MCA category weightings

Category	Weighting	Reason for adoption
Project objectives	25%	Main drivers for the project.
Robustness to future uncertainty	12.5%	Important future consideration, however, the extent of the uncertainty has been assumed and may not play out according to those assumptions. Therefore, the category has been given a moderate weighting.
Risk	2.5%	This category is a scan of risks on a feasibility level project. There are still opportunities to mitigate this risk as the project progresses and therefore it was given a low weighting.
Environmental	20.0%	Environmental, social and economic criteria were given equal weightings as there was not enough broader community engagement in the feasibility study to determine which category the community would value more.
Social	20.0%	
Economic	20.0%	
Total	**100%**	

8.3 MULTI-CRITERIA ANALYSIS ASSESSMENT RESULTS

The net option scores that result from the assessment scoring and weighting detailed in this report are shown in Figure 8. The score for each category is shown, together with the net score (dashed box).

Overall, seven scenarios present net positive outcomes. These scenarios are:

- **Scenario 9** - The extended combined option with a net positive score of 1.2.
- **Scenario 8** - The combined option with a net positive score of 1.09.
- **Scenario 6** - All zone configuration opportunities with a net positive score of 0.91.
- **Scenario 2** - Transition out of irrigation with a net positive score of 0.54.
- **Scenario 4** - Remove or reconnect zone 3 with a net positive score of 0.20.
- **Scenario 7** - Secure access to D&S water with a net positive score of 0.12.
- **Scenario 3** - Remove or reconnect all services in Zone 5 with a net positive score of 0.09.

The high MCA scores for Scenarios 8 and 9 are driven by strong alignment to the project objectives through the improvement of reliability of supply for water shareholders in the System. Although not scored explicitly in the assessment of project objectives, the inclusion of improved D&S supply also aligns strongly to the project objectives and enjoys strong support from the community which is reflected in the high social wellbeing scores of these two options. These Scenarios are further enhanced by positive economic scores being driven by more reliable water access to support irrigated agriculture.

The positive results for Scenario 6 and Scenario 2 are driven by strong positive environmental outcomes, however for Scenario 2, the net score is reduced by the significant economic impact associated with lost productivity resulting from removing irrigated agriculture from the region. Scenario 6 scores better on the economic and social criteria as it assumes water shares will be recovered from people who are not using them, whilst providing improved reliability for individuals who wish to continue irrigated agriculture. This is reflected in positive economic score for this scenario.

Scenario 7 achieves a small positive outcome through small benefits for each of the project objective criteria, and the wellbeing benefit associated with more security of critical water supplies.

Scenarios 3 and 4, as stand-alone options, do not provide an improvement in the reliability of supply for water share users under average conditions and therefore receive neutral or ‘0’ scores against the project objective criteria. They do perform better in the robustness to future uncertainty category, as a reduction in demand on the system is a benefit under future climate change scenarios. Both scenarios also result in positive economic scores resulting from increased productivity due to more reliable access to water.

One scenario received an overall net negative score:

- **Scenario 5** - Mokoan pipeline supply channel efficiencies with a net negative score of -0.49.

The economic criteria were the drivers for net negative score for Scenario 5. The high cost of this option relative to the water saved is a major challenge for this option. There were no substantial benefits of this option for project objectives or robustness (driven by reliability of supply under various scenarios), or environmental benefits that were identified for this option.

Figure 8: MCA net scores

It is important to remember that an MCA is a decision support tool, not a decision-making tool. It is useful for comparing a group of criteria that do not have common metrics. The results may change depending on the assumptions that are made through the assessment process, the scoring process, and the weighting applied to each category and criterion. To understand the impact of the assumptions on the outcome of this assessment, sensitivity analysis on the results was completed. The sensitivity analysis was run using the 'upper bound' and 'lower bound' assessment scores for each assessment criteria. This analysis showed that the net scores are highly sensitive to the assumptions and judgement calls made during the assessment process. The results of this sensitivity analysis are presented in Attachment 1.

9 FURTHER COMMUNITY ENGAGEMENT

After the initial round of option and zone-based scenario assessments was completed, a secondary round of community engagement sessions took place.

First, one-on-one sessions were held with the project team visiting a variety of water entitlement holders throughout the Broken System. These individualised sessions aimed to cover the full range of zones, ultimately engaging 60% of the water entitlement holders.

Next, community members were invited to attend one of five information sessions held over two days to receive an update on the Broken Reconfiguration Feasibility Study (BRFS). During these sessions, the team provided a summary of the study's background and the case for change. Attendees generally agreed that "doing nothing" was not a viable path forward for the Broken System to thrive in the future.

Based on the analysis of water and land use practices, the study team identified five main profiles of Broken System entitlement holders. Information on the common characteristics of each group, along with potential options to improve outcomes specific to their circumstances, was discussed. These profiles and proposed options were broadly accepted by attendees, with no disputes or suggestions for additional profiles.

9.1 WHAT WE HEARD

Attendee responses to the options presented included:

- Throughout the sessions, there was no suggestion or urging from the participants to remove any of the options from consideration.
- In each session, participants were asked if other options should be considered. No additional options were raised.
- Whole Farm planning was high on the priority list. There is a clear desire from the community for this support.
- Data presented from the initial one-on-one engagement sessions on the options aligned with expectations, with no significant surprises noted.

When discussing the ‘Planning to continue in irrigation’ Profile and associated BRFS options presented, attendee perspectives offered included the following:

- While some participants expressed interest in investigating opportunities for increased on farm storage, others noted the losses associated with evaporation and unsuitable soil conditions made it impractical for some properties.
- Managed Aquifer Recharge may be suitable at an individual scale and some support to investigate this was observed.
- Previously conducted on-farm planning has not provided confidence to invest more money given the system reliability concerns.
- Pointed out the average age of a farmer is 59 and thus it may be unrealistic to be securing loans and financial support. Some of the options (such as whole farm planning and on farm storage) may only be suitable with significant government funding.
- Reliability is based around 100% allocation however a lot of active irrigators don’t actually require this reliability as they can ‘innovate’ and ‘manage the system’. There is a desire for simplified processes to allow greater use of unused water (trading of allocation and carryover).
- Reiterated trading options do not increase overall system reliability however assist irrigators to manage water related risks.
- One participant suggested farmers have always managed their own risks and would continue to make the tough decisions around future planning.
- Reiterated carryover opportunity needs to be looked at and considered.
- Broken Creek irrigators struggle to pump from the creek as it simply doesn’t run at a high enough level.

   - Some support shown for an irrigation pipeline for Broken Creek irrigators however limitations and difficulties were noted.

When discussing the 'Uncertain and requiring additional information' Profile and associated BRFS options presented, attendee perspectives offered included the following:

- Requests for water market trading education and assistance for the community.
- It was noted people often find the trading process very complicated and confusing. Often water share is available but people aren't selling and brokers have minimal interest in following up with very minimal money to be made in the Broken System.
- Noted a priority aim is to assist entitlement holders make informed decisions. It is a reality that not all properties and customers may be suited to stay in irrigation, the study cannot resolve all issues for all irrigators.

When discussing the 'Planning to transition out of irrigation' Profile and associated BRFS options presented, attendee perspectives offered included the following:

- Previous whole farm planning programs have been aimed at modernisation in gravity irrigation systems and this may need to be adapted for the Broken System. It was explained that for this option the focus is the on the 'sit down and planning' at an individual level but it is understood this would need some tweaking for a Broken specific solution.
- Questions around the logic for decommissioning Gowangardie Weir. It is an important long-standing structure with environmental values upstream of the weir. It was noted that the main concern with the weir is fish passage and that effects that removal of the weir may have on irrigators would be considered in any decommission investigations. Some customers rely on fixed pool and river height data from the above weir.

When discussing the 'No irrigation but require secure D&S access' Profile and associated BRFS options presented, attendee perspectives offered included the following:

- General support expressed in each session for options to provide reliable access to basic D&S water needs.
- Queried if implementing Stock and Domestic supply options would require water from customers' existing HRWS. The options would require HRWS from the existing entitlement pool for implementation. However, the exact form this option takes is an area to explore in more detailed investigations if the feasibility study demonstrates sufficient community support.
- Continued growth of lifestyle blocks and overall community D&S use makes D&S options complex i.e. Does a lifestyle block have the same right as an irrigator who relies on water for livelihood?
- Questions on whether 2 ML is sufficient for D & S use.

When discussing the 'Own Water Share and trade annual allocation' Profile and associated BRFS options presented, attendee perspectives offered included the following:

- Question about whether there was any back-trade in dry years. It was explained that back-trade can only occur when trade out occurs and in dry years this does not occur.

10 COST BENEFIT ANALYSIS

Following the secondary round of community engagement sessions, the final list of assumptions and full package of preferred Reconfiguration Scenarios were refined and subsequently assessed. The Reconfiguration Scenarios were subject to a detailed cost benefit analysis that allowed for a more thorough analysis of each scenario and the identification of likely benefits and/or risks to be mitigated.

A detailed Cost Benefit Analysis (CBA) was undertaken for the remaining scenarios. This CBA complements the outcomes of the detailed environmental, social and cultural assessments. The key questions that were addressed include:

- What is the net public benefit of each scenario – do the benefits outweigh the costs?
- What is the distribution of benefits amongst the different groups?
- What is the distribution of costs amongst the different groups?

CBA is a holistic appraisal method that compares the base case (i.e., the 'do nothing differently' or status quo scenario) with one or more alternative options. It aggregates all the costs and benefits associated with the various options across a 30-year assessment period to estimate the net impact on society, and to different stakeholder groups. CBA includes both market impacts, such as capital and operating costs, but also impacts for which there are no market prices, such as changes to environmental values.

These costs and impacts were derived based on the available information and necessary assumptions at the feasibility study stage. The CBA results are not expected to resemble precise and exact costings for a potential future project and Scenario implementation. The CBA approach is useful to inform decision-making, providing valuable insights into the net impacts from different initiatives. The approach also underpins most business cases and government investment decisions.

All costs and benefits are estimated over a specified timeframe and discounted to current, present value terms. The key metrics and decision rules for the assessment and comparison of options are:

- The present value of costs (PVC)—the total value of all costs discounted to present value terms.
- The present value of benefits (PVB)—the total value of all benefits discounted to present value terms.
- The net present value (NPV)—the net benefit based on the PVB less PVC; for a scenario to be economically viable, the NPV must be greater than $0 (i.e. total benefits exceed total costs).
- Benefit-cost ratio (BCR)—a ratio of PVB divided by PVC; for a scenario to be economically viable, the BCR must be greater than 1.

10.1 INTERPRETATION OF RESULTS

The outcomes of the cost benefit analysis are presented alongside the outcomes of the environmental, social and cultural assessments and associated MCA for each scenario to provide a complete set of information to inform the final scenario evaluation.

It should be noted that these options will also result in social impacts. However, these have not been assessed within the CBA. Further information of the social (and other) outcomes were assessed as part of the multi-criteria analysis.

In order to complete the cost benefit analysis, key assumptions were made which can be seen in detail in Attachment 4. The categories requiring significant assumptions are shown below:

- Capital costs.
- Operating and maintenance costs.
- Agricultural productivity.
- Environmental outcomes from changes in environmental water.

10.2 RESULTS OF COST BENEFIT ANALYSIS

10.2.1 GENERAL ASSUMPTIONS

The general assumptions applied in the CBA were:

- The assessment period was assumed to be 30 years, consistent with the DTF's (2013) guidelines.
- The discount rate used was 7% (with a range of 4–10% for sensitivity analysis), consistent with the DTF's (2013) guidelines.
- Although climate change is expected to increase the variability of water availability between years and decrease volumes of inflows in the catchment, it was assumed that the net impact from this variability would be consistent across the base case and reconfiguration scenarios.

10.2.2 CBA RESULTS

The NPVs and BCRs were calculated for the net benefit of each scenario relative to the base case. This was done taking the outcomes for each scenario minus the outcomes from the base case. The NPVs and BCRs for each scenario are shown in Table 8.

While both NPV and BCR provide a similar picture of economic viability and are hence reported, only the NPV can be used to compare and rank scenarios when they are not all independent of each other.

Table 8: Preliminary CBA results, $million (FY2024 dollars)

Scenario	NPV ($M)	BCR
2: Transition out of irrigation	-$205.05	-2.47
3: Reconfigure zone 5	-$8.10	0.75
4: Reconfigure zone 3	-$5.80	0.56
6: Systemwide initiatives	-$9.69	0.74
7: Secure access to D&S water	$6.63	7.96
8: Combination scenario	-$23.38	0.70
9: Extended combination scenario	-$41.36	0.64

Scenario 2 stands out as the scenario with the most negative result with a NPV of -$205 million (a net loss to society). The costs of this Scenario are largely driven by the loss of agricultural productivity as a result of a full transition out of irrigation for the whole district.

For Scenarios 3, 4, 6, 8 and 9, the costs are driven by implementation costs and ongoing costs, while productivity gains as a result of increased reliability of water supply drive the benefits.

Scenario 7 is generally a low-cost option, with productivity gains for D&S users driving the positive NPV for this scenario.

The assessment results are based on the level of information available at the feasibility study stage. There will be scope to refine and improve assumptions and ultimately the BCR itself through business case development, as opportunities to enhance benefits and reduce/improve cost certainty are explored.

11 CONCLUSION

In line with Recommendation 7 of the Broken Review, the feasibility study focused on:

- Thorough investigation into all feasible options for system reconfiguration in terms of the regulated Broken System, from small-scale local adjustments to water supply for individuals through to decommissioning of areas currently under irrigation.
- Investigating how the risks posed by options could have been mitigated or further benefits to the system achieved – including any potential changes to rules (e.g. carryover or passing flow rules).

The detailed analysis was undertaken and presented to identify possible options for the reconfiguration of the Broken System and to pinpoint those aligning with the feasibility and success criteria established. Options were explored across a wide range of scales, encompassing supply to individual properties and potential alterations or modifications to the operation of water regulation infrastructure.

Assessments considered short-term, medium-term, and long-term impacts on water availability, water demand, area under irrigation, and the value of agricultural production. These assessments drew upon research outcomes and lessons from prior projects conducted in the project. Water availability encompassed both consumptive (irrigation, domestic, and stock) and non-consumptive (environmental, recreational, cultural) values and demands. Anticipated effects of climate change were considered in the analysis, informed by the department's water availability climate change guidelines. This included examining the potential need for fundamental changes to the Broken System to adapt to forecast changes in water availability and agricultural production.

Consultation with the broader Broken System irrigation community and GMW was required to challenge assumptions and enrich the assessments.

Following completion of the community engagement activities and technical assessments, the Broken Reconfiguration Feasibility Study - Feasibility Report was finalised. In concluding the report, Scenario 9 was identified as the preferred scenario based on the results of the study. The steps required to advance through business case development are outlined in the Feasibility Report.

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Attachment	Multi-Criteria Assessment Report
Attachment No.	1
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Broken System Reconfiguration Project

DETAILED ASSESSMENT REPORT

July 2024

alluvium

Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for Sequana Partners under the contract titled 'Broken System Reconfiguration Feasibility Study'.

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1 Introduction

The Broken system is the regulated part of the Broken Basin in north-eastern Victoria. The basin is made up of the Broken River, which is a tributary of the Goulburn River, and the catchment of the Broken Creek, which diverges from the Broken River at Caseys Weir and flows to the Murray River. The basin covers an area of approximately 7,724 km2. The project area comprises the section of the Broken River from Lake Nillahcootie to its confluence with the Goulburn River at Shepparton, and the Upper Broken Creek, from the Broken River confluence at Caseys Weir to Waggarandall Weir.

In December 2019, the Victorian Minister for Water announced a review of the regulated Broken River system. The Broken system review 2020-22 recognised that average annual inflows have declined, impacting all water users, and responded to the clear need to consider how to manage the system in a future, drying climate.

The review aimed to investigate the impact of ongoing dry conditions and low inflows in the recent past, as well as under future climate projections, and to identify feasible system management changes to respond to the changing climate.

The seventh recommendation of the Broken River system review was a feasibility study of how the Broken system could be reconfigured – including the potential for a reduced irrigation footprint – so the local community can understand the long-term options for the future of the valley with reduced water availability.

The intent of the current project is to develop and assess a list of options which can be combined (as required) and applied to different zones within the project area to achieve a reconfiguration of the Broken system. This project assesses the zone based option combinations (scenarios) against technical, environmental, social, cultural and economic criteria and presents a final scenario and associated recommendations.

Alluvium Consulting Australia, EcoFutures, Natural Capital Economics and Mosaic Insights were engaged to undertake a quadruple bottom-line assessment of the reconfiguration options, known as the 'scenarios'. The assessment was carried out using a multi-criteria analysis approach. This report presents the approach and outcomes of that assessment.

Full details of the options being assessed is contained in the body of the feasibility report.

2 Multi criteria analysis

The assessment framework is centred around the application of a multi-criteria analysis (MCA).

MCA is a decision support tool that was developed as part of a field of study called "operations research", where decision makers assess multiple options across a range of decision factors (reasons or considerations) that may have different and inconsistent assessment measures, including non-monetary valuation. MCA has been adopted for environmental management as it is valuable in assessing unique elements of a project that do not include financial components. Put simply, it is valuable as a technique for "comparing apples and oranges".

When applied with care and transparency, an MCA provides a structured framework for comparing options. The basic structure of an MCA is shown in Figure 1. Weightings are applied to each of the categories of objectives to reflect their relative importance to decision-makers and stakeholders. Under each objective, there are typically a number of assessment criteria. These criteria are also typically weighted within the objective to reflect their relative importance. The assessments against each criterion can be based upon either the outputs of previous technical analysis (e.g. a hydrological model), or use a semi-qualitative approach based on expert discussion and/or community engagement. This approach enables different considerations to be incorporated into the same framework of options evaluation.

Figure 1. *Typical structure of an MCA*

MCA is most effective when there is a clear basis for scoring project options and where this evaluation framework is agreed and documented before the analysis commences. However, MCA ultimately involves some subjective and non-testable judgements on values. In addition, it does not tell the decision-maker whether individual proposals are of net social benefit (i.e. whether anything at all should be chosen), or the optimal scale of any particular proposal.

MCA is therefore a decision support tool, not a decision-making tool. The MCA provides a framework to assess and summarise the evidence and attributes of options against common criteria, using weightings to suit the context of the project. The outputs can then be discussed with stakeholder advisory groups, and documented to support project decision-making. Project leads may ultimately make a decision that conflicts with the MCA output, providing the reasoning is clearly documented and supported by appropriate evidence. Advice from stakeholder advisory groups will be a key consideration in this decision-making.

3 Multi criteria analysis assessment criteria

3.1 Multi criteria analysis assessment objective categories

To be consistent with the Victorian government guidance on the use of a quadruple bottom line assessment for investments in rural water infrastructure, this assessment considers the social, cultural, environmental and economic outcomes of each scenario. It also includes a category that expressly measures the intended outcomes of the project, including robustness to future uncertainties and risk mitigation opportunities. The details of the categories of criteria are presented in Table 1.

At the request of the two Registered Aboriginal Parties that were consulted for this project, assessment of cultural criteria has not been included in this assessment. Both parties have been provided with the opportunity to provide their own statements regarding options.

Table 1 Objective category descriptions

Objective Categories	Description
Project objectives	This category exists to capture the project objectives that sit outside the quadruple bottom line assessment (i.e. the other MCA categories). The criteria in this category relate to the objectives and principles of the Broken System Reconfiguration Project. Criteria within this category have been drawn from the project principles and feasibility criteria.
Social	This category exists to capture the social impacts of the project options. The social criteria will consider social, recreational and wellbeing benefits and impacts.
Environment	The environment category considers the impacts that project options have on the environment. This category will measure the impact or benefits to the waterway.
Economic	The economic category considers the impacts that project options have on the local economy and consider the distribution of costs and benefits amongst stakeholders.
Risk	The risk category considers major risks to the project objective or unintended consequences that may results from each option that are not considered in other criteria of this assessment.
Robustness to uncertainty	The robustness to uncertainty category exists to consider how resilient the benefits of each option are in the face of future uncertainties. This includes climate change, and changes to water demand in the catchment.

Criteria will be placed into a category to allow differential weighting as part of the assessment. Criteria may fit in one or more category, and choice of category will be driven by the assessment type. For example the assessment of how well each scenario supports environmental values under climate change could sit in either the robustness to future uncertainty category, or the environmental category. As the assessment approach for this criterion matches the assessment approach of the other environmental criterion, it has been kept in the environmental category.

3.2 Multi criteria assessment criteria

Criteria within each assessment category are shown in Table 2. The criteria in this phase of the evaluation build on the project success criteria and align with the project principles and government policy direction. A draft set of assessment criteria were presented to the Consultative Committee and its feedback was included through the refinement and addition of some criteria.

Table 2 MCA Assessment criteria

Category	Criteria #	Criteria
Project Objective	PO1	Sustainable irrigation sector future: Reliability of water supply for High Reliability Water Shares (HRWS) relative to the do nothing scenario.
	PO2	Sustainable irrigation sector future: Reliability of water supply Low Reliability Water Shares (LRWS) relative to the do nothing scenario
Robustness to future uncertainty	Rob1	Provides improvement under projected future climate change: Reliability of supply of HRWSs under a high climate change future, relative to the do nothing scenario under a high climate change future.
	Rob2	Provides improvement under a range of future water use scenarios: Reliability of supply for HRWS under a demand scenario that represents full Sustainable Diversion Limit demand, relative to a do nothing scenario that includes full Sustainable Diversion Limit demand.
Risk	Ris1	Risk of unintended consequences: Scan of risks that have not been captured in other MCA criteria.
Environmental	Env1	Environmental values: The extent to which each option protects or enhances the environmental values of the Broken River system.
	Env2	Support of environmental values under future high climate change projection: The extent to which each option protects or enhances the environmental values of the Broken River system in a high climate change future
Social	Soc1	Change to recreational, amenity and social connection outcomes: The impact of each option on the recreational, amenity and social connections values of the study area relative to the do nothing scenario.
	Soc 2	Wellbeing and social cohesion: The impact of each scenario on the mental and physical wellbeing of the local community and aspects of liveability.
Economic	Eco1	Value for money – capital costs: comparison of the capital cost of the project on a costs per ML saved basis between the different scenarios.
	Eco2	Value for money - project operating and maintenance costs: comparison of the operating and maintenance costs per ML of water saved across the different scenarios
	Eco3	Economic impacts and benefits : comparison of the change in productivity related to the change in water use in the catchment.

3.3 Multi criteria assessment process

Each criterion is assessed in using appropriate evidence. This may range from outcomes of water resource modelling, expert elicitation, literature reviews and stakeholder engagement outputs. The result of that assessment is then scored based on its level and type of impact on the criteria. Positive impacts (benefits) receive a positive score, and negative impacts receive a negative score. Assessment scales are developed for each criterion, from neutral to extreme end of the positive and/or negative spectrum.

The details of the assessment approach, results the assessment scales are presented in the following section.

4 Multi criteria assessment approach and results

4.1 PO1. Reliability of water supply for high reliability water share owners

The intent of this criteria is to capture the change in reliability of water supply HRWS owners may experience as a result of the proposed changes to the Broken system. It measures the change in the February seasonal allocation for each year compared to the do nothing scenario. The measure used to inform this assessment is the reliability of supply which is the percentage of years that received 100% allocation. For example, if in 9 years out of 10 the February allocation reached 100% then it is considered to have a 90% reliability of supply.

Assessment approach

Water resource modelling was undertaken for each scenario as detailed in HARC (2024). This modelling produced a monthly timeseries of allocations based on the existing water allocation process. This monthly allocation timeseries was used to assess the change in reliability of supply for HRWSs under each scenario. The approach to this assessment was:

- Years were categorised as wet years, average years, and dry years based on rainfall at Nillahcootie Reservoir. The 30% of lowest rainfall years were classed as dry, the 30% of highest rainfall years were classed as wet, and the remaining 40% were classed as average.
- The reliability of supply for each group of years was calculated for each Scenario.
- For scenarios 2 to 9, the change in reliability of HRWS under each climate condition relative to current conditions (Scenario 1) was calculated.

For scenarios 7, 8 and 9, an additional water entitlement product has been introduced. This product would give all D&S priority access to the first 2 ML of water of their entitlement annually. This product is not common across all scenarios and would not improve reliability across the entire HRWS allocation. Therefore, we have not included it in the assessment of this criterion. Improved access to water through this product will factor indirectly into other criteria in this MCA, and will be fully costed into the relevant scenarios under the cost benefit analysis.

Table 3 below shows the results of the reliability of supply calculation under each climatic condition for each scenario.

Table 3 HRWS reliability of supply assessment calculations

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
	HRWS Reliability	**HRWS Reliability**	**HRWS Reliability**	**HRWS Reliability**	**HRWS Reliability**	**HRWS Reliability**	**HRWS Reliability**	**HRWS Reliability**	**HRWS Reliability**
Dry years	67%	79%	69%	69%	69%	67%	67%	79%	90%
Average years	92%	94%	92%	92%	92%	92%	90%	92%	94%
Wet years	90%	95%	93%	93%	93%	95%	90%	95%	95%

Assessment scale

The assessment scale shown in Table 4 was developed to score the impact of the change in reliability of supply to the HRWS owners. The scoring is based the impact on the water share holder of the reduced reliability of supply. As reliability of supply is a measure of the % of time when a water share holder receives their full allocation, a reduction in reliability of supply equates to more years with a <100% allocation. Anecdotal evidence from the consultation process for this project suggests that many irrigators in the system have secured more entitlement than they need to allow for lower allocation years.

Table 4 Change in HRWS reliability assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	Extreme negative impact	Very high negative impact	High negative impact	Medium negative impact	Small negative impact	No change	Small benefit	Medium benefit	High benefit	Very high benefit	Extreme benefit
Assessment guideline (% change in reliability)	>-20%	-15% to -20%	-11% to -15%	-6% to -10%	-1% to -5%	0%	1% to 5%	6% to 10%	11% to 15%	16% to 20%	>20%

Assessment results

The results of the assessment are shown in Table 5. The average conditions score was adopted for the MCA, with the dry and wet year scores being used to form the upper and lower bounds of the assessment. The climatic condition with the greatest score formed the upper bound, and the climatic condition with the lower level of change formed the lower bound.

Table 5 Change in HRWS reliability assessment results

	Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 9	
	Change in HRWS Reliability	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**
Dry	13%	3	3%	1	3%	1	3%	1	0%	0	0%	0	13%	3	23%	5
Average	2%	1	0%	0	0%	0	0%	0	0%	0	-2%	-1	0%	0	2%	1
Wet	5%	1	3%	1	3%	1	3%	1	5%	1	0%	0	5%	1	5%	1

4.2 PO2: Reliability of water supply for low reliability water share owners

The intent of this criteria is to capture the change in reliability of water supply LRWS owners may experience as a result of the proposed changes to the Broken system. This criterion measures the change in the February seasonal allocation for each year compared to the Scenario 1 – Do Nothing . It is the LRWS equivalent of PO1: Reliability of water supply for high reliability water share owners.

Assessment approach

The same assessment approach that was used for PO1 was used for this criterion. The approach to this assessment was:

- Years were categorised as wet years, average years, and dry years based on rainfall at Nillahcootie Reservoir.
- The reliability of supply for each group of years was calculated for each scenario.
- For scenarios 2 to 9, the change in reliability of LRWS under each climate condition relative to current conditions (Scenario 1) is calculated.

The results of the assessment are shown in Table 6.

Table 6 LRWS reliability of supply assessment calculations

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
	LRWS Reliability	**LRWS Reliability**	**LRWS Reliability**	**LRWS Reliability**	**LRWS Reliability**	**LRWS Reliability**	**LRWS Reliability**	**LRWS Reliability**	**LRWS Reliability**
Dry year	56%	72%	69%	64%	59%	64%	56%	69%	82%
Average year	42%	54%	52%	48%	44%	48%	42%	52%	62%
Wet year	55%	70%	68%	63%	58%	63%	55%	68%	80%

Assessment scale

The assessment scale shown in Table 7 was developed to score the impact of the change in reliability of supply to the LRWS owners. The scoring reflects the impact on the water share holder of the reduced reliability of supply of what is already a low reliability product.

Table 7 Change in LRWS reliability assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	Extreme negative impact	Very high negative impact	High negative impact	Medium negative impact	Small negative impact	No change	Small benefit	Medium benefit	High benefit	Very high benefit	Extreme benefit
Assessment guideline (% change to reliability of supply)	>-20%	-15% to -20%	-11% to -15%	-6% to -10%	-1% to -5%	0%	1% to 5%	6% to 10%	11% to 15%	16% to 20%	>20%

Assessment results

The results of the assessment are shown in Table 8. The average conditions score was adopted for the MCA, with the dry and wet year scores being used to form the upper and lower bounds of the assessment. The climatic condition with the greatest score formed the upper bound, and the climatic condition with the lower level of change formed the lower bound.

Table 8 Change in LRWS reliability Assessment results

	Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 9	
	Change in LRWS Reliability	**Score**	**Change in LRWS Reliability**	**Score**	**Change in LRWS Reliability**	**Score**	**Change in LRWS Reliability**	**Score**	**Change in LRWS Reliability**	**Score**	**Change in LRWS Reliability**	**Score**	**Change in LRWS Reliability**	**Score**	**Change in LRWS Reliability**	**Score**
Dry year	15%	3	13%	3	8%	2	3%	1	8%	2	0%	0	13%	3	26%	5
Average year	12%	3	10%	2	6%	2	2%	1	6%	2	0%	0	10%	2	19%	4
Wet year	15%	3	13%	3	8%	2	2%	1	8%	2	0%	0	13%	3	25%	5

4.3 Rob1: Delivers value under future projected climate change

The intent of this criteria is to test how well each scenario will deliver benefits into the future, given the current understanding of future climate change impacts. For this assessment each scenario was modelled using inputs adjusted to represent 2065 high climate change projections. This criterion uses the calculated reliability of supply for the HRWS in each scenario under the high climate change projection. The change in reliability between the Scenario 1 – Do Nothing (assuming high climate change) and each scenario (assuming high climate change) is then used to score this criterion.

Assessment approach

Water resource modelling was undertaken for each scenario using inputs that were derived to align with the 2065 high climate change projections in accordance with the Department of Energy, Environment, and Climate Action (DEECA) Climate Change Guidelines (DELWP, 2020) as detailed in HARC (2024). This modelling produced a monthly timeseries of allocations based on the existing water allocation process in the system. This monthly timeseries was used to assess the change in reliability of supply for HRWSs under each scenario. The approach to this assessment was:

- Years were categorised as wet years, average years, and dry years based on rainfall at Nillahcootie Reservoir. The same classification of wet, average and dry years was carried through from the assessment of Criteria PO1 and PO2.
- The reliability of supply for each group of years was calculated for each scenario.
- For scenarios 2 to 9, the change in reliability of HRWS condition relative to the do nothing scenario (Scenario 1) is calculated.

For scenarios 7, 8 and 9, an additional water entitlement product has been introduced. This product has not been included in this assessment.

Table 9 below shows the results of the reliability of supply calculation under each climatic condition for each scenario.

Table 9 Change in HRWS reliability of supply assessment calculations under a high climate change to 2065 projection

	scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability
Dry	26%	33%	26%	26%	26%	26%	26%	31%	31%
Average	54%	65%	56%	62%	54%	56%	54%	62%	60%
Wet	63%	78%	63%	65%	63%	63%	63%	68%	68%

Assessment scale

The assessment scale shown in Table 10 Change in HRWS reliability under a high climate change to 2065 projection assessment scale was developed to score the impact of the change in reliability of supply to the HRWS owners. The scoring is based on the impact on the water share holder of the reduced reliability of supply.

Table 10 Change in HRWS reliability under a high climate change to 2065 projection assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	Extreme negative impact	Very high negative impact	High negative impact	Medium negative impact	Small negative impact	No change	Small benefit	Medium benefit	High benefit	Very high benefit	Extreme benefit
Assessment guideline (% change in reliability of supply)	>-20%	-15% to -20%	-11% to -15%	-6% to -10%	-1% to -5%	0%	1% to 5%	6% to 10%	11% to 15%	16% to 20%	>20%

Assessment results

The results of the assessment are shown in Table 11. The average conditions score was adopted for the MCA, with the dry and wet year scores being used to form the upper and lower bounds of the assessment. The climatic condition with the greatest score formed the upper bound, and the climatic condition with the lower level of change formed the lower bound.

Table 11 Change in reliability of supply under high climate change to 2065 projection results

	Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 9	
	Change in HRWS Reliability	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**
Dry year	8%	2	0%	0	0%	0	0%	0	0%	0	0%	0	5%	1	5%	1
Average year	12%	3	2%	1	8%	2	0%	0	2%	1	0%	0	8%	2	6%	2
Wet year	15%	3	0%	0	3%	1	0%	0	0%	0	0%	0	5%	1	5%	1

4.4 Rob2: Delivers value under a range of future water use scenarios

The intent of this criteria is to test how well each zone based scenario will continue to deliver benefit if the demand for water increases in the system in the future. To test each scenario's robustness to future increases in demand, each scenario was modelled with demand equal to the full Sustainable Diversion Limit (SDL). The SDL is the maximum long-term annual average quantity of water that can be taken on a sustainable basis, from the waterway.

This criterion measures change in reliability of HRWS for each scenario with full SDL level demand against the do-nothing scenario (Scenario 1) also with a full SDL level of demand. The change in February allocation is used to assess reliability. Current climate conditions are assumed for this assessment.

Assessment approach

Water resource modelling was undertaken for each scenario as detailed in HARC (2024) with the water demand increased to equal the SDL. This modelling produced a monthly timeseries of allocations based on the existing water allocation process in the system. This monthly timeseries of allocation was used to assess the change in reliability of supply for HRWSs under each scenario. The approach to this assessment was:

- Years were categorised as wet years, average years, and dry years based on rainfall at Nillahcootie Reservoir. The same classification of wet, average and dry years as used in the assessment of PO1 and PO2 was maintained for this criterion.
- The reliability of supply for each group of years was calculated for each scenario.
- For scenarios 2 to 9, the change in reliability of HRWS under full demand relative to do nothing scenario (Scenario 1) at full demand is calculated.

For scenarios 7 ,8 and 9, an additional water entitlement product has been introduced. This product has not been included in this assessment.

Table 12 below shows the results of the reliability of supply calculation under each climatic condition for each scenario.

Table 12 Full SDL demand HRWS reliability of supply assessment calculations

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability	HRWS Reliability
Dry year	56%	79%	54%	62%	56%	64%	56%	72%	92%
Average year	87%	94%	87%	87%	85%	90%	85%	92%	90%
Wet year	88%	95%	85%	85%	88%	90%	88%	95%	80%

Assessment scale

The assessment scale shown in Table 13 was developed to score the impact of the change in reliability of supply to the HRWS owners. The scoring is based on the impact on the water share holder of the reduced reliability of supply.

Table 13 Change in HRWS under full SDL demand reliability assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	Extreme negative impact	Very high negative impact	High negative impact	Medium negative impact	Small negative impact	No change	Small benefit	Medium benefit	High benefit	Very high benefit	Extreme benefit
Assessment guideline (% change to reliability of supply)	>-20%	-15% to -20%	-11% to -15%	-6% to -10%	-1% to -5%	0%	1% to 5%	6% to 10%	11% to 15%	16% to 20%	>20%

Assessment results

The results of the assessment are shown in Table 14. The average conditions score was adopted for the MCA, with the dry and wet year scores being used to form the upper and lower bounds of the assessment. The climatic condition with the greatest score formed the upper bound, and the climatic condition with the lower level of change formed the lower bound.

Table 14 Change in HRWS reliability under full SDL demand assessment results

	Scenario 2		Scenario 3		Scenario 4		Scenario 5		Scenario 6		Scenario 7		Scenario 8		Scenario 9	
	Change in HRWS Reliability	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**	**Change in HRWS Reliability**	**Score**
Dry	23%	5	-3%	-1	5%	1	0%	0	8%	2	0%	0	15%	3	36%	5
Average	8%	2	0%	0	0%	0	-2%	-1	4%	1	-2%	-1	6%	2	4%	1
Wet	8%	2	-3%	-1	-3%	-1	0%	0	3%	1	0%	0	8%	2	-8%	-2

4.5 Ris1: Risk of unintended consequences

The purpose of this criterion is to assess risks of each scenario that sit outside of the other assessment criteria for this project. Given this assessment is evaluating scenarios at a high level feasibility phase, a high level scan of project risks was considered appropriate. The intent was to highlight any risks that may impact on the projects.

A PESTLE framework was used to identify the potential external factors that may impact each zone-based scenario. The PESTLE framework considers six categories:

1. Political
2. Economic
3. Social
4. Technological
5. Legal
6. Environmental

The assessment will be informed by the lessons from pervious similar projects. Risks were assessed in accordance with DEECA's risk management framework and mitigation measures were identified where applicable.

Assessment approach

This high level assessment followed the DEECA Risk Management Guidelines (DEECA 2023). It identified a number of potential sources of risk (causes) that could impact the scenarios based on the six PESTLE categories. It also considered the consequence of each of these causes (Table 15).

Table 15 Causes and consequence of risk to the scenarios based on a high level PESTLE scan

Category	Cause	Consequence Description
Political	Scenario does not receive political support	Option cannot proceed due to political opposition
Economic	Change in water market in downstream systems	Increase in inter-valley trade of water shares out of Broken system leading to less people being interested in relinquishing Broken system water shares
	No water available to trade from Goulburn system into Broken system	Water entitlement holders in the Broken system cannot purchase water shares from the Goulburn system
Social	Significant broader community resistance to scenario	Community resistance may lead to scenario not proceeding
	Significant Traditional Owner resistance to scenario	Traditional Owner resistance may lead to scenario not proceeding
Technological	Change in irrigation / agricultural technology	Decrease in water demand in catchment may reduce benefits associated with scenario

Category	Cause	Consequence Description
Legal	Scenario does not align with existing legislation or regulation	Proposed scenario cannot be implemented due to non-compliance with legislation or regulation
Environmental	Environmental approvals for construction of infrastructure are required	Increased project costs associated with meeting environmental approval requirements (offsetting habitat loss, relocating infrastructure to avoid sensitive areas)
	Unintended environmental consequences	Permanent damage to ecosystem due to changes to scenario.

For each scenario, an assessment of each risk was conducted. This included consideration of:

1. The applicability of each risk to each scenario. Not each risk will be relevant to every scenario.
2. The likelihood (or chance) of the risk event happening. The likelihood rating used for this assessment is shown in Table 16.
3. The harm (negative consequence) of the risk event rated based on the relevant categories of DEECA Risk Framework as shown in Table 17(see DEECA 2023, Table 6(a) for full version).
4. Rating of the level of risk based on the DEECA 2023 Risk Matrix (refer Table 18).
5. The highest risk rating across a scenario is adopted as the likely risk rating for the MCA, with the residual risk following any identified mitigation actions being adopted as the lower bound of the risk rating.

Table 16 Likelihood rating (taken from DEECA 2023)

Likelihood Rating		%	Description
1	Rare	0 – 4	• Event may occur only in exceptional circumstance
2	Unlikely	5 – 19	• The event could occur at some time • There is little opportunity, reason or means to occur
3	Possible	20 – 49	• The event might occur • There is some opportunity, reason or means for the event to occur
4	Likely	50 – 79	• The event is likely to occur in most circumstances • There is considerable opportunity, reason or means for the event to occur
5	Almost certain	80 - 100	• The event is expected to occur in most circumstances • There is a great opportunity, reason or means for the event to occur

Table 17 Consequence rating taken from DEECA 2023

Rating	Financial	Environmental	Political / Reputational	Legal	Service and Program Delivery
1 Negligible Harm	• Program/Project: increased cost/loss <1% of its budget • Insignificant localised impact affecting a single community • Insignificant financial loss to local economy, industry, stakeholder	• Negligible effect on the natural and/or built environment and/or heritage sites/artefacts • Environmental recovery is negligible and/or under 1 year • Contained locally within a single site/area	• Very limited public and political interest • Minimal adverse local attention • Complaint from one stakeholder	• Non-compliance with legislation, identified internally and resulting in internal acknowledgement and process review	• Insignificant impact (<5% delays) on project or program milestones • No inconvenience to customers/ stakeholders/ communities
2 Minor Harm	• Program/Project: Increased cost/ loss 1-5% of its budget • Minor financial loss to local economy/ industry/ stakeholder	• Limited effect on the natural and/or built environment and/or the environment suffers harm for 1-5 years • Limited impact on heritage sites/artefacts • Environmental recovery on minor scale up to 5 years • Restricted to single township or locality	• Adverse localised public and political interest • Limited attention on a single issue in local media over a short period	Non-compliance with legislation or breach of duty of care and either: • resolved internally with no further escalation; or • resulting in prosecution or civil action involving exposure to minor compensation, and/or minor negative precedent	• Customers/stakeholders'/ communities slightly inconvenienced • Minor impact (5-10% delay) on project or program milestones

Rating	Financial	Environmental	Political / Reputational	Legal	Service and Program Delivery
3 Moderate Harm	• Program/Project: Increased cost/ loss 2-10% of its budget • Significant financial loss to region/ industry/ stakeholder	• Moderate effect on the natural and/or built environment and/or environment suffers harm for 5-10 years • Moderate impact on heritage sites/artefacts • Environmental recovery on a small scale and/or over a period 5-10 years • Impacts on a municipality or multiple localities	• Adverse localised negative public and political attention • Short term negative local media attention • Local community concern on a single issue over a sustained period	Non-compliance with legislation or breach of duty of care resulting in: • external investigation or report to responsible authority; and/or • prosecution or civil action, with one of moderate level of compensation or moderate level of negative precedent	• Customers/stakeholders'/ communities inconvenienced • Significant impact (10-20% delay) on project or program milestones
4 Major Harm	• Program/Project: Increased cost/loss 10-20% of its budget • Major financial loss to region/ industry /stakeholder	• Major effect on natural and/or built environment and/or environment suffers harm for 10-20 years • Major impact on heritage sites/artefacts • Environmental recovery on a large scale and/or over 10-20 years • Impacts on a region or multiple municipalities	• Serious adverse public attention at State/National level • Negative State/National media on one or more issues over a prolonged period • Repeated displeasure by the Minister • Medium-term negative public interest (correspondence and phone calls) and political	Non-compliance with legislation or breach of duty of care resulting in: • external investigation or report to responsible authority • public enquiry (i.e., Royal Commission/ Parliamentary Committee) • prosecution or civil action with high level compensation and high-level negative precedent • sanctions imposed by external regulator	• Major impact on customers/ stakeholders/ communities • Major impact (20-50% delay) on project or program milestones

Rating	Financial	Environmental	Political / Reputational	Legal	Service and Program Delivery
5 Extreme Harm	• Program/Project: Increased cost/loss >20% of its budget • Very serious financial loss to region/ industry/ stakeholder	• Very serious effect on natural and/or built environment and/or environment suffers long term harm (20+ years) • Very serious impact on heritage sites/ artefacts • Environmental recovery on a very large scale and/or over 20+ years • Impacts on state or multiple regions	• Very serious public outcry at State/National level • Negative State/National media over a prolonged period • Breakdown of public confidence in the Government / department / Minister or key project/program • On-going or prolonged negative public interest (correspondence and phone calls) and political interest (in Parliament)	Non-compliance with legislation or breach of duty of care resulting in: • prosecution or civil action leading to imprisonment of an officer • public enquiry (i.e., Royal Commission/ Parliamentary Committee) • uninsured compensation payments • negative precedent requiring very serious impact and major reform to the department • severe sanctions imposed by external regulator	• Severe impact on customers /stakeholders/ • communities • Vital or very serious delays (>50% delay) to program/ project delivery or project/ program objective is not met

Table 18 Risk matrix taken from DEECA 2023

		Harm (Consequence)				
		Negligible	Minor	Moderate	Major	Extreme
Likelihood	Almost Certain	Medium	Significant	High	High	High
	Likely	Medium	Medium	Significant	High	High
	Possible	Low	Medium	Medium	Significant	High
	Unlikely	Low	Low	Medium	Medium	Significant
	Rare	Low	Low	Low	Medium	Significant

		Scenario 2				Scenario 3			
Cause	**Consequence description**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**
Political									
Project does not receive political support	Project does not proceed due to political opposition	Possible	Extreme Harm (Project does not proceed - objectives not met	High	Ongoing consultation with relevant government bodies throughout project development	Rare	Moderate Harm (adverse localised negative public attention)	Low	
Economic									
Change in water market in downstream systems	Significant increase in inter-valley trade out of system - less people want to relinquish water shares	n/a (all irrigators transitioned out)				Possible	Minor Harm	Medium	
No water to trade into Broken system	Water cannot be bought in the Goulburn system to supply Broken system	n/a (all irrigators transitioned out)				Unlikely	Extreme Harm (increased project costs approx > 20% of budget to build additional pipeline from u/s Gowangardie)	Significant	Further investigation into willingness to permanently trade within Goulburn system
Social									
Significant community resistance to proposal	Lack of community support for proposals	Possible	Major Harm (Project may not proceed without community support)	Significant	Further community engagement to understand position	Unlikely	Moderate Harm (adverse localised negative public attention)	Medium	Further community engagement to understand position
Significant Traditional Owner resistance to proposal	Lack of support from Traditional Owners for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium	Further engagement with traditional owners to understand position	Possible	Moderate Harm (adverse localised negative public attention)	Medium	Further engagement with traditional owners to understand position
Technological									
Change in irrigation / agricultural technology	Decrease in water demand in catchment	n/a (all irrigators transitioned out)				Possible	Negligible	Low	
Legal									
Proposal does not comply with existing legislation / regulation	Proposed solution cannot be implemented due to non-compliance with legislation / regulation	n/a - Transition out of irrigation carries political risks but is not a breach of regulation or legislation.				n/a - new infrastructure proposal could have costs impacted by regulation. Impact of cost of meeting regulation captured in other risk causes			
Environmental									
Environmental approvals for construction of infrastructure	Increased project cost associated with meeting environmental approvals	n/a (no infrastructure being constructed)				Possible (EPBC listed species within reach)	Major Harm (increased project costs 10% - 20% of budget to avoid sensitive areas)	Significant	
Unintended environmental consequences	Permanent damage to ecosystem due to changes to water delivery (not assessed elsewhere)	Unlikely Changes to water storage on properties may reduce habitat for broad range of species	Moderate (impacts on multiple localities).	Medium	Further study of area required to understand potential impacts	Possible (significant population of platypus in Gowangardie weir; loss of drought refuge habitat)	Minor	Medium	Opportunities to use recovered water to minimise harm should be explored

		Scenario 4				Scenario 5			
Cause	**Consequence description**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**
Political									
Project does not receive political support	Project does not proceed due to political opposition	Possible	Extreme Harm (Project does not proceed - objectives not met	Significant		n/a - GMW infrastructure upgrade			
Economic									
Change in water market in downstream systems	Significant increase in inter-valley trade out of system - less people want to relinquish water shares	Possible	Minor Harm (small number of irrigators being asked to relinquish water shares)	Medium		n/a - not reliant on water trade to realise benefits			
No water to trade into Broken system	Water cannot be bought in the Goulburn system to supply Broken system	n/a (Tungamah pipeline supplies from within the Broken system)				n/a - not reliant on water trade to realise benefits			
Social									
Significant community resistance to proposal	Lack of community support for proposals	Unlikely (small number of properties impacted)	Moderate Harm (adverse localised negative public attention)	Medium		Rare (existing channel efficiencies)	Minor Harm (adverse localised attention for short period)	Low	
Significant Traditional Owner resistance to proposal	Lack of support from Traditional Owners for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium		Unlikely (existing channel efficiencies)	Minor Harm (adverse localised attention for short period)	Low	
Technological									
Change in irrigation / agricultural technology	Decrease in water demand in catchment	Possible	Negligible	Low		Possible	Negligible	Low	
Legal									
Proposal does not comply with existing legislation / regulation	Proposed solution cannot be implemented due to non-compliance with legislation / regulation	n/a - new infrastructure proposal that could have costs impacted by regulation, but has opportunities to meet the requirements of this regulation. Impact of cost of meeting regulation captured in other risk causes				n/a - existing infrastructure and operations			
Environmental									
Environmental approvals for construction of infrastructure	Increased project cost associated with meeting environmental approvals	Possible EPBC listed species within reach	Major Harm (increased project costs 10% - 20% of budget to avoid sensitive areas)	Significant	Further investigation to determine requirements under EPBC act	Unlikely (existing channel)	Minor Harm (increased project costs 105% of budget to avoid sensitive areas)	Low	
Unintended environmental consequences	Permanent damage to ecosystem due to changes to water delivery (not assessed elsewhere)	Possible (Major creek supports platypus)	Moderate (impact on population of platypus in Major Creek)	Medium	Opportunities to use recovered water to minimise harm should be explored	Unlikely (existing channel)	Minor	Low	

		Scenario 6				Scenario 7			
Cause	**Consequence description**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**
Political									
Project does not receive political support	Project does not proceed due to political opposition	Unlikely	Major Harm (Some sections of the community do not like voluntary purchasing causing state level negative attention and a loss of political willingness to proceed)	Medium		Unlikely	Major Harm (Some sections of the community do not like creation of new D&S product causing state level negative attention and a loss of political willingness to proceed)	Medium	
Economic									
Change in water market in downstream systems	Significant increase in inter-valley trade out of system - less people want to relinquish water shares	Unlikely	Major (low take up of water share buy-back compromises project outcomes)	Medium		n/a - option not reliant on people relinquishing water shares			
No water to trade into Broken system	Water cannot be bought in the Goulburn system to supply Broken system	n/a (not reliant on trading water into Broken system)				n/a - option not reliant on trade into Broken system			
Social									
Significant community resistance to proposal	Lack of community support for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium		Possible	Moderate Harm (adverse localised negative public attention)	Medium	
Significant Traditional Owner resistance to proposal	Lack of support from Traditional Owners for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium		Possible	Minor Harm (adverse localised attention for short period)	Low	
Technological									
Change in irrigation / agricultural technology	Decrease in water demand in catchment	Possible	Negligible	Low		Possible	Negligible	Low	
Legal									
Proposal does not comply with existing legislation / regulation	Proposed solution cannot be implemented due to non-compliance with legislation / regulation	n/a (opportunistic and voluntary program)				Rare (similar D&S products exist in other systems)	Minor Harm (Design of D&S product - can be resolved internally)	Low	
Environmental									
Environmental approvals for construction of infrastructure	Increased project cost associated with meeting environmental approvals	n/a (no construction of infrastructure)				n/a (no construction of infrastructure)			
Unintended environmental consequences	Permanent damage to ecosystem due to changes to water delivery (not assessed elsewhere)	Unlikely Changes to water storage on properties may reduce habitat for broad range of species	Moderate harm (impacts on multiple localities)	Medium		n/a (no change to water delivery pattern related to this option)			

		Scenario 8			
Cause	**Consequence description**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**
Political					
Project does not receive political support	Project does not proceed due to political opposition	Unlikely	Extreme Harm (Project does not proceed - objectives not met	Significant	Opportunities to reduce impact to the waterway could be included which may improve political support.
Economic					
Change in water market in downstream systems	Significant increase in inter-valley trade out of system - less people want to relinquish water shares	Possible (reluctance to give up water entitlements)	Minor Harm	Medium	
No water to trade into Broken system	Water cannot be bought in the Goulburn system to supply Broken system	Unlikely	Extreme Harm (increased project costs approx > 20% of budget to build additional pipeline from u/s Gowangardie)	Significant	Further investigation into willingness to permanently trade within Goulburn system
Social					
Significant community resistance to proposal	Lack of community support for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium	
Significant Traditional Owner resistance to proposal	Lack of support from Traditional Owners for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium	
Technological					
Change in irrigation / agricultural technology	Decrease in water demand in catchment	Possible	Negligible	Low	
Legal					
Proposal does not comply with existing legislation / regulation	Proposed solution cannot be implemented due to non-compliance with legislation / regulation	Rare (similar D&S products exist in other systems)	Minor Harm (Design of D&S product - can be resolved internally)	Low	Government can change legislation / regulation to allow for this option
Environmental					
Environmental approvals for construction of infrastructure	Increased project cost associated with meeting environmental approvals	Possible EPBC listed species within reachs where new infrastructure being built	Major Harm (increased project costs 10% - 20% of budget to avoid sensitive areas)	Significant	Further investigation to determine requirements under EPBC act (reduce impact to minor)
Unintended environmental consequences	Permanent damage to ecosystem due to changes to water delivery (not assessed elsewhere)	Likely (Major creek supports platypus)	Moderate (impact on population of platypus in Major Creek)	Significant	Opportunities to use recovered water to minimise harm should be explored

		Scenario 9			
Cause	**Consequence description**	**Likelihood Rating**	**Consequence Rating**	**Risk Rating**	**Control**
Political					
Project does not receive political support	Project does not proceed due to political opposition	Unlikely	Extreme Harm (Project does not proceed - objectives not met	Significant	Opportunities to reduce impact to the waterway could be included which may improve political support.
Economic					
Change in water market in downstream systems	Significant increase in inter-valley trade out of system - less people want to relinquish water shares	Possible (reluctance to give up water entitlements)	Minor Harm	Medium	
No water to trade into Broken system	Water cannot be bought in the Goulburn system to supply Broken system	Unlikely	Extreme Harm (increased project costs approx > 20% of budget to build additional pipeline from u/s Gowangardie)	Significant	Further investigation into willingness to permanently trade within Goulburn system
Social					
Significant community resistance to proposal	Lack of community support for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium	
Significant Traditional Owner resistance to proposal	Lack of support from Traditional Owners for proposals	Possible	Moderate Harm (adverse localised negative public attention)	Medium	
Technological					
Change in irrigation / agricultural technology	Decrease in water demand in catchment	Possible	Negligible	Low	
Legal					
Proposal does not comply with existing legislation / regulation	Proposed solution cannot be implemented due to non-compliance with legislation / regulation	Rare (similar D&S products exist in other systems)	Minor Harm (Design of D&S product - can be resolved internally)	Low	Government can change legislation / regulation to allow for this option
Environmental					
Environmental approvals for construction of infrastructure	Increased project cost associated with meeting environmental approvals	Possible EPBC listed species within reaches where new infrastructure being built	Major Harm (increased project costs 10% - 20% of budget to avoid sensitive areas)	Significant	Further investigation to determine requirements under EPBC act (reduce impact to minor), and further investigation of implications of Gowangardie Weir decommissioning on platypus.
Unintended environmental consequences	Permanent damage to ecosystem due to changes to water delivery (not assessed elsewhere)	Likely (Major creek supports platypus)	Moderate (impact on population of platypus in Major Creek)	Significant	Opportunities to use recovered water to minimise harm should be explored

Assessment scale

The assessment scale shown in Table 19 was developed to reflect the risk ratings for each of the options.

Table 19 Risk assessment scale

Score	-4	-3	-2	-1	0
Assessment	High risk	Significant risk	Medium Risk	Low Risk	No change
Assessment guideline (% of maximum volume)	-15% to -20%	-11% to -15%	-6% to -10%	-1% to -5%	0%

Assessment results

The results of the assessment are detailed in Table 20.

Table 20 Risk assessment results

	Recreational Assessment			Justification
	Lower Bound	Likely	Upper Bound	
Scenario 2	-3 Significant	-4 High Risk	-4 High Risk	High Risk – Project objectives will not be met in this scenario if there is not political support for the transition of irrigation. Risk could reduce to 'Significant' through ongoing consultation with relevant groups during project development and implementation to build political support.
Scenario 3	-2 Medium	-3 Significant	-3 Significant	Significant risk resulting from: • Potential changes to project cost to avoid sensitive habitat areas (EPBC listed species present along waterway) or if the cost of buying water from the Goulburn system increases dramatically. Risk could reduce to 'Medium' with better understanding of sensitive habitats along pipe route.
Scenario 4	-2 Medium	-3 Significant	-3 Significant	Significant risk resulting from: • Political support for project could be undermined by a reduction in streamflow through Broken Creek in this option. • Potential changes to project cost to avoid sensitive habitat areas (EPBC listed species present along waterway) • Environmental impact of changes to streamflow on known Platypus populations in Broken Creek. Risk could reduce with better understanding of sensitive habitats along pipe route, and modifications to this option to reduce the impact of streamflow changes resulting from this option.

	Recreational Assessment Lower Bound	Likely	Upper Bound	Justification
Scenario 5	-1 Low	-1 Low	-1 Low	Low risk due to the nature of the scenario being an improvement of infrastructure.
Scenario 6	-2 Medium	-2 Medium	-2 Medium	Medium risk due to potential disagreement on voluntary purchase of water entitlements within the community, that reduces political support for the option, and potential for lower volumes of uptake of program that reduces the achievement of project outcomes. No risk control measures identified.
Scenario 7	-2 Medium	-2 Medium	-2 Medium	Medium risk rating due to potential disagreement in some part of the community with the creation of a more secure product for D&S users.
Scenario 8	-2 Medium	-3 Significant	-3 Significant	Significant risk resulting from: • Political support for project could be undermined by reduction in streamflow through Broken Creek in this option as it was originally developed. • Potential changes to project cost to avoid sensitive habitat areas (EPBC listed species present along waterway) or if the cost of buying water from the Goulburn system increases dramatically. • Environmental impact of changes to streamflow on known Platypus populations in Broken Creek. Risk could reduce to 'Medium' with better understanding of sensitive habitats along pipe route, and modifications to this option to reduce the impact of streamflow changes resulting from this option.
Scenario 9	-2 Medium	-3 Significant	-3 Significant	Significant risk resulting from: • Political support for project could be undermined by reduction in streamflow through Broken Creek in this option as it was originally developed. • Potential changes to project cost to avoid sensitive habitat areas (EPBC listed species present along waterway) or if the cost of buying water from the Goulburn system increases dramatically. • Environmental impact of changes to streamflow on known Platypus populations in Broken Creek. • Changes to Gowangardie Weir. There are benefits associated with fish passage, but further understanding of its use as a drought refuge for endangered species is required. Risk could reduce to 'Medium' with better understanding of sensitive habitats along pipe route, and further investigations into decommissioning of Gowangardie weir.

4.6 Env1: Support of existing ecological function

The purpose of this criteria is to assess how each proposed scenario will impact upon the ecological values of the Broken River and upper Broken Creek. Ecological objectives for each waterway have been set by Goulburn Broken Catchment Management Authority (GBCMA). According to the 2023-24 Seasonal Watering Proposal developed by GBCMA:

" The Broken River's overarching ecological objective is to maintain the frequency, timing, duration and magnitude of low flows and freshes to improve habitat for native fish, macroinvertebrates and aquatic vegetation.

The upper Broken Creek's overarching ecological objectives are to :

- *Provide permanent habitat for native fish, platypus, macroinvertebrates and other fauna in the upper reach and opportunistic habitat in the lower reaches.*
- *Protect and enhance the diversity and extent of instream, littoral and riparian vegetation.*
- *Maintain water quality to support native fish and macroinvertebrates. "*

(Goulburn Broken Catchment Management Authority, 2023)

Achievement of these ecological objectives is influenced by the magnitude, timing and frequency of critical flow events in each waterway. These criteria test how well each scenario is able to support the ecology of each waterway through the provision of an appropriate flow regime.

Assessment approach

A Broken River Environmental Watering Plan was completed in 2013 (Cottingham et al, 2013) and an upper Broken Creek Environmental Flow Study was completed in 2017 (Jacobs, 2017). These technical studies established ecological objectives and associated environmental flow recommendations. The achievement of the environmental flow recommendations is used in this assessment as a surrogate for environmental outcomes. This assessment assumes that if a flow component is delivered, the aligned ecological objective is achieved.

The assessment of the environmental flow achievement is calculated based on the ability of streamflows (either unregulated flow or water released for irrigation or D&S purposes) and the available environmental water to meet the minimum environmental flow recommendations of the Broken River and Broken Creek.

The monthly water resource model incorporated environmental flow requirements in the following priority order:

1. Summer autumn low flow requirement on all Broken River reaches to be modelled as 100 ML/d, and Broken Creek low flow requirement of 10 ML/d.
2. Winter spring low flow requirement on all Broken River reaches to be modelled as 150 ML/d, and Broken Creek low flow requirement of 15 ML/d.
3. Summer / autumn fresh event of 450 ML/d for 2 days Broken River Reach 1 only in April.
4. Winter / Spring fresh event of 4500 ML/d for 2 days on all Broken River reaches to achieve the requirement in Reach 3 (the most downstream reach of the study area)

The water resource modelling allocated water from the environmental water holdings to achieve the environmental flow recommendations in priority order. The prioritization of the environmental water events was provided by Goulburn Broken CMA (S Casanelia per comms January 2024). This advice is based on environmental flow recommendations for the Broken River detailed in Broken River Environmental Watering Plan (Cottingham et al, 2013) and the environmental flow recommendations for Broken Creek detailed in Upper Broken Creek Flows Study (Jacobs, 2017). The timing of the fresh events was selected to minimise the risk to the river of an adverse water quality event of the summer fresh event, and to maximise the benefits of the winter / spring fresh event.

The achievement of environmental flow recommendations was assessed using the outputs of the water resource modelling undertaken by HARC. A report into the modelling approach, assumptions and outcomes are provided in HARC (2024). The water resource modelling provided monthly streamflows at the 4 compliance points relevant to environmental flow provision in the study area. These compliance points are shown in Table 21.

Table 21 Environmental flow compliance points in the study area

Study zones	Environmental flow reach	Compliance point
Zone 1	Broken River Reach 1: Lake Nillahcootie to Holland Creek	Broken River downstream of Back Creek Junction
Zone 2	Broken River Reach 2: Hollands Creek to Caseys Weir	Broken River upstream of Caseys Weir
Zone 3	Upper Broken Creek Reach 1: Caseys Weir to Waggarandall Weir	Broken Creek downstream of Caseys Weir
Zone 4 and 5	Broken River Reach 3: Caseys Weir to the Goulburn River	Broken River downstream of Gowangardie Weir

For each zone-based scenario the water resource model supplied the minimum passing flow requirements specified in the Bulk Entitlement (Broken System – Goulburn Murray Water) Conversion Order 2004. The model then allocated water from the environmental water shares held in storage to achieve the priority environmental flow recommendations in the order detailed above. The resulting streamflows at each compliance point were assessed as the basis for this criterion. The assessment was based on the following calculations:

1. Calculate the deficit between the recommended summer low flow for each month and the modelled streamflow for each month between December and May for each reach of the study area. Where the low flow recommendation was exceeded for the month, no deficit was recorded.
2. Calculate the deficit between the recommended winter low flow for each month and the modelled streamflow for each month between June and November for each reach of the study area. Where the low flow recommendation was exceeded for the month, no deficit was recorded.
3. Calculate the deficit between the recommended summer fresh in Reach 1 of the Broken River and the modelled streamflow in April of each year. This calculation subtracted the water required to meet the low flow recommendations in this month, and then used the remaining volume to assess whether there was sufficient water to supply a fresh event. Where the streamflow above the low flow recommendation exceeded the fresh flow requirement, no deficit was recorded.
4. Calculate the deficit between the recommended spring fresh in Reaches 1, 2 and 3 of the Broken River and the modelled streamflow in November of each year. This calculation subtracted the water required to meet the low flow recommendations in this month, and then used to remaining volume to assess whether there was sufficient water to supply a fresh event. Where the streamflow above the low flow recommendation exceeded the fresh flow requirement, no deficit was recorded.

Where no deficit is recorded, it is assumed that the environmental flow recommendations for that month and flow requirement were achieved, and therefore the desired ecological objective was achieved for that month. Where there is a deficit for a particular flow recommendation in a month, it is assumed that the ecological objective was not achieved for that month.

The flow deficit for each scenario was compared to current conditions (Scenario 1) to inform the scoring of the environmental criteria and to answer the following questions:

1. What is the impact of the new flow regime (under each scenario) on the achievement of the environmental flow recommendations? This was measured as a difference between the deficit in

achieving the environmental flows in the do nothing scenario and the deficit in achievement the environmental flows in the relevant scenario.

2. How frequently are the environmental flows not being met under each scenario relative to the do nothing scenario?
3. What is the ecological implication of this change (improvement or decline) in achievement of the environmental flow recommendations? This is based on purpose of each flow component and the role it plays in supporting the key values of the waterway. Table 8 and Table 9 ecological function of each flow recommendation for Broken River and Broken Creek respectively.

Table 22 Implications of failing to achieve environmental flow recommendations in the Broken River

Flow component	Ecological value	Ecological objectives	Season	Ecological function of flow component
Summer low flow	Riffles, slackwater, pools, aquatic vegetation, native fish and macroinvertebrates	Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.	Summer / Autumn	• Low flows represent minimum habitat and this will affect fish condition with risks to fecundity. • Low flows critical in summer to maintain water quality, especially in pools. Important influence on fish that are sensitive to temperature and oxygen levels. • Riffle: Loss of hydraulic habitat and dependent invertebrates. • Submerged species such as Valisneria need flowing water to maintain condition. Littoral species such as Phragmites and Typha will decline if exposed
Winter low flow	Riffles, slackwater, pools, aquatic vegetation, native fish and macroinvertebrates	Maintain hydraulic habitat diversity (riffles, slackwater and pools) which supports native fish, macrophytes and macroinvertebrates.	Winter / spring	• Winter low flows need to sustain range of habitats, including each of which supports a community of dependent animals. • Slackwaters: provide habitat for small fish, shrimp and zooplankton. Shrimp and zooplankton are both important sources of food for fish. • Riffles provide complex, stable habitat that supports algal biofilms and macroinvertebrates that provide food for fish and riparian insectivores (spiders, birds, bats). Macroinvertebrate life cycles often start with eggs being laid at the end of summer or autumn with larvae residing within the riffle over winter. • Macrophyte beds are important primary producers that also help trap and retain particulate matter and provide surfaces for biofilms that represent a high-quality food resource for macroinvertebrates. Macrophyte productivity is important to carbon inputs to the system and nutrient cycling.

Flow component	Ecological value	Ecological objectives	Season	Ecological function of flow component
Summer fresh	In-channel habitat diversity and native fish	Turn over bed sediments and scour around large wood. Provide flow cues to stimulate native fish breeding and migration movements.	Summer / Autumn	• Scouring: Freshes scour sediments out of the interstices between cobbles in riffle habitats. This helps maintain habitat heterogeneity which affords the invertebrates protection against predation and scour. In warm water with high nutrients, food quality of biofilms decreases. Freshes can scour biofilms leading to more productive and nutritious food for invertebrates. • Flushing: Freshes flush organic matter, invertebrates and zooplankton into the water column where they are more accessible prey. • Fish; Fish constrained by low flows in a limited reach may exhaust the food resources and freshes provide an opportunity to move to a difference reach where more food may be available.
Winter / Spring Fresh	In-channel habitat diversity and native fish	Scour sediment and biofilms and inundate benches, provide for fish movement		• Scour: Similar to summer freshes, winter/spring freshes will scour sediments and flush organic matter and biota, helping to maintain the system's disturbance regime. Also important for biofilms as species that emerge in summer will be building up fat reserves to undergo pupation. • Fish: Some species of fish will move to breed and in some cases movement or breeding may be cued by changes in flow.

Table 23 Implications of failing to achieve environmental flow recommendations in the upper Broken Creek

<table>
<tr><th>Flow component</th><th>Ecological value</th><th>Ecological objectives</th><th>Season</th><th>Ecological function of flow component</th></tr>
<tr><td>Summer low flow</td><td rowspan="2">Maintain perennial nature of the reach.
Maintain aquatic habitat including vegetation and wood.

Maintain aquatic habitat for all native fish species

Maintain access to habitat and sufficient food resources</td><td rowspan="2">Maintain self-sustaining populations of macroinvertebrates

Maintain conditions for self-sustaining populations of small-bodied native fish
Maintain conditions for survival of large-bodied native fish

Maintain platypus population and support successful breeding and juvenile dispersal</td><td>Summer / Autumn</td><td>• Species adapted to living in perennial systems are generally sensitive to loss of flow.
• Macroinvertebrates: Habitat is defined by hydraulics which affects breathing, food availability or vulnerability to predation.
• Small fish need to both find food and avoid becoming prey. The loss of flow and contraction of habitat makes both of these tasks more challenging. Low flows are also a period when water quality may decline which may have sub-lethal or lethal effects on them or their prey.</td></tr>
<tr><td>Winter low flow</td><td>Winter / Spring</td><td>• Higher flows influence the amount of habitat and, in complex ways, the types of habitat available. Additional habitat is usually associated with greater amounts and diversity of food resources and less competition for the food.
• Winter flows will help maintain riffles in good condition which will be important in providing platypus and fish with food resources through spring and summer.</td></tr>
</table>

Achievement of environmental flows – low flows

The modelled streamflow for each scenario was assessed against the recommended environmental flows in each reach of the study area. For each scenario, there was less water in the waterway than required to meet the low flow recommendations. The annual average deficit of water was calculated for each scenario, and is shown in Table 24. The annual average deficit is the sum of the largest deficit in the Broken River plus the deficit in the Broken Creek. This recognises that meeting the low flow requirement in one reach of the Broken River will also meet it in the others, however additional water will be required to meet the low flow requirement in the Broken Creek.

Table 24 Average annual low flow deficit per scenario

Scenario	Summer avg annual deficit (ML)	Autumn avg annual deficit (ML)	Winter avg annual deficit (ML)	Spring avg annual deficit (ML)
1	- 573	- 689	- 3,264	- 2,452
2	- 307	- 313	- 3,633	- 2,530
3	- 386	- 763	- 3,205	- 2,402
4	- 538	- 872	-3,100	- 2,365
5	- 588	- 698	-3,250	- 2,444
6	- 90	- 674	-3,438	- 2,494
7	- 581	- 697	- 3,260	- 2,454
8	- 238	- 1,272	- 3,123	-2,387
9	-161	-1441	-3105	-2372

The difference between the deficit of water for each scenario and the do nothing scenario (Scenario 1), is shown in Table 25.

Table 25 Change in low flow deficit in each scenario compared to the do nothing scenario

Scenario	Summer	Autumn	Winter	Spring
2	46%	55%	-11%	-3%
3	33%	-11%	2%	2%
4	6%	-26%	5%	4%
5	-3%	-1%	0%	0%
6	84%	2%	-5%	-2%
7	-1%	-1%	0%	0%
8	58%	-85%	4%	3%
9	72%	-109%	5%	3%

The other critical consideration when looking at the achievement of low flows in a waterway is the duration of periods of deficit. One month where the low flow recommendation is not met does not have as severe an impact as 12 months. Table 26 shows the median duration of low flow deficit months for each scenario, together with the maximum duration and number of full years over the model run that low flows were not achieved.

Table 26 Duration of low flow deficits

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Median monthly duration of low flow deficit	9	7	10	11	10	8	9	10	10
Max monthly duration of low flow deficits	12	12	11	12	12	12	12	12	12
Years over model run with 12 months low flow deficit*	27	10	0	53	27	1	26	10	7

* Model run period is 130 years

Achievement of summer fresh and spring fresh events

The third and fourth priority flow events are the achievement of a summer fresh event in Reach 1 of the Broken River, followed by the achievement of a spring fresh event along the length of the Broken River. The number of years that these are achieved are shown in Table 27.

Table 27 Years of summer and spring fresh flow achievement by scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Years summer fresh Broken River Reach 1 delivered	84	124	74	74	82	77	83	35	14
Years spring fresh delivered to Broken River	17	17	17	17	17	17	17	17	17

The hydrological assessment results are combined with the ecological function of each flow component to assess the impact of each scenario on the ecological function of the waterway.

Limitations:

This assessment is based on a monthly timestep water resource model. Environmental flow recommendations are specified at a daily timestep. The outputs from a monthly model are therefore ill suited to assessing compliance against environmental flow recommendations. An example is presented in Figure 2. In this example the baseflow recommendation is 15 ML/d (shown in the blue line). The actual daily flow is shown in the green line, and the monthly flow as an average daily flow volume is shown in the black line. Based on an assessment of the monthly average flow, the case presented below would not achieve the environmental flow recommendation for the month. However, if the daily timestep flow was used, the flow would achieve the environmental flow recommendation for part of the month.

It is possible, but complex, to disaggregate the monthly model outputs into daily flow series in the Broken system. This exercise would need to consider the pattern of unregulated flows entering the waterway, which can often be linked to catchment rainfall. Disaggregation would also need to consider the daily pattern of irrigation and other operational releases which are not related to specific climatic factors such as daily rainfall and are therefore difficult to disaggregate with confidence. For this reason it was decide that daily disaggregation would not improve the accuracy of the assessment. If more detailed understanding of the achievement of environmental flows is required for future stages of the project, a daily timestep model should be used.

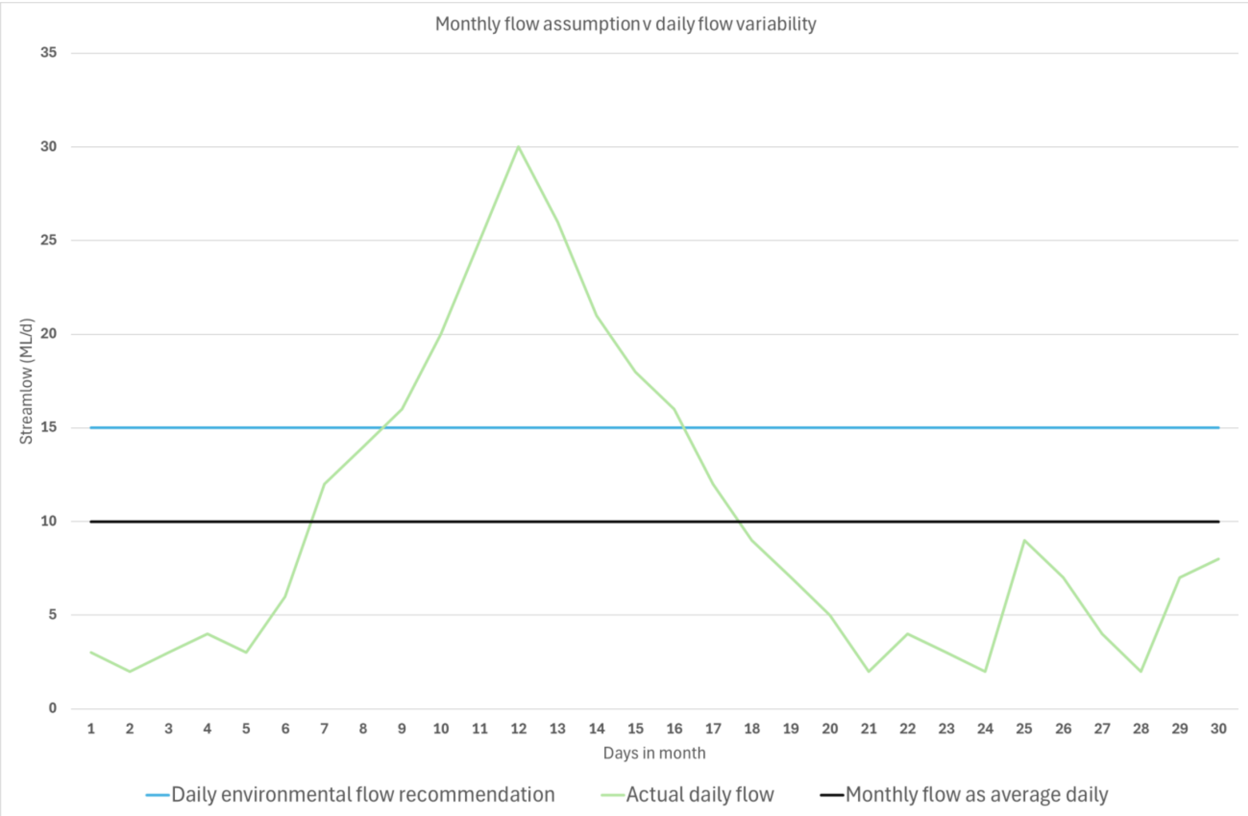

Figure 2 Example of the difference between assessing environmental flow compliance using daily flow (green line) and monthly flow as an averaged daily (black line).

Assessment scale

The assessment scale shown in Table 28 was developed to score the ability of each scenario to support the existing ecological function of Broken River and the upper Broken Creek.

Table 28 Assessment scale for support of existing ecological function

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	Low (negative)	Neutral	Low (positive)	Low/Medium (positive)	Medium (positive)	Medium/High (positive)	High (positive)
Recreation assessment guideline	High negative impact on environmental outcomes	Medium-high negative impact on environmental outcomes	Medium negative impact on environmental outcomes	Low-medium negative impact on environmental outcomes	Low negative impact on environmental outcomes	No change	Low positive impact on environmental outcomes	Low-medium positive impact on environmental outcomes	Medium positive impact on environmental outcomes	Medium-high positive impact on environmental outcomes	High positive impact on environmental outcomes

Assessment results

The assessment results for this criterion are shown in Table 29.

Table 29 Supporting existing ecological function assessment results

	Supporting existing ecological function assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 2	2	3	4	Increases in low flow provision throughout summer, autumn and spring, and a greater achievement in the summer fresh event drive the positive scoring of this option. A decrease in low flow achievement in winter is outweighed by the benefits of improving critical flow events in other seasons.
Scenario 3	0	1	2	Scenario 3 leads to an improvement in the summer/autumn low flow achievement rate, and small improvement in the winter/spring low flow rate. There is also a decline frequency of achievement for the summer fresh. The decrease in summer fresh events will reduce the benefits of the achievement in low flow somewhat leading to the low positive rating of this scenario.

	Supporting existing ecological function assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 4	-3	0	1	Scenario 4 sees an overall improvement in low flow recommendation achievement in the Broken River, as there is no reduction in irrigation releases in this reach, and an increase in environmental water holdings that will allow active delivery of low flows. However, this scenario includes a reduction in streamflow in Broken Creek. The impact on the values of Broken Creek has reduced the rating of this option, however it is considered that benefits to Broken River negate the negative impact associated with the reduction in streamflow in the Broken Creek. There is no improvement in the achievement of summer fresh events in this scenario.
Scenario 5	-1	0	1	There is no significant change in the achievement of environmental flows in this scenario relative to the do nothing scenario.
Scenario 6	1	2	3	In scenario 6 there is a large increase in summer/autumn low flow achievement, due to an increase in available environmental water holdings. The environmental water shares are not enough to maintain the increase in low flow through the winter / spring period. There is a small decline in winter / spring low flow achievement. There is also a reduction in the achievement of the fresh events which is why this scenario has received a low / medium benefit score.
Scenario 7	-1	0	1	There is no significant change in the achievement of environmental flows in this scenario relative to the do nothing scenario.
Scenario 8	-4	0	1	This scenario results in a reduction of low flow achievement in Autumn, with improvements in Winter, Spring and Summer. As with Scenario 4, there is a reduction in streamflow in Broken Creek, however the benefits of improved flows in the Broken River are considered to negate this impact. There is also a decline in the achievement of summer fresh events.
Scenario 9	-4	0	1	The impacts of this scenario are similar to Scenario 8, however there is a small improvement in the achievement of baseflow in summer, winter and spring in the Broken River. Again the impacts of reduced streamflow on the Broken Creek has been considered in the assessment but are considered to be negated by the improvement in flows in the Broken River.

4.7 Env2: Support of environmental values under future high climate change projection

The purpose of this criteria is to assess how well each scenario will support the existing ecological function of the waterway in a future when climate change has impacted the flow regime and water availability within the Broken system.

As no guidance is available about the future ecological objectives of the system, this assessment assumes that the existing ecological objectives as used in the assessment of criteria Env1 are still applicable. This criterion assesses the achievement of the key elements of the flow regime under a 'High Climate Change to 2065" projection (refer to HARC (2024) for details).

Assessment approach

The assessment approach to this criterion is the same as was used to assess Env1 but using different model outputs. The assessment of the environmental flow achievement is calculated based on the ability of streamflows (either unregulated flow or water released for irrigation or D&S purposes) and the available environmental water to meet the minimum environmental flow recommendations of the Broken River and Broken Creek under a High Climate Change to 2065 projection. To assess this criterion the water resource models were run with inputs derived to reflect the High Climate Change to 2065, as detailed in HARC (2024).

For each zone-based scenario the water resource model supplied the minimum passing flow requirements specified in the Bulk Entitlement (Broken System – Goulburn Murray Water) Conversion Order 2004. The model then allocated water from the environmental water shares held in storage to achieve the priority environmental flow recommendations in the order detailed above. The resulting streamflows at each compliance point were assessed as the basis for this criterion. The same calculation method detailed for Env1 was used to calculate the deficit against the priority flow components.

The flow deficit for each zone based scenario was compared to do-nothing under the High Climate Change to 2065 project (Scenario 1) to inform the scoring of the environmental criteria and to answer the following questions:

1. What is the impact of the new flow regime (under each scenario) on the achievement of the environmental flow recommendations? This was measured as a difference between the deficit in achieving the environmental flows in the do nothing scenario and the deficit in achievement the environmental flows in the relevant scenario.
2. How frequently are the environmental flows not being met under each scenario relative to the do nothing scenario?
3. What is the ecological implication of this change (improvement or decline) in achievement of the environmental flow recommendations? This is based on purpose of each flow component and the role it plays in supporting the key values of the waterway. Table 22 and Table 23 ecological function of each flow recommendation for Broken River and Broken Creek respectively.

Achievement of environmental flows – low flows

The modelled streamflow for each scenario was assessed against the recommended environmental flows in each reach of the study area. For each scenario, there was less water in the waterway than required to meet the low flow recommendations. The annual average deficit of water was calculated for each scenario, and is shown in Table 30. The annual average deficit is the sum of the largest deficit in the Broken River plus the deficit in the Broken Creek. This recognises that meeting the low flow requirement in one reach of the Broken River will meet is in the others, however additional water will be required to meet the low flow requirement in the Broken Creek.

Table 30 Average annual low flow deficit per scenario

Scenario	Summer avg annual deficit (ML)	Autumn avg annual deficit (ML)	Winter avg annual deficit (ML)	Autumn avg annual deficit (ML)
1	-1267	-1326	-4776	-4295
2	-749	-1028	-5057	-4328
3	-634	-1468	-4818	-4372
4	-1131	-1548	-4792	-4376
5	-1274	-1329	-4762	-4282
6	-90	-641	-3397	-2453
7	-1281	-1346	-4768	-4289
8	-403	-1847	-4799	-4375
9	-506	-1279	-4971	-4560

The difference between the deficit of water for each scenario and the do nothing scenario (Scenario 1), is shown in Table 31.

Table 31 Change in low flow deficit in each scenario compared to the do nothing scenario

Scenario	Summer	Autumn	Winter	Spring
2	41%	22%	-6%	-1%
3	84%	-14%	-1%	-2%
4	21%	-15%	0%	-2%
5	-1%	0%	0%	0%
6	92%	52%	29%	43%
7	-16%	-3%	0%	0%
8	67%	-39%	0%	-2%
9	60%	4%	-4%	-6%

The other critical consideration when looking at the achievement of low flows in a waterway is the duration of deficit periods . One month where the low flow recommendation is not met does not have as severe an impact as 12 months. Table 32 shows the median duration of low flow deficit months for each scenario, together with the maximum duration and number of full years over the model run that low flows were not achieved.

Table 32 Duration of low flow deficits

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Median monthly duration of low flow deficit	12	11	10	12	12	8	12	11	11
Max monthly duration of low flow deficits	12	12	12	12	12	12	12	12	12
Years over model run with 12 months low flow deficit*	76	37	12	108	79	2	75	30	34

* Model run period is 130 years

Achievement of summer fresh and spring fresh events

The third and fourth priority flow events are the achievement of a summer fresh event in Reach 1 of the Broken River, followed by the achievement of a spring fresh event along the length of the Broken River. The number of years that these are achieved are shown in Table 33.

Table 33 Years of summer and spring fresh flow achievement by scenario

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Years summer fresh Broken River Reach 1 delivered	81	89	67	69	82	78	81	34	85
Years spring fresh delivered to Broken River	3	1	1	3	3	17	3	17	1

The hydrological assessment results are combined with the ecological function of each flow component to assess the impact of each scenario on the ecological function of the waterway.

Assessment scale

The assessment scale for this criterion is shown in Table 34.

Table 34 Support of environmental values under high climate change assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	Low (negative)	Neutral	Low (positive)	Low/Medium (positive)	Medium (positive)	Medium/High (positive)	High (positive)
Recreation assessment guideline	High negative impact on environmental outcomes	Medium-high negative impact on environmental outcomes	Medium negative impact on environmental outcomes	Low-medium negative impact on environmental outcomes	Low negative impact on environmental outcomes	No change	Low positive impact on environmental outcomes	Low-medium positive impact on environmental outcomes	Medium positive impact on environmental outcomes	Medium-high positive impact on environmental outcomes	High positive impact on environmental outcomes

Assessment results

The results of this assessment are shown in Table 35.

Table 35 Support of environmental values under high climate change projection assessment results

	Supporting existing ecological function assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 2	-2	0	1	Increase in water availability and significant increase in summer/winter low flows and increase in summer freshes. Decrease in winter / spring events.
Scenario 3	-1	0	1	This scenario has a low positive impact because of the increase in summer / autumn baseflow and an improvement, but a decrease in fresh flow in achievement of all priority flow components.

	Supporting existing ecological function assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 4	-4	-2	-1	Scenario 4 sees an overall decline in low flow recommendation achievement in the Broken River, as there is no reduction in irrigation releases in this reach, and an increase in environmental water holdings that will allow active delivery of low flows. This change is primarily in Autumn, with improvements in Summer, with Winter and Spring remaining comparable. However this scenario includes a reduction in streamflow in Broken Creek, with regular periods of no flow, despite the increased availability of environmental water. The impact on the values of Broken Creek drives rating of this option. There is also a decline in the achievement of summer fresh events in this scenario which will impact on the Broken River, reducing the benefits associated with the increased baseflows.
Scenario 5	-1	0	1	There is no significant change in the achievement of environmental flows in this scenario relative to the do nothing scenario.
Scenario 6	1	3	4	There is a large increase in flows, and in particular baseflows, across all seasons and an increase in spring fresh achievement. The slight decline in summer freshes is stops the scenario being ranked more highly.
Scenario 7	-1	0	1	There is no significant change in the achievement of environmental flows in this scenario relative to the do nothing scenario.
Scenario 8	1	2	3	There is an increase in baseflow across Spring and Summer which will have a benefit to the waterway, though there is decline in the Winter and Spring. The decline in spring low flows will be an impediment to fish movement and migration, however there is also an improvement in the spring fresh achievement. The substantial decline in summer fresh events prevents the scenario being scored more highly.

	Supporting existing ecological function assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 9	1	2	3	Like Scenario 8, this scenario provides for an increase in baseflow across Spring and Summer which will provide increased habitat for aquatic species and help manage water quality risks. The decline in spring low flows will be an impediment to fish movement and migration. This scenario provided a small improvement in fresh flow achievement in summer / autumn relative to the do nothing scenario.

4.8 Soc1: Change to recreational, amenity and social connection outcomes

This criterion assesses changes to the recreational and amenity values of the Broken system, recognising the important role these values play in providing in social connection.

Assessment approach

The assessment compares the outcomes expected to be achieved under the option to the do nothing scenario option, which is the future trajectory for this issue under the current water management settings. The following sub questions were considered for the assessment of this criterion:

1. Is the project site currently used for recreation activities?
2. If yes, what recreation opportunities does it currently offer? (e.g. fishing, swimming, paddling, water skiing, bird watching or walking trails)
3. What times of year is the site most commonly used for recreation? (e.g. summer)
4. Is the project option likely to enhance or diminish the recreation opportunities?
5. Will the project option restrict recreation opportunities sometimes or all the time?
6. What is the level of impact to recreation opportunities on the scale?

This assessment is informed by community engagement reports, and community surveys, relevant reports, and published literature, combined with inferences from the environment modelling and other assessments (e.g. hydrological modelling outputs).

Assessment scale

The assessment scale shown in Table 36 was developed to score the impact of reconfiguration options on recreation values of the catchment. These values include fishing, swimming, paddling, water skiing, bird watching or walking trails.

Table 36 Recreational values assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	Low (negative)	Neutral	Low (positive)	Low/Medium (positive)	Medium (positive)	Medium/High (positive)	High (positive)
Recreation assessment guideline	High negative impact on recreation opportunities	Medium-high negative impact on recreation opportunities	Medium negative impact on recreation opportunities	Low-medium negative impact on recreation opportunities	Low negative impact on recreation opportunities	No change	Low positive impact on recreation opportunities	Low-medium positive impact on recreation opportunities	Medium positive impact on recreation opportunities	Medium-high positive impact on recreation opportunities	High positive impact on recreation opportunities

Assessment results

The results of the assessment are outlined in Table 38. Based on the findings, most reconfiguration scenarios will have limited impact on recreation. Some assumptions were made in interpreting the hydrological assessments for this assessment. For instance it was assumed that increased environmental flows will benefit recreational values. We have linked environmental flows to increased biodiversity, leading to improved recreational activities such as fishing and bird watching. Higher streamflow can also be linked to increase recreation such as paddling and swimming.

Table 37 Recreational values assessment results

	Recreational Assessment			Justification
	Lower bound	Likely	Upper Bound	
Scenario 2	1	1	2	Higher environmental flows will result in positive recreation due to ecological benefits e.g. increased biodiversity supporting visual amenity, and recreational benefits such as fishing, birdwatching, kayaking.
Scenario 3	0	0	1	Slight increase in streamflow, but not considered significant enough to provide noticeable improvement to amenity.
Scenario 4	0	0	0	There is likely little recreational impact for the whole community. Based on the environmental assessment this scenario will receive higher levels of flows in comparison to the base case during winter, spring and summer, critical times for aquatic life, but potentially lower levels during the Autumn months.
Scenario 5	0	0	0	The pipe replacement will not affect recreational as it does not change an area with any nearby residents'
Scenario 6	0	1	3	Offering water buy backs may benefit community members wanting to transition out of irrigated agriculture Ecological modelling suggests more water in the system relative to the baseline generating benefits to fisheries and aquatic animals and therefore positive recreational outcomes
Scenario 7	0	0	0	Modelling of benefits to fisheries negligible relative to the baseline
Scenario 8	-1	0	2	Ecological modelling suggest more water in the system relative to the baseline generating benefits to fisheries and aquatic animals and thusly positive recreational outcomes
Scenario 9	-1	0	2	Ecological modelling suggest more water in the system relative to the baseline generating benefits to fisheries and aquatic animals and thusly positive recreational outcomes

4.9 Soc2: Wellbeing / social cohesion measure of increased certainty for community

This criterion assesses the community wellbeing benefits or impacts from each of the zone based zone based scenarios, relative to the do nothing scenario.

Assessment approach

The assessment compares the outcomes expected to be achieved under the option to the do nothing scenario, which is the future trajectory for this issue under the current water management settings. For the purpose of this framework, community wellbeing refers to the mental and physical heath of the local community and aspects of liveability. The following sub questions were considered for the assessment of this criterion:

1. How does the project site currently contribute to the local community's wellbeing?
2. Does project option enhance or diminish opportunities for physical activity?
3. Does the project option enhance or diminish meeting places for community to connect?
4. Does the project option enhance or diminish community safety?
5. Does the project option enhance or diminish stressors to the local community?
6. Does the project option impact liveability?
7. Does the project option impact non-Aboriginal heritage values or sites?
8. What is the overall level of impact to the community wellbeing values?

This assessment is informed by community engagement reports, and community surveys, relevant reports, and published literature, combined with inferences from the environment modelling and other assessments (e.g. hydrological modelling outputs).

Assessment scale

The assessment scale shown in Table 38 was developed to score the impact of potential reconfiguration options on wellbeing and social cohesion values of the catchment.

Table 38 Community wellbeing assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	Low (negative)	Neutral	Low (positive)	Low/Medium (positive)	Medium (positive)	Medium/High (positive)	High (positive)
Wellbeing assessment guideline	High negative impact on community wellbeing	Medium-high negative impact on community wellbeing	Medium negative impact on community wellbeing	Low-medium negative impact on community wellbeing	Low negative impact on community wellbeing	No change	Low positive impact on community wellbeing	Low-medium positive impact on community wellbeing	Medium positive impact on community wellbeing	Medium-high positive impact on community wellbeing	High positive impact on community wellbeing

Assessment results

The results of the assessment are outlined in Table 39 Community wellbeing assessment . Most reconfiguration scenarios will have limited impact on community wellbeing. The consider the wellbeing of direct stakeholders, irrigators, large organisations that could affect broader community. Some assumptions were made in assessing the hydrological assessments. For instance it was assumed that increased environmental flows will results in benefits for wellbeing values. It also considers the wellbeing benefits associated with more certainty regarding the allocation of water under certain scenarios.

Table 39 Community wellbeing assessment scores

Scenario	Wellbeing Assessment Lower bound	Likely	Upper bound	Justification
Scenario 2	-3	-1	1	Higher environmental flows will result in positive wellbeing impacts due to ecological benefits e.g. increased biodiversity supporting visual amenity and health benefits. Potential negative wellbeing impacts occur from loss of agricultural identity and lifestyles. It is not possible to shift to dryland agriculture as this would adversely affect wineries and the University of Melbourne Agricultural College. This may have wider impacts on the community.
Scenario 3	0	0	1	Preference for piped irrigation to come from the Shepparton Irrigation Area due to the improved reliability of Goulburn supply.
Scenario 4	-2	0	1	While this follows a more natural pattern of flow and will likely benefit the aquatic life, there is increased uncertainty and that is reflected in the lower and upper bounds of the wellbeing assessment (as we assume wellbeing is tied to biodiversity benefits). The likely seasonality of the flow will affect the adjacent landowners but there is potential for adaptation and potentially less likely that this reconfiguration will affect property values.
Scenario 5	0	0	0	The pipe replacement will not affect recreational or wellbeing benefits as it does not change an area with any nearby residents.
Scenario 6	0	1	4	Ecological modelling suggests more water in the system relative to the baseline, generating benefits to fisheries and aquatic animals and therefore positive wellbeing outcomes. Additionally, offering water buy backs may benefit community members wanting to transition out of irrigated agriculture Increased certainty in water allocations will benefit wellbeing for those continuing with irrigated agriculture.
Scenario 7	0	1	2	Potential wellbeing benefit for a wider community for certain groups due to increased certainty of water allocations. Stakeholder engagement showed strong support for this option: 87.5% of responses in favour

Scenario	Wellbeing Assessment			Justification
	Lower bound	Likely	Upper bound	
				• 5% against • 7.5% neutral
Scenario 8	-1	0	2	Ecological modelling suggest more water in the system relative to the baseline generating benefits to fisheries and aquatic animals and thusly positive wellbeing outcomes.
Scenario 9	-1	0	2	Ecological modelling suggest more water in the system relative to the baseline generating benefits to fisheries and aquatic animals and thusly positive wellbeing outcomes.

4.10 Econ1: Project capital costs

This criterion compares the capital costs per ML of water saved across the different scenarios, measured against benchmarks of what could be considered "high", "medium" and "low" capital costs.

Assessment approach

The assessment is informed by capital cost estimations provided by Advance Survey Design to Sequana for each MCA scenario. The estimated capital costs have been divided by the amount of water savings per scenario (ML saved from loss savings and the retirement of entitlements).

The capital costs that have been used for the assessment include infrastructure costs, planning and design costs, costs associated with entitlement purchases, and farm reconfiguration costs. The assumptions underpinning the estimations of capital costs for each scenario, as well as estimations of water savings, can be found in the feasibility report.

Upper and lower bound values have been assessed by applying a 20 percent variation to costs, i.e. the lower bound capital costs are 20 percent lower than the 'best guess' and the upper bound capital costs are 20 percent higher than the 'best guess'.

Assessment scale

The capital costs per ML of water saved have been assessed against the following scale:

- Low capital costs: $0 – $10,000 per ML saved
- Medium capital costs: $10,001 – $20,000 per ML saved
- High capital costs: Over $20,000 per ML saved

The ranges for the assessment scale have been provided by Sequana. For the purpose of scoring the MCA scenarios, these ranges have been split up into a 5-point scale, as shown in Table 40.

Table 40 Assessment scale for project capital costs

Score	0	-1	-2	-3	-4	-5
Assessment	No change	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	High (negative)
Project capital cost assessment guideline	No change in capital costs per ML saved compared to do nothing scenario	$0-$5000 per ML saved	$5001-$10,000 per ML saved	$10,001-$15,000 per ML saved	$15,001-$20,000	More than $20,000 per ML saved

Assessment results

Table 41 shows the capital costs, water savings and the resulting cost-effectiveness for each scenario. These values represent the 'best guess'. In Table 42, each scenario has been scored according to the assessment scale shown in Table 40.

Table 41 Capital cost – estimation of cost-effectiveness (best guess)

	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Capital costs ($)	$59,105,688	$32,947,078	$12,550,576	$4,705,392	$37,705,682	$952,000	$81,896,380	$108,233,108
Water saved (ML)	19,001	3,814	6,038	107	8,091	24	14,689	16,346
Cost-effectiveness ($/ML)	$3,111	$8,638	$2,079	$43,976	$4,660	$39,667	$5,575	$6,621

Table 42 Project capital cost assessment results

Scenario	Project Cost Assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 2	-1	-1	-1	Each option has been assessed against the assessment scale in Table 41, with scoring applied according to the estimated $/ML saved.
Scenario 3	-2	-2	-3	As above
Scenario 4	-1	-1	-1	As above
Scenario 5	-5	-5	-5	As above
Scenario 6	-1	-1	-2	As above
Scenario 7	-5	-5	-5	As above
Scenario 8	-1	-2	-2	As above
Scenario 9	-2	-2	-2	As above

4.11Econ2: Project operating and maintenance costs

The purpose of this criteria is to compare the operating and maintenance costs per ML of water saved across the different scenarios, measured against benchmarks of what could be considered “high”, “medium” and “low” levels of operating and maintenance costs.

Assessment approach

The assessment is informed by operating and maintenance cost estimations provided by Advance Survey Design to Sequana for each MCA scenario. The estimated costs have been divided by the amount of water savings per scenario (ML saved from loss savings and the retirement of entitlements). The assumptions underpinning the estimations of operating and maintenance costs for each scenario, as well as estimations of water savings, can be found in the feasibility report. To align with the values used to assess what levels represent ‘high’, ‘medium’ and ‘low’ costs, the operating and maintenance costs for each scenario have been estimated in present value terms based on a 50-year cash flow and a discount rate of 4.5 percent.

Upper and lower bound values have been assessed by applying a 20 percent variation to costs, i.e. the lower bound costs are 20 percent lower than the 'best guess' and the upper bound costs are 20 percent higher than the 'best guess'.

Assessment scale

The present value of operating and maintenance costs per ML of water saved have been assessed against the following scale:

- Low costs: $0 – $1,300 per ML saved
- Medium capital costs: $1,301 – $4,500 per ML saved
- High capital costs: Over $4,500 per ML saved

The ranges for the assessment scale have been provided by Sequana and are defined as operations, maintenance and replacement cost per ML of water savings for a typical type of water savings irrigation district infrastructure works. The costs are calculated over a 50-year period cash flow and discounted to present value terms using a discount rate of 4.5 percent.

For the purpose of scoring the MCA scenarios, these ranges have been split up into a 5-point scale, as shown in Table 43 below.

Table 43 Assessment scale for project operating and maintenance costs

Score	0	-1	-2	-3	-4	-5
Assessment	No change	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	High (negative)
Project capital cost assessment guideline	No change in capital costs per ML saved compared to do nothing scenario	$0-$650 per ML saved	$651-$1,300 per ML saved	$1,301-$2,900 per ML saved	$2,901-$4,500	More than $4,500 per ML saved

Assessment results

Table 44 shows the 'likely' operating and maintenance costs, water savings and the resulting cost-effectiveness for each scenario. In Table 44, each scenario has been scored according to the assessment scale shown in Table 43.

Table 44 Operating and maintenance cost – estimation of cost-effectiveness (best guess)

	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Operating and maintenance costs ($)	$0	$1,398,561	$2,085,125	$1,712,583	$0	$0	$5,196,269	$6,856,148
Water saved (ML)	19,032	3,814	6,038	107	5,907	24	14,689	11065
Cost-effectiveness ($/ML)	$0	$367	$345	$16,005	$0	$0	$354	$620

Table 45 Project operating and maintenance cost assessment results

Scenario	Project Cost Assessment Lower bound	Likely	Upper bound	Justification
Scenario 2	0	0	0	Each option has been assessed against the assessment scale in Table 43, with scoring applied according to the estimated $/ML saved.
Scenario 3	-1	-1	-1	As above
Scenario 4	-1	-1	-1	As above
Scenario 5	-5	-5	-5	As above
Scenario 6	0	0	0	As above
Scenario 7	0	0	0	As above
Scenario 8	-1	-1	-1	As above
Scenario 9	-1	-1	-1	As above

4.12 Econ3: Productivity gain from change to reliability of supply

This criterion assesses the possible change in productivity related to the change in water use in the catchment.

Assessment approach

A range of agricultural practices are utilised within the Broken system, with livestock, cropping and dairy enterprises accounting for the majority of water use. The reconfiguration scenarios could affect agricultural production in the area, through changes to the reliability of water supply.

As identified in the Broken System Review 2020-2022, climate change is intensifying the impacts to this annual system, increasing variability between years, and decreasing volumes of inflows in the catchment. System users have reported low confidence to invest in irrigation infrastructure due to annual variability, uncertainty, and timing of allocations.

For this analysis, it was assumed that irrigators under the do nothing scenario would be unable to maintain the current level of production into the future, while the reconfiguration options would increase the reliability of the system and thereby help avoid this reduction in production.

The change in agricultural productivity relative to the do nothing scenario was estimated over a 30-year period and discounted to present value using a discount rate of 7%. The key components of this calculation included:

- the avoided loss of production from higher reliability (measured by change in gross margins), and
- the opportunity cost of dryland cropping, which partly offsets the value of avoided loss of production.

These two components are explained in more detail below.

Avoided loss of production

In the base case, it was assumed that enterprises would use more of their land for dryland cropping rather than irrigated land use as a result of lower water availability. Under the reconfiguration scenarios, some of that conversion to lower value dryland use was assumed to be avoided due to higher reliability of water supply.

First, the value of agricultural production under the **do nothing scenario** was calculated using the following method:

- Customer data on water use was collated for each land use type (horticulture, cropping, cattle, dairy, sheep and D&S) for each zone. The water use for the base case was calculated as the average annual use over the past 5 years, from 2018/19 to 2022/23.
- For each commodity type, water volumes were converted to a total irrigated area using the water consumption rates (ML/ha) given in Table 46. For example, if the current water use for cropping in a certain zone is 300 ML per year, then, using the water consumption rate for cropping of 2 ML per hectare, the irrigated area (ha) of cropping would be estimated to 150 ha.
- Gross margins for the respective commodities (shown in Table 47) were then applied to the estimated total irrigated areas to determine the estimated total gross margin for each commodity in each zone, as an approximation of the current value of agricultural production under the base case.

Then, the relative increase in total gross margins for **each scenario**, resulting from avoided loss in irrigated area, was estimated as follows:

- The relative increase in reliability for each scenario, compared to the do nothing scenario, was used to estimate an associated avoided loss in water use, irrigated area, and gross margin.
- The productivity change was calculated as the difference between the estimated total gross margin in the base case and each scenario.

System reliability is expressed as the number of years out of 100 where users can expect to receive 100% allocation against their High Reliability Water Shares (HRWS). The reliability estimates for HRWS and LRWS from modelling and estimations performed by HARC and Alluvium Consulting are shown in Table 48. The reliability of Goulburn system HRWS was used for scenarios 3 and 4, where some customers are reconnected to the Goulburn system.

Table 46 Water consumption rates by commodity type

Commodity	Stocking rate (head/ha)	Water consumption (ML/head)	Water consumption (ML/ha)
Horticulture	N/A	N/A	7.6
Cropping (wheat)	N/A	N/A	2
D&S	N/A	N/A	0.029
Cattle	1.54	0.024	0.037
Sheep	11.20	0.003	0.029
Dairy	1.54	0.042	2.80

*Note: Dairy water consumption (ML/ha) includes allowance for irrigating pastures.

Table 47 Gross margin by commodity type

Commodity	Gross margin ($/ha)
Horticulture	$6,766
Cropping (wheat)	$971
D&S	$603
Cattle	$940
Sheep	$603
Dairy	$2,270

Table 48 Estimated reliability

Commodity	Gross margin ($/ha)	
Reliability (%)	HRWS	LRWS
Scenario 1 (Do Nothing)	84.0	77.9
Scenario 2	90.1	87.0
Scenario 3	85.5	82.4
Scenario 4	85.5	82.4
Scenario 6	85.5	82.4
Scenario 7	83.2	77.9
Scenario 8	89.3	86.3
Scenario 9	93.1	90.8

Opportunity costs

Opportunity costs can be thought of as the value of the alternative lost when another alternative is chosen. In this case, it was assumed that – through higher reliability in the reconfiguration scenarios - agricultural enterprises would avoid the need to scale down operations. Assuming the alternative to irrigated agriculture is dryland cropping, the value of avoided production loss is partly offset by the value of dryland cropping. D&S landholders are not ''commercial'' in nature and idle land was not assumed to be converted to dryland cropping for these users.

In scenarios 3 and 4, some irrigators are assumed to be reconnected to the Goulburn system. This entails the purchase of Goulburn HRWS. It was assumed that those selling entitlement from the Goulburn system currently use water for low value cropping, and was used to represent the opportunity cost of the sale of those water shares.

Assessment scale

The values for productivity change have been normalised on a scale from -5 to 5, with the scenario with the largest reduction in productivity receiving a score of -5 and the scenario with the largest increase in productivity receiving a score of 5.

Upper and lower bound values have been assessed by applying a 20 percent variation to productivity gains or losses, i.e. the lower bound values are 20 percent lower than the 'best guess' and the upper bound values are 20 percent higher than the 'best guess'.

Table 49 Productivity gain assessment scale

Score	-5	-4	-3	-2	-1	0	1	2	3	4	5
Assessment	High (negative)	Medium/High (negative)	Medium (negative)	Low/Medium (negative)	Low (negative)	Neutral	Low (positive)	Low/Medium (positive)	Medium (positive)	Medium/High (positive)	High (positive)
Assessment guideline (normalised value between 0 and 1)	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1

Assessment results

The estimated productivity gains or losses relative to the do nothing scenario are shown in Table 50. The resulting scores are given in Table 51.

Table 50 Productivity gain from change to reliability of supply (likely)

	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Productivity gain/loss relative to Scenario 1 (NPV over 30-year-period, discount rate 7 %)	-$200,572,431	$11,991,456	$5,765,316	$3,696,491	$3,327,038	$6,882,976	$22,665,590	$30,425,640
Normalised value	0.00	0.92	0.89	0.88	0.88	0.90	0.97	1.00

Table 51 Productivity gain assessment results

Scenario	Project Cost Assessment			Justification
	Lower bound	Likely	Upper bound	
Scenario 2	-5	-5	-5	Each option has been assessed against the assessment scale in Table 49.
Scenario 3	4	4	4	As above
Scenario 4	4	4	4	As above
Scenario 5	4	4	4	As above
Scenario 6	4	4	4	As above
Scenario 7	4	4	4	As above
Scenario 8	5	5	5	As above
Scenario 9	5	5	5	As above

5 MCA analysis process

5.1 Category Weightings

As part of an MCA assessment, weightings are given to each category to represent its importance to the decision-making process. Given this project is a feasibility study with limited engagement with the broader community there was little guidance on the level of importance the community would place on one category over another. Therefore it was considered appropriate to apply equal weightings of 20% each to the categories related to the environmental, social and economic categories, as these are direct impacts of the scenarios. The robustness to future uncertainty and risk categories have been given a combined weighting of 15% as the key assumptions within these categories are less certain. For example the increase in demand to SDL level of demand would require significant increase to the water use in the catchment.

Category	Weighting	Reason for adoption
Project objectives	25%	Main drivers for the project
Robustness to future uncertainty	12.5%	Important future consideration, however, the extent of the uncertainty has been assumed and may not play out according to those assumptions. Therefore the category has been given a moderate weighting.
Risk	2.5%	This category is a scan of risks on a feasibility level project. There are still opportunities to mitigate this risk as the project progresses and therefore it was given a low weighting.
Environmental	20.0%	Environmental, social and economic criteria were given equal weightings as there was not enough broader community engagement in the feasibility study to determine which category the community would value more.
Social	20.0%	
Economic	20.0%	
Total	**100%**	

5.2 Criteria weightings

Weightings are assigned to the criteria to allow for differences in the relative importance of each criterion within a category. The details of the criteria weighting for the MCA assessment are shown in Table 52

Table 52 Criteria weightings

Category	Criteria #	Criteria	Weighting	Proportion of Category	Reason for weighting
Project objectives	PO.1	Reliability of water supply for HRWS	15%	60%	HRWS are more important to water security than LRWS so weighted higher
	PO.2	Reliability of water supply for LRWS	10%	40%	
Robustness to future uncertainty	Rob.1	Delivers value under a range of scenarios (climate change)	6%	50%	Equal weighting adopted
	Rob.2	Delivers value under a range of future water use (demand) scenarios	6%	50%	
Risk	Ris.1	Risk of unintended consequences	3%	100%	n/a
Environmental	Env.1	Support of existing ecological function	16%	80%	Env1 weighted higher because impacts are experienced under current conditions.
	Env.2	Support of existing environmental values under high climate change projection	4%	20%	
Social	Soc.1	Change to recreational / amenity / social connection outcomes	10%	50%	Equally weighted to reflect equal importance of both criteria
	Soc.2	Wellbeing / social cohesion measure of increased certainty for community	10%	50%	
Economic	Eco.1	Project capital cost	7%	33%	Equally weighted to reflect the equal importance of all criteria
	Eco.2	Economic benefit of change to reliability of water supply	7%	33%	
	Eco.3	Project operating and maintenance cost	7%	33%	

6 MCA results

6.1 How the net option score is calculated

The results of the assessment for the criteria and the category and criteria weightings are combined to provide the outcomes of the MCA assessment. Figure 3 illustrates how the weightings for each criterion and category are applied to the assessment score to create an overall option score.

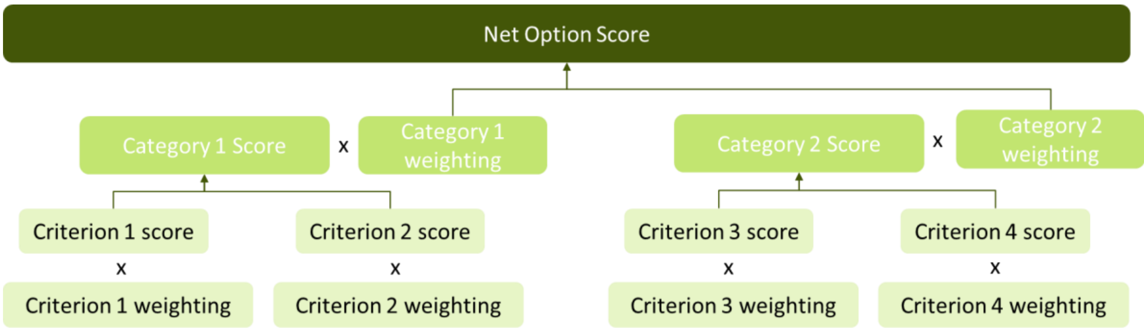

Figure 3 Net option score calculation diagram

As the scores for many of the criteria can range from both positive (benefits) to negative (negative impacts), it is possible for a criterion or category to have a negative score. The Net Option Score is the sum of the weighted category scores.

6.2 MCA assessment results

The net option scores that result from the assessment scoring and weighting detailed in this report are shown in

Figure 4. The score for each category is shown, together with the net score (dashed box).

Overall, three scenarios present net positive outcomes. These three scenarios are:

1. Scenario 9 - The combined option with a net positive score of 1.2
2. Scenario 8 - The combined option with a net positive score of 1.09
3. Scenario 6 - All zone configuration opportunities with a net positive score of 0.91
4. Scenario 2 – Transition out of irrigation with a net positive score of 0.54
5. Scenario 4 – Remove or reconnect zone 3 with a net positive score of 0.20
6. Scenario 7 – Secure access to D&S water with a net positive score of 0.12
7. Scenario 3 – Remove or reconnect all services in Zone 5 with a net positive score of 0.09

The high MCA scores for Scenarios 8 and 9 are driven by strong alignment with the project objectives through the improvement of reliability of supply for water share holders in the system. Although not scored explicitly in the assessment of project objectives, the inclusion of a greater security D&S product also aligns strongly with the project objectives, and enjoys strong support from the community which is reflected in the high social wellbeing scores of these two options. These scenarios are further enhanced by positive economic scores being driven by more reliable water access to support irrigated agriculture.

The positive results for Scenario 6 and Scenario 2 are driven by strong positive environmental outcomes, however for Scenario 2, the net score is reduced by the significant economic impact associated with lost productivity resulting from removing irrigated agriculture from the region. Scenario 6 scores better on the economic and social criteria as it assumes water shares will be recovered from people who are not using them, whilst providing improved reliability for individuals who wish to continue irrigated agriculture. This is reflected in positive economic score for this scenario.

Scenario 7 achieves a small positive outcome through small benefits for each of the project objective criteria, and the wellbeing benefit associated with more security of critical water supplies.

Scenarios 3 and 4 as stand alone options do not provide an improvement in the reliability of supply for water share users under average conditions, and therefore receive neutral or '0' scores against the project objective criteria. They do perform better in the robustness to future uncertainty category, as a reduction in demand on the system is a benefit under future climate change scenarios. Both scenarios also result in positive economic scores resulting from increased productivity due to the more reliable access to water.

The scenarios that received negative net scores are:

1. Scenario 5 – Mokoan pipeline supply channel efficiencies with a net negative score of -0.49

The economic criteria were the drivers for net negative scores for each Scenario 5 - Mokoan Pipeline supply channel efficiency improvements option. The high cost of this option relative to the water saved is a major challenge for this option. There were no substantial benefits of this option for project objectives or robustness (driven by reliability of supply under various scenarios), or environmental benefits that were identified for this option.

It is important to remember that an MCA is a decision support tool, not a decision-making tool. It is useful for comparing a group of criteria that do not have common metrics. The results may change depending on the assumptions that are made through the assessment process, the scoring process and the weighting applied to each category and criterion. To understand the impact of the assumptions on the outcome of this assessment, sensitivity analysis on the results was completed and the results are presented in Section 7.

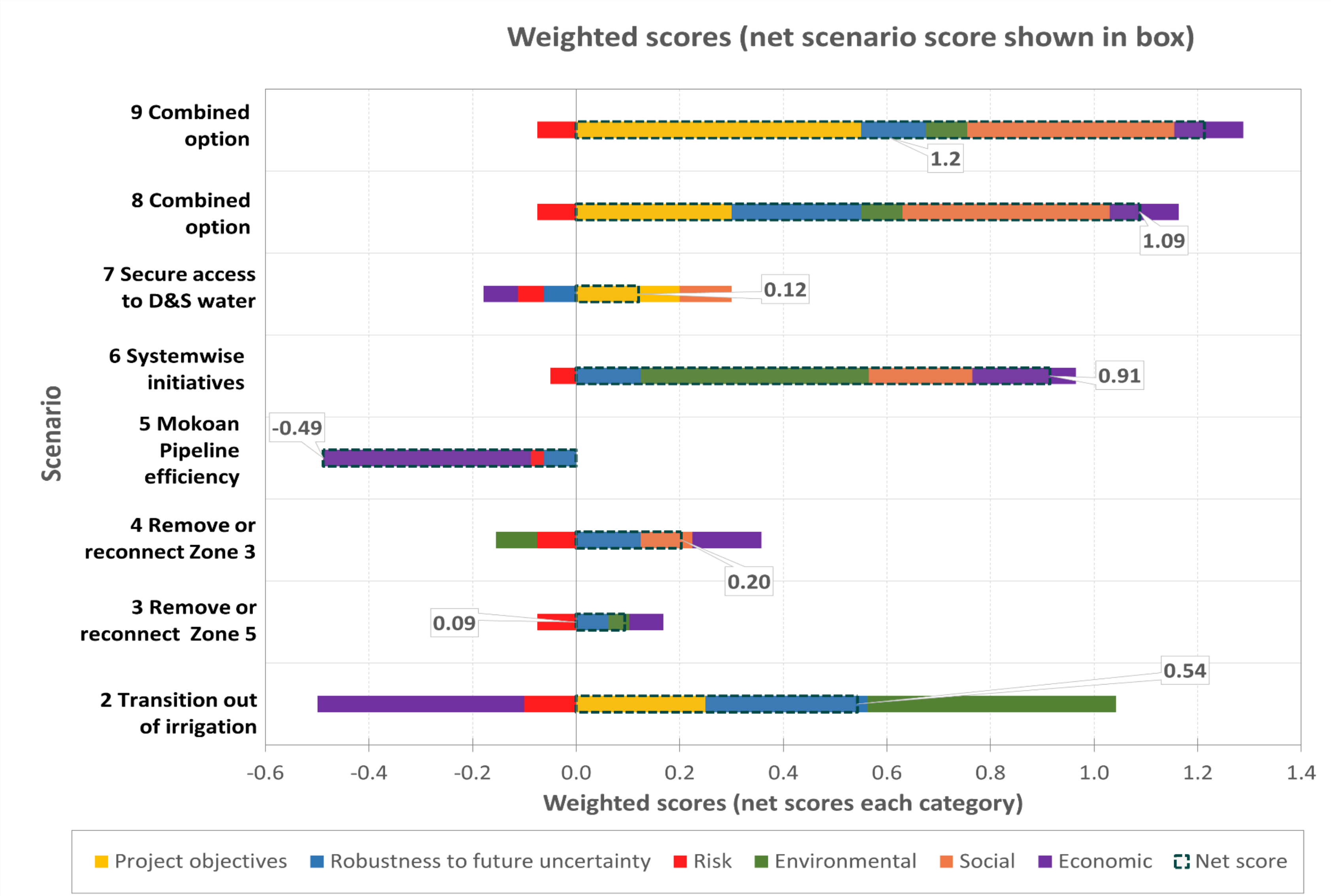

Figure 4 MCA weighted net scores

7 Sensitivity analysis

To understand the sensitivity of the MCA results to the assumptions and judgements made as part of the scoring process, we undertook an analysis of how the results would change if we ran them based on the 'Lower Bound' assessment score, and the 'Upper Bound' assessment scores. The results of these assessments are shown in Figure 5 and Figure 6. The outcomes of this sensitivity testing results in a large change the net scores, with all scenarios showing a net positive (albeit a weak one for Scenario 5) when the upper bound assessment scores are used. When the lower bound is used, all options except Scenarios 2 and 6, record net negative results.

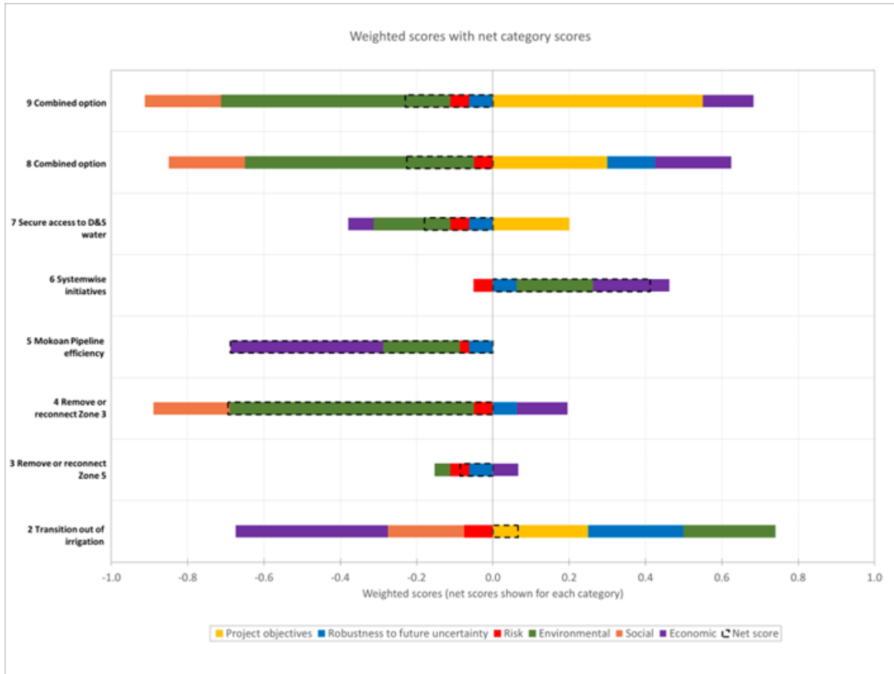

Figure 5 MCA scores using lower bound assessment scoring

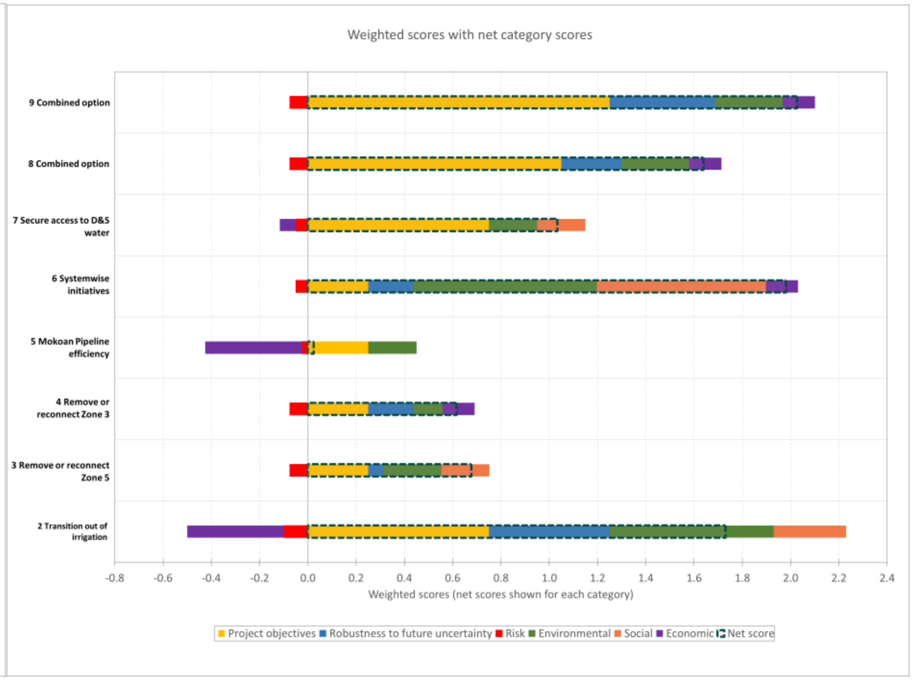

Figure 6 MCA scores using upper bound assessment scoring

The highly sensitive nature of the MCA results suggests that further investigation of all of the options in the cost benefit assessment phase is warranted.

8 References

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Attachment	Preliminary Option Assessment Results
Attachment No.	2
Author	Sequana

Broken System Reconfiguration Feasibility Study

Option assessment framework

Overview

The Broken Reconfiguration Feasibility Study is assessing the potential opportunities for strategic reconfiguration of Broken River system operation and water usage to best meet the long-term needs and aspirations of water entitlement holders and other key stakeholders.

A set of option assessment criteria have been developed and endorsed by the Consultative Committee.

This option assessment framework sets out the draft rubric that will be used for the preliminary option assessment phase.

The objective for the preliminary option assessment phase is to narrow down the full options list to a short list for further, more detailed development, analysis and assessment. It is expected that the assessment rubric will also be further developed in order to provide a more relevant or specific assessments as the level of information available on the short listed options is improved.

Assessment rubric

No.	Criteria	Assessment Scale	Details
1	**Sustainable irrigation sector future**: Does the option offer a pathway to support productive irrigated agriculture	3 point scale Negative, Neutral, Positive	The assessment will compare the outcomes expected to be achieved under the option to the base case option, which is the future trajectory for this issue under the current water management settings. Where there is some change but it is very small or negligible, a Neutral rating will be assigned. The key factors that have informed the assessment should be captured in the comments field in the option assessment document.
2	**D&S Supplies**: Is the options capable of providing for secure, year-round access to water for D&S and urban needs	3 point scale Negative, Neutral, Positive	The assessment will compare the outcomes expected to be achieved under the option to the base case option, which is the future trajectory for this issue under the current water management settings. Where there is some change but it is very small or negligible, a Neutral rating will be assigned. The key factors that have informed the assessment should be captured in the comments field in the option assessment document.
3	**Environmental values**: To what extent does the option protect or enhance the environmental values of the Broken River system	3 point scale Negative, Neutral, Positive	The assessment will compare the outcomes expected to be achieved under the option to the base case option, which is the future trajectory for this issue under the current water management settings. Where there is some change but it is very small or negligible, a Neutral rating will be assigned. The key factors that have informed the assessment should be captured in the comments field in the option assessment document.
4	**Social**: Does the option support social values, including recreational fishing and passive enjoyment of the river system?	3 point scale Negative, Neutral, Positive	The assessment will compare the outcomes expected to be achieved under the option to the base case option, which is the future trajectory for this issue under the current water management settings. Where there is some change but it is very small or negligible, a Neutral rating will be assigned. The key factors that have informed the assessment should be captured in the comments field in the option assessment document.
5	**Cultural**: Does the option support Traditional Owner cultural values and self-determination?	3 point scale Negative, Neutral, Positive	The assessment will compare the outcomes expected to be achieved under the option to the base case option, which is the future trajectory for this issue under the current water management settings. Where there is some change but it is very small or negligible, a Neutral rating will be

No.	Criteria	Assessment Scale	Details
			assigned. The key factors that have informed the assessment should be captured in the comments field in the option assessment document.
6	**Robustness**: Is the option robust, adaptable and capable delivering benefits under potential future climate change?	3 point scale Negative, Neutral, Positive	The assessment will compare the outcomes expected to be achieved under the option to the base case option, which is the future trajectory for this issue under the current water management settings. Where there is some change compared to the base case but it is very small or negligible, a Neutral rating will be assigned. The key factors that have informed the assessment should be captured in the comments field in the option assessment document. A confidence rating for the assessment (high, medium or low) should also be noted in in the comments field, together with brief notes on suggested further analysis to improve the confidence rating if required.
7	**Risks**: What is the ability of each option to mitigate and manage major risk issues that could limit or prevent achievement of success criteria?	3 point scale High, Medium, Low	The assessment will be based on the expected residual risk to achievement of the success criteria, after application of feasible mitigation measures. The criterion subject to the risk should be noted in the comments field, and a description provided of the mitigations assumed to be applied if these are not already included in the option description.
8	**Value for Money**: Is the option affordable and represents value for money to project funders and to water users, and expected to be able to attract the necessary funding?	3 point scale High, Medium, Low	The assessment will be based on informed judgement and comparators such as levelized cost per ML of water saving etc. where these are relevant and available. The comments field should include the sub-assessments of value for money from a water user perspective and a government funder perspective. The lowest of these ratings shod be adopted as the overall rating for the criterion. The assessors should also include any suggested changes to the options that have been identified that may improve the value for money rating.
9	**Community Acceptance**: Is the option consistent with stakeholder aspirations and likely to achieve support from the community?	3 point scale Unacceptable, Neutral, Acceptable	The assessment will rely on informed judgement based on community feedback to date and earlier surveys and reviews, and will be subject to further input from the Consultative Committee. The assessment should consider likely community acceptability from the perspective of an informed, "reasonable person" community member. The key factors that have informed the assessment should be captured in the comments field in the option assessment document, including any particular aspects of the option that are likely to be considered unacceptable by the majority of stakeholders.
10	**Regulatory and policy alignment**: Is the option consistent with government strategy and polices, and expected to be able to comply with relevant regulatory provisions (including	3 point scale Not aligned, Partially	Where the option is assessed as requiring only minor changes to existing government policy or legislation that are considered to have a high likelihood of receiving support, an

No.	Criteria	Assessment Scale	Details
	water legislation and planning approvals etc)	Aligned, Aligned	assessment of Partially Aligned should be allocated to the option. The key factors or considerations that have informed the assessment should be captured in the comments field in the option assessment document, particularly in relation to any Partially Aligned rating.
11	**Impacts and benefits**: Is the distribution of benefits or impacts between the involved parties likely to be judged as fair and reasonable overall.	2 point scale Unacceptable, Acceptable	The assessment will rely on informed judgement and will be subject to further input from the Consultative Committee. The assessment should consider likely community acceptability from the perspective of an informed, "reasonable person" community member. The key factors that have informed the assessment should be captured in the comments field in the option assessment document, including any particular aspects of the impacts or benefits sharing under the option that are likely to be considered unacceptable by the majority of stakeholders. The assessors should also include any suggested changes that have been identified that may improve the acceptability of the option.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	1	**Description:**	Exempt first 2 ML of water use each season for D & S purposes.

Aim:	To provide immediate access to D&S water at the beginning of a new season, regardless of the seasonal allocation.
What's Involved:	The creation of a new entitlement class (Very High Reliability Water Shares). Potentially involves mitigation measures to offset impact, e.g. relinquishing 3ML HRWS to Receive 2ML VHRWS.
Current Information gaps:	Extent of impact on allocation for existing entitlements Government appetite for creating a new entitlement class and setting a precedent for D&S users in other systems.

Assessment Criteria

Option Number: 1 **Description:** Exempt first 2 ML of water use each season for D & S purposes.

Criteria	Initial Rating	Confidence Level	Assessment notes
Sustainable Irrigation Future	Neutral	H	Not aimed at enhancing irrigation opportunity - possible marginal impact in delaying allocation to balance of HRWS
D&S Security	Positive	H	Improves security of access to D&S water
Environmental Values	Neutral	H	No change in impact on environmental values
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Neutral	L	No change in impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Negative	M	Unlikely to be substantially impacted by climate change or other future factors Unclear how this option would cater for future growth in D&S demands

Criteria	Initial Rating	Confidence Level	Assessment notes
Risks	Low	L	Initially assessed as having a reasonable prospect of mitigating risks. Assessment confidence set as low until detailed risk review is available
Value for Money	High	M	Govt funder: Requires modest upfront investment to create new entitlement class, but will not require significant ongoing costs to administer Water user: no cost
Community Acceptance	Acceptable	H	Raised by the committee as an option that would address a major concern within the community. Likely to move to high confidence following community engagement
Regulatory and Policy Compliance	Partially aligned	M	Currently not aligned but may be possible through the creation of a new entitlement class (Note that special classes of Very high reliability exist in Goulburn, and spill reliability in Ovens/King)
Impacts and benefits	Acceptable	L	Negligible impact on system stakeholders. Beneficial for D&S users across the system. Confidence likely to be upgraded following CBA

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Requires further investigation on how this option would work with future greater D & S demand

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	2	**Description:**	Align D & S use with Section 8 conditions. i.e. 24/7 D & S use

Aim:	To provide certainty of D&S supply.
What's Involved:	Legislation change allowing greater D & S security for some users
Current Information gaps:	Impact from further growth in D & S demands

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Assessment Criteria

Option Number: 2 **Description:** Align D & S use with Section 8 conditions. i.e. 24/7 D & S use

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Neutral	H	Not aimed at enhancing irrigation opportunity - possible impact due to uncapped nature of entitlement and future growth effecting entitlements
D&S Security	Positive	H	Improves security of access to D&S water
Environmental Values	Neutral	M	No change in impact on environmental values, growth in use may create additional issues
Social Values	Neutral	M	Unlikely to change the impact on social values, growth in use may change the assessment
Cultural Values	Neutral	L	No change in impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Negative	M	This option would continue to expand with future growth in D&S demands Doesn't provide appropriate signals about development within sustainable resource limits.

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Medium	L	Initially assessed as mitigating some risks however may create additional risks. Assessment confidence set as low until detailed risk review is available
Value for Money	Medium	M	Govt funder: Requires upfront investment for potential legislative change Water user: no cost
Community Acceptance	Unacceptable	L	May create concerns for irrigators with additional delays to water allocation. Would need community testing to increase confidence
Regulatory and Policy Compliance	Not aligned	H	Requires change to legislation and sets an undesirable precedent for other catchments
Impacts and benefits	Unacceptable	H	Offers windfall gain to D&S users at the expense of other existing rights. Increases water use in already stressed system.

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

Not aligned with legislative requirements and unacceptable to community

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	3	**Description:**	D&S Reserve. Utilise Cosgrove System savings

Aim:	To improve the likelihood of D&S being available to users at the beginning of a new season.
What's Involved:	Approximately 400 ML of HRWS from the 830 ML secured through the Cosgrove Project (currently held by GMW) credited to a special reserve.
Current Information gaps:	Modelling/findings from previous investigation will need to be sourced.

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Assessment Criteria

Option Number: 3 **Description:** D&S Reserve. Utilise Cosgrove System savings

Criteria	Initial Rating	Confidence Level	Assessment notes
Sustainable Irrigation Future	Neutral	H	Not aimed at enhancing irrigation opportunity
D&S Security	Positive	H	Improves security of access to D&S water
Environmental Values	Neutral	M	No change in impact on environmental values, may result in marginal impact in transition between wet and dry years
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Neutral	L	No change in impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Neutral	M	Could allow sale of further entitlements based on the savings pool to D & S users to cater for future demands

Criteria	Initial Rating	Confidence Level	Assessment notes
Risks	Low	L	Initially assessed as having a reasonable prospect of mitigating risks. Assessment confidence set as low until detailed risk review is available
Value for Money	High	M	Govt funder: Requires modest upfront investment costs to administer, potential revenue of sale to future D & S users Water user: no cost, potential to buy additional entitlement
Community Acceptance	Acceptable	M	Likely to be well received by community if additional water allocation can be provided without cutting allocation elsewhere. Community engagement will increase confidence
Regulatory and Policy Compliance	Partially aligned	M	Some minor work required to administrate the option
Impacts and benefits	Acceptable	L	Negligible impact on system stakeholders. Beneficial for D&S users across the system. Confidence likely to be upgraded following CBA

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Shortlisted for detailed review, drawing on previous investigations

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	4
Description:	Explore options for increasing groundwater access for D&S
Aim:	To enhance security of access to D&S water for properties near a groundwater source.
What's Involved:	Licensing and installation of groundwater bores to supplement D&S supply.
Current Information gaps:	Available quantity and quality of groundwater in the project footprint. Customer appetite for investing in new on-farm infrastructure.

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Assessment Criteria

Option Number: 4 **Description:** Explore options for increasing groundwater access for D&S

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Neutral	M	Not aimed at enhancing irrigation opportunity. Confidence can be improved through analysis of hydrological impacts on stream flows
D&S Security	Positive	M	Improves security of access to D&S water. Dependant on access to suitable quality ground water. May not be suitable for all D & S users
Environmental Values	Negative	L	Drawing water may have an impact on something. Will need to investigate further to gain greater confidence
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Negative	L	Could have an impact on culturally sensitive sites. Likely aligned with any environmental impacts. Low confidence assigned until TO advice is received
Robustness	Positive	M	If available groundwater will generally remain more available under climate change conditions. Far less impacts than on surface water

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Medium	L	High risk that suitable ground water is not available for all users and thus it would be unlikely to achieve all outcomes
Value for Money	Medium	M	Govt funder: Value for money could be improved with strategic purchases and subsidiary considerations Water user: Customers would need to front the initial costs to install equipment, this could be improved by government assistance
Community Acceptance	Acceptable	M	Unlikely to have opposition as an existing common practise however may be limited
Regulatory and Policy Compliance	Aligned	H	Provisions exist in current Water Act
Impacts and benefits	Acceptable	L	Outcomes are desirable however may have limited application and only beneficial for limited customers

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Option needs further investigation to determine suitability for all customers. The outcome of this option is subject to the suitability of both quality and quantity

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	5	**Description:**	Connection to alternate D & S schemes

Aim:

To provide a more reliable D&S supply source for customers in close proximity to existing piped networks.

What's Involved:

Extensions to the existing pipelines, with tapping points for reconnected Broken System users.

Connecting properties will need to install complimentary on-farm infrastructure in line with the Tungamah terms of use, including tank storage.

Purchase of Goulburn 1A entitlement.

Current Information gaps:

Available capacity in the exististing systems.

Property owner willingness to connect (up front costs + higher ongoing fees).

The cost of connecting new properties.

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Assessment Criteria

Option Number: 5 **Description:** Connection to alternate D & S schemes

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Neutral	H	Not aimed at enhancing irrigation opportunity
D&S Security	Positive	H	Improves security of access to D&S water for relevant customers
Environmental Values	Neutral	M	Does not change the flow regime in the system
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Neutral	L	Unlikely to impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Positive	M	Improve reliability and negate impact of future changes for the relevant customers

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Low	M	No major risks identified, using existing and proven technology
Value for Money	Medium	M	Govt: No savings however existing government programs designed for building drought resilience User: Requires upfront investment and will also require customers to pay the costs as per the alternate service. Value for money dependant on costs
Community Acceptance	Acceptable	M	As per previous criteria, community would need to accept the alternate sources conditions and costs
Regulatory and Policy Compliance	Aligned	H	Existing provisions already available. May have some concerns on development in disturbed land
Impacts and benefits	Acceptable	M	Some impact on system stakeholders. Beneficial for D&S users across the system.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

The option needs further investigation to determine suitability for customers, it will likely only benefit some customers close to alternate sources

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**6**	**Description:**	D & S scheme with local off stream storage

Aim:

To create a more secure means of suppplying D&S water through a new pipe network.

What's Involved:

Construction of dam for storage as well as a pump station and pipeline for the delivery of water to D & S users.

Current Information gaps:

Property owner willingness to pay the up front costs required to construct infrastructure.

The overall cost of connection including the cost to connect additional new properties.

The impact of geophysical limitations, e.g. rocky ground, high ground, etc.

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Assessment Criteria

Option Number: 6 **Description:** D & S scheme with local off stream storage

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Neutral	M	Not aimed at enhancing irrigation opportunity
D&S Security	Positive	H	Improves security of access to D&S water for relevant customers however customers will lose 2 ML to gain very 1 ML
Environmental Values	Neutral	M	Does not change the flow regime in the system
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Neutral	L	Construction may have an impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Positive	M	Improve reliability and negate impact of future changes for the relevant customers

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Medium	M	Construction risks with pipeline, pump station and storage to be built
Value for Money	Low	M	Govt: No savings however existing government programs designed for building drought resilience User: Requires significant upfront investment, pump station and storage would be an expensive construction
Community Acceptance	Neutral	M	Community would need to accept the construction costs and also accept losing '2 for 1' ML for the added reliability
Regulatory and Policy Compliance	Partially aligned	M	Existing provisions already available. May have some concerns on development in disturbed land. may be challenges in getting regulatory approval
Impacts and benefits	Unacceptable	M	The high construction costs will outweigh the positive impacts

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

Far too costly, not a viable option

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	7	**Description:**	Access to/ Enhance the Winton Wetlands as a storage for Mokoan Pipeline supply
Aim:	To reduce or suppliment a portion of the Broken demand by using Winton Wetlands as an alternate water source		
What's Involved:	Utilising water held in Winton Wetlands to service property owners on the Mokoan Pipeline (additional storage and a reduction in demand on the Broken system). Possible alterations to the wetlands sill to optimise water retention. A reversal of environmental restoration works by reintroducing a form of artifical retention.		
Current Information gaps:	Potential impact on environmental outcomes and water quality in Winton Wetlands. Traditional Owner views on the suggested changes to what is known to be a culturally significant place.		

Victoria State Government — Energy, Environment and Climate Action | Goulburn-Murray WATER

Assessment Criteria

Option Number: 7 **Description:** Access to/ Enhance the Winton Wetlands as a storage for Mokoan Pipeline supply

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	M	Benefits may be limited due to water quality issues in Winton Wetlands
D&S Security	Positive	M	Benefits may be limited due to water quality issues in Winton Wetlands
Environmental Values	Negative	M	Impact on the ecological values of the wetland as well as the river downstream
Social Values	Negative	L	Altering the character of a wetland may have a negative impact on local residents
Cultural Values	Negative	L	Likely cultural values associated with the wetland. Low confidence assigned until TO advice is received
Robustness	Negative	M	Storages likely to be associated with an increase to evaporative losses in dry years. Will be negatively effected by climate chance implications

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	High	M	Introducing wider risks including environmental, social and cultural impacts
Value for Money	Low	M	Devaluing prior investment already involved with the environmental restoration efforts. Significant costs for design, approvals and construction of infrastructure in wetland setting.
Community Acceptance	Unacceptable	M	Some community may be happy with re-instating storage however this will be low volume and not the same as previous Mokoan storage. Much more likely to attract community opposition with the environmental impacts
Regulatory and Policy Compliance	Not aligned	H	Would require a significant reversal of recent decision making in government policy
Impacts and benefits	Unacceptable	M	The potential negative impacts created will outweigh the marginal positive impacts

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

Not a viable solution as major impacts on environmental and social

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	8	**Description:**	Managed Aquifer Recharge

Aim:

To reduce or suppliment a portion of the Broken demand by using an alternate water source.
To add reliability through water storage, reducing the effects of climate change implications

What's Involved:

Utilising MAR as a water management method.

Seek oppurtunities for funding through testing programs being conducted nearby

Current Information gaps:

Available quantity and quality of groundwater in the project footprint.

Customer appetite for investing in new on-farm infrastructure.

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Assessment Criteria

Option Number: 8 **Description:** Managed Aquifer Recharge

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	L	If successful would be beneficial however confidence in low due limitations of aquifer suitability and water quality issues
D&S Security	Positive	L	Improves security of access to D&S water. Dependant on access to suitable quality ground water. May not be suitable for all D & S users
Environmental Values	Negative	L	Whilst MAR can support water availability and quality it can also have an impact on water quality and local ecosystems depending on the method of recharge.
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Negative	L	Could have an impact on culturally sensitive sites. Likely aligned with any environmental impacts. Low confidence assigned until TO advice is received
Robustness	Positive	L	If available groundwater will generally remain more available under climate change conditions. Far less impacts than on surface water

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	High	M	High level of uncertainty regarding suitability of MAR. Would require detailed assessment and analysis beyond the scope of this project to determine feasibility.
Value for Money	Medium	L	Would likely require extensive investigation and assessment (including environmental assessments). Would also incur a cost of developing infrastructure and management rules.
Community Acceptance	Acceptable	L	Subject to the outcome of the assessment. Would need to demonstrate that there would be no adverse impacts from MAR.
Regulatory and Policy Compliance	Partially aligned	M	MAR is a practice utilised through the world - however is not currently practiced in Northern Victoria. Specific licensing and operations rules would be required.
Impacts and benefits	Unacceptable	H	The benefits of MAR are not applicable in this area as much of the area will provide high salinity ground water and is also unconfined. There is uncertainty regarding the suitability of the aquifer in this location as the losses would be significant.

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

The option offers a desirable solution in theory. However, expert advice confirmed the solution is not viable in this area due to unfavourable aquifer conditions. In the upper reaches of the project area the bedrock aquifers are not confined and can't retain water for future extraction. In the lower reaches the sedimentary plains are highly saline in all but the areas surrounding and connected to the river.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	9	**Description:**	East bound irrigation pipeline from East Goulburn Main

Aim:

To reduce a portion of the Broken demand by using an alternate irrigation water source

Provide greater irrigation reliability to a portion of the system irrigators

What's Involved:

Construction of a pipeline from the East Goulburn Main channel.

Customers would need to follow the rules and regulations of the Goulburn system

Current Information gaps:

Cost of Pipeline

Number of customers accepting of system change

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Assessment Criteria

Option Number: 9 **Description:** East bound irrigation pipeline from East Goulburn Main

Criteria	Initial Rating	Confidence Level	Assessment notes
Sustainable Irrigation Future	Positive	H	Would provide access to Goulburn system - which offers increased reliability and greater management options (e.g. carryover rules).
D&S Security	Positive	H	Would provide access to Goulburn system - which offers increased reliability and greater management options (e.g. carryover rules).
Environmental Values	Neutral	M	Would require Environmental assessment to ensure there are no adverse environmental impacts as a result of pipeline construction.
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Negative	L	Could have an impact on culturally sensitive sites. Likely aligned with any environmental impacts. Low confidence assigned until TO advice is received
Robustness	Positive	M	Improve reliability and negate impact of future changes for the relevant customers

Criteria	Initial Rating	Confidence Level	Assessment notes
Risks	Medium	M	Construction risks with pipeline and pump station to be built.
Value for Money	Medium	L	Has the potential to be a high cost - however will depend on the length and size of the pipeline.
Community Acceptance	Acceptable	H	Utilised extensively as a solution throughout neighbouring reconfiguration projects.
Regulatory and Policy Compliance	Aligned	H	Utilised extensively as a solution throughout neighbouring reconfiguration projects. Water Act support both privately owned solutions or Water Corp owned infrastructure.
Impacts and benefits	Acceptable	H	Offers reliability benefits for customers albeit will likely be limited to a specific region given the associated construction costs.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Offers a solution that provides increased reliability, albeit likely to a limited numbers of customers. Key component of feasibility will be the cost associated with construction.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**10**	**Description:**	Pipeline from other regulated systems (e.g. Eildon or Ovens) into the Broken, upstream of Lake Nillahcootie

Aim:	To increase the available water in the system improving reliability
What's Involved:	Construction of a pipeline from a nearby regulated system.
Current Information gaps:	Cost of construction Full contruction footprint and potential environmental and cultural impacts

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Assessment Criteria

Option Number: 10 **Description:** Pipeline from other regulated systems (e.g. Eildon or Ovens) into the Broken, upstream of Lake Nillahcootie

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	L	If constructed would offer increased reliability to Broken system customers. Confidence level reflects uncertainty of feasibility.
D&S Security	Positive	L	If constructed would offer increased reliability to Broken system customers. Confidence level reflects uncertainty of feasibility.
Environmental Values	Negative	M	Would require extensive construction activity over a large footprint. May impact environmental values in other systems.
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Negative	L	Could have an impact on culturally sensitive sites. Likely aligned with any environmental impacts. Low confidence assigned until TO advice is received
Robustness	Neutral	L	Other regulated systems may also experience impacts in dry periods - This may impact on the ability to transfer water when it is most required.

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	High	L	Construction risks with pipeline and ability of source systems to transfer water when most required.
Value for Money	Low	M	Cost associated with pipeline construction and associated investigations.
Community Acceptance	Neutral		Likely that there will be opposition if proposed - some support from Broken system customers
Regulatory and Policy Compliance	Partially aligned		Would require changes to current Bulk Entitlements.
Impacts and benefits	Unacceptable		Extensive assessment undertaken historically. Outcomes of this identify costs and source system suitability as key limitations.

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

Whilst providing an option for increased reliability for the Broken System, potentially comes at a very high cost and could impact other systems during dry periods.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**11**	**Description:**	Transfer Broken demand to The Goulburn system for properties inside the SIA

Aim:	To reduce or suppliment a portion of the Broken demand by using an alternate water source Provide greater reliability to a users inside the Shepparton Irrigation Area
What's Involved:	Transfer of customers from Broken System to Goulburn System Construction of required infrastrcture i.e. pipelines and pumps etc
Current Information gaps:	Cost of Pipeline Number of customers accepting of system change

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Assessment Criteria

Option Number: 11 **Description:** Transfer Broken demand to The Goulburn system for properties inside the SIA

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	H	Would provide access to Goulburn system - which offers increased reliability and greater management options (e.g. carryover rules).
D&S Security	Positive	H	Would provide access to Goulburn system - which offers increased reliability and greater management options (e.g. carryover rules).
Environmental Values	Neutral	M	Would require Environmental assessment to ensure there are no adverse environmental impacts as a result of construction activities.
Social Values	Neutral	M	Unlikely to change the impact on social values May be small improvements in social wellbeing associated with confidence in CHWN
Cultural Values	Neutral	L	Unlikely to impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Positive	M	Improve reliability and negate impact of future changes for the relevant customers

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Low	M	Solutions to connect customers to SIA are well tested and understood as a result of the Connections and WEP program.
Value for Money	Medium	L	Has the potential to be a high cost - however will depend on the infrastructure required to facilitate the connection.
Community Acceptance	Acceptable	H	Utilised extensively as a solution throughout neighbouring reconfiguration projects.
Regulatory and Policy Compliance	Aligned	H	Utilised extensively as a solution throughout neighbouring reconfiguration projects. Water Act support both privately owned solutions or Water Corp owned infrastructure.
Impacts and benefits	Acceptable	H	Offers reliability benefits for customers albeit will likely be limited to a specific region given the associated construction costs.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Offers a solution that provides increased reliability, albeit likely to a limited numbers of customers. Key component of feasibility will be the cost associated with connections.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**12**	**Description:**	Create an ability to access unregulated flows in the early season

Aim:	To provide Irrigators the ability to access additional water earlier in the season
What's Involved:	Interaction with VMMS would need to be altered to allow irrigators to access unregulated flows
Current Information gaps:	If water will be available when actually needed for irrigation The potential negative environmental impacts associated with reducing the unregulated flows in the system

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Assessment Criteria

Option Number: 12 **Description:** Create an ability to access unregulated flows in the early season

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	M	Would provide access to additional water - however given proximity to catchment may not be available when required for irrigation.
D&S Security	Neutral	M	No material increase in security of D&S access.
Environmental Values	Negative	L	Will have negative impact on environment if unregulated flows are reduced .
Social Values	Neutral	M	Unlikely to change the impact on social values
Cultural Values	Neutral	L	Unlikely to impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Negative	M	Commitment of unregulated flows to VMMS. Building reliance on unregulated flows is unlikely to support long term system resilience - particularly in climate change scenarios.

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Medium	L	May impact on commitment to VMMS - particularly in climate change scenarios.
Value for Money	High	M	Likely a relatively low cost solution to implement.
Community Acceptance	Neutral	M	Similar product offered in the Ovens system
Regulatory and Policy Compliance	Not aligned	L	Whilst a similar product exists in other systems - Broken system unregulated flows are factored into VMMS.
Impacts and benefits	Unacceptable	L	Interaction with VMMS would need to be resolved. Query whether access to unregulated flows will assist 'system-wide' when required in lower allocation seasons.

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

Not considered a suitable reconfiguration option. May have merit for assessment under Recommendation 1-6.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**13**	**Description:**	Winter fill storage (on farm enhancement)

Aim:

To provide additional water allocation reliability and security for both Irrigation and D & S security

What's Involved:

Constructing on farm dams for individual properties up to the size of their allocation.

The on farm dams would be filled whilst there is allocation available

Current Information gaps:

Costs of Dam construction

The amount of increases losses from damn storage

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Assessment Criteria

Option Number: 13 **Description:** Winter fill storage (on farm enhancement)

Criteria	Initial Rating	Confidence Level	Assessment notes
Sustainable Irrigation Future	Positive	L	May provide additional access to stored water on-farm subject to size of storage.
D&S Security	Positive	L	Would provide on-farm storage for D&S supplies - subject to available space on the individual property.
Environmental Values	Neutral	L	Unlikely to have an impact on the environment - subject to effective management of storage construction.
Social Values	Neutral	M	Unlikely to change the impact on social values
Cultural Values	Neutral	L	Unlikely to impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Neutral	L	Benefits of solution include accessing flows when losses are at their lowest - offset by increased evaporation and seepage from on-farm storages.

Criteria	Initial Rating	Confidence Level	Assessment notes
Risks	Low	L	Relatively low risk solution however may offer limited benefits.
Value for Money	Low	M	Costly on farm enhancements required
Community Acceptance	Neutral	M	As per previous criteria, it is likely the acceptance of on farm enhancements would be low
Regulatory and Policy Compliance	Partially aligned	L	Customers would require allocation to access Winter fill - other unregulated systems have a winter fill product.
Impacts and benefits	Acceptable	M	On-Farm storage is a common practice used by irrigators. Size of storages in order to achieve material benefit will be key factor.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Unlikely to be a stand-alone option however may be a complimentary option in conjunction with other solutions.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**14**	**Description:**	Supported transition to 'dry-land' agriculture.

Aim:	To reduce the demand on the Broken System To enable productive agriculture to continue without the reliance on the full water allocation
What's Involved:	Voluntary change of traditional practises to allow sustainable agriculture to continue without the reliance of water from the system
Current Information gaps:	The costs associated with transitioning from irrigation to dry land farming

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Assessment Criteria

Option Number: 14 **Description:** Supported transition to 'dry-land' agriculture.

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Negative	M	Doesn't support sustainable irrigation however does enable sustainable agriculture in the region. Water usage trends show this is already occurring.
D&S Security	Neutral	M	No impact to D&S security. May offer minor benefits depending on what occurs with entitlements for properties that transition to dry land.
Environmental Values	Neutral	L	Unlikely to have an impact on the environment - subject to effective transition.
Social Values	Neutral	M	Unlikely to change the impact on social values
Cultural Values	Neutral	L	Unlikely to impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Positive	H	Successful transition provides a level of resilience to future climate scenarios - likely to rely on access to secure D&S supplies.

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Low	M	Low risk option - previous reconfiguration projects have transitioned or enhanced existing dryland properties.
Value for Money	Medium	M	Subject to the extent of transitional support offered - however could be effectively managed to maintain value for money - subject to what happens to entitlement.
Community Acceptance	Acceptable	M	Water usage trends show that this practice is organically occurring.
Regulatory and Policy Compliance	Aligned	H	Current regulatory and policy settings do not limit/impact on a transitional arrangement.
Impacts and benefits	Acceptable	M	Low risk voluntary option.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Other reconfiguration projects have offered transitional support in combination with other options. Has proved successful previously.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**15**	**Description:**	Supported Market Correction

Aim:	To assist users utilise existing tools available. To allow users to transfer out their entitlement if not being used and allow users to gain additional allocation if needed
What's Involved:	Users purchasing additional water entitlement so they still have enough allocation in years of 50% allocation. Waiving of fees such as transfer fees or stamp duty etc.
Current Information gaps:	Number of users looking to trade out entitlement

Energy, Environment and Climate Action

Assessment Criteria

Option Number: 15 **Description:** Supported Market Correction

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	M	Would result in entitlement moving to active use.
D&S Security	Positive	M	Some D&S syndicates have adopted an approach already where they hold greater levels of entitlement to manage risk of low allocations.
Environmental Values	Neutral	H	No change in impact on Environmental outcomes
Social Values	Neutral	H	No change in impact on social values.
Cultural Values	Neutral	M	No change in impact on cultural values.
Robustness	Positive	M	Doesn't change overall system reliability or robustness - however may improve individuals resilience. No obligation on entitlement holders to remain active users.

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Medium	M	Low risk in that the mechanisms exist for the transfer to occur - however sets a precedent for supported market correction.
Value for Money	Medium	L	Subject the expectation in regards for support to achieve market correction.
Community Acceptance	Acceptable	M	Would be supported by those obtaining additional entitlement - however may receive negative reaction given extent of individual benefits.
Regulatory and Policy Compliance	Partially aligned	M	Mechanism exists within existing legislation - however desire for support is generally not aligned with Govt position.
Impacts and benefits	Acceptable	M	Benefits exist for individuals who would be supported to obtain additional entitlement. Potentially offers no enduring benefits - depending on what new entitlement holders do in the future.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Option focusses on transfer of entitlement to individuals however does not offer any enduring benefits.

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	16	**Description:**	Water entitlement purchase and retirement of entitlement to improve system reliability

Aim: To reduce the demand on the Broken System

What's Involved: Purchasing of targeted users water entitlement with the intention of retirement of allocation

Current Information gaps: If there are willing funding sources who would purchase entitlement without receiving something back

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Assessment Criteria

Option Number: 16 **Description:** Water entitlement purchase and retirement of entitlement to improve system reliability

Criteria	Initial Rating	Confidence Level	Assessment notes
Sustainable Irrigation Future	Positive	H	Additional allocation to remain in the system would help reliability for irrigation. May allow for early allocation
D&S Security	Positive	H	Additional allocation to remain in the system would help reliability for D & S
Environmental Values	Neutral	M	No change in impact on Environmental outcomes
Social Values	Neutral	M	Voluntary buy back are not likely to create social risks
Cultural Values	Neutral	L	Unlikely to impact on Cultural values. Low confidence assigned until TO advice is received
Robustness	Positive	M	Climate change effects continue to reduce water in system, however reducing allocation may assist with early and greater reliability in the remaining allocation

Criteria	Initial Rating	Confidence Level	Assessment notes
Risks	Low	L	Initially assessed as having a reasonable prospect of mitigating risks. Assessment confidence set as low until detailed risk review is available
Value for Money	Low	M	Govt: Requires upfront investment to buy back the allocations without generally community benefit. Could benefit from additional user costs Users: Good value for money, no additional costs unless co-contribution is required
Community Acceptance	Acceptable	M	Raised by the committee as an option that many users would still opt for. However may get push back on the use of public money
Regulatory and Policy Compliance	Not aligned	M	Currently not aligned as it would be using public money for private benefit
Impacts and benefits	Acceptable	M	Significant impact on system stakeholders who remain on the system. Beneficial for D&S users across the system.

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

May be improved if cost and benefit sharing arrangements could be considered

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	17	**Description:**	Targeted water entitlement purchase and returned to the environment
Aim:	To reduce the irrigation demand on the system while improving the positive Environmental impacts on the system		
What's Involved:	Purchasing of targeted users water entitlement to be added to the Environmental water allocation		
Current Information gaps:	If there are any additional irrigation and D & S benefits from entitlement purchase with full allocation returned to the Environment		

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Assessment Criteria

Option Number: 17 **Description:** Targeted water entitlement purchase and returned to the environment

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Neutral	H	No change to existing reliability
D&S Security	Neutral	H	No change to existing reliability
Environmental Values	Positive	M	Assumes increased Environmental allocation thus a positive impact on Environmental outcomes
Social Values	Positive	M	Increased shared benefits from Environmental entitlement
Cultural Values	Neutral	L	Potential to improve cultural values however low confidence assigned until TO advice is received
Robustness	Positive	M	Climate change effects continue to reduce water in system, no benefit for irrigators however additional environmental water improves robustness to climate change effects

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Low	L	Initially assessed as having a reasonable prospect of mitigating Environmental risks. Assessment confidence set as low until detailed risk review is available
Value for Money	Medium	M	Govt: Requires upfront investment to buy back the allocations. Value for money is dependant of price of water. Likely to provide good value for money for Environmental use Users: No additional costs or benefits
Community Acceptance	Unacceptable	L	Likely to receive mixed reactions. May get push back from stakeholders as this option does not assist irrigation
Regulatory and Policy Compliance	Partially aligned	M	Currently have the ability to buy back however it is not a preferable approach
Impacts and benefits	Acceptable	M	Beneficial for Environmental outcomes across the system. No benefits for irrigation

Preliminary Assessment Outcome

Not shortlisted

Assessment Summary

Not shortlisted due to lack of community acceptance. Could be altered and combined with other options (option 13) to improve acceptance

Preliminary Assessment - Summary

Prepared by: Sequana Partners
Prepared for: Department of Energy, Environment and Climate Change
Date prepared: 24/11/2023

Option Number:	**18**	**Description:**	Water entitlement (HRWS and/or LRWS) purchase. % of entitlement purchased and % entitlement retained by environment and/or Cultural water

Aim:	To reduce the demand on the Broken System through retirement while still providing positive Environmental outcomes
What's Involved:	Purchasing of targeted users water entitlement with the intention of retirement of a percentage of the allocation whilst also returning a percent to the Environmental water allocation
Current Information gaps:	The percentage of entitlement required to be retired to achieve intended positive outcomes

Assessment Criteria

Option Number: 18 **Description:** Water entitlement (HRWS and/or LRWS) purchase. % of entitlement purchased and % entitlement retained by environment and/or Cultural water

Criteria	Initial Rating & Confidence Level		Assessment notes
Sustainable Irrigation Future	Positive	H	Would offer an increase in system reliability - subject to the volume of HRWS retired.
D&S Security	Positive	H	Would offer an increase in system reliability - subject to the volume of HRWS retired.
Environmental Values	Positive	M	Assumes increased Environmental allocation thus a positive impact on Environmental outcomes
Social Values	Positive	M	Increased shared benefits from Environmental entitlement
Cultural Values	Positive	L	Inclusion of cultural water may facilitate enhanced cultural outcomes. Low confidence until TO advice is received.
Robustness	Positive	M	Climate change effects continue to reduce water in system, reduced entitlements and additional environmental/cultural water improves robustness to climate change effects

Criteria	Initial Rating & Confidence Level		Assessment notes
Risks	Low	L	Initially assessed as having a reasonable prospect of mitigating Environmental risks. Assessment confidence set as low until detailed risk review is available
Value for Money	Medium	M	Govt: Requires upfront investment to buy back the allocations. Value for money is dependant of price of water. Likely to provide good value for money for Environmental use Users: No additional costs or benefits
Community Acceptance	Neutral	L	Likely to receive mixed reactions. However does provide an option that supports irrigators who wish to remain, environment and cultural options.
Regulatory and Policy Compliance	Partially aligned	M	Currently have the ability to buy back however it is not a preferable approach
Impacts and benefits	Acceptable	M	Beneficial for Irrigators, Environmental and cultural outcomes across the system.

Preliminary Assessment Outcome

Shortlisted for detailed review

Assessment Summary

Shortlisted on the basis that it provides multiple benefits. Would require clear community and Government alignment.

Attachment	Water Resources Modelling Report
Attachment No.	3
Author	HARC Services

OFFICIAL: Sensitive

Broken Reconfiguration

Water Resources Modelling

Final 3

17th July 2024

Document status

Client	Sequana
Project	Broken Reconfiguration
Report title	Water Resources Modelling
Version	Final 3
Authors	Kate Austin
Project manager	Kate Austin
File name	VIC00116_R_ModellingReport_old losses_kaa_f3.docx
Project number	VIC00116

Document history

Version	Date issued	Reviewed by	Approved by	Sent to	Comment
Draft A	2/02/24	K Austin	K Austin	Sequana	Base case results only
Draft A v2	8/02/24	K Austin	K Austin	Sequana	Updated with slightly different results due to model fix
Draft B	15/05/24	K Austin	K Austin	Sequana	With scenario results included
Final 1	28/05/24	K Austin	K Austin	Sequana	With comments on Draft B addressed
Final 2	11/06/24	K Austin	K Austin	Sequana	With comments on Final 1 addressed
Final 3	17/07/24	K Austin	K Austin	Sequana	With additional scenario modelling and post processing included

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Contents

Executive Summary

HARC was engaged by Sequana to provide water resources support and advice for the Broken Reconfiguration project. Modelling was undertaken to provide a better understanding of system losses and of system performance under a range of reconfiguration scenarios. Performance was also tested under future climate and full demand. The GSM REALM model was used for this assessment.

Base case model updates

HARC had previously carried out scenario modelling for DEECA to support the Broken Review in 2021 and investigation into a Broken D&S Reserve in 2023. The base case model from 2023 was adopted as a starting point for this project and key model settings reviewed. A number of changes were made to the base case model for this project including:

- Explicitly represent D&S demand (2 ML/yr per customer) in each reach
- Split lower Broken River reach and water shares upstream and downstream of Gowangardie Weir to accommodate the Broken Reconfiguration zones
- Set Shepparton WWD demand to zero as this is now supplied from Cosgrove pipeline
- Set Tungamah urban demand to zero as this is not currently being used by North East Water.

Settings for carryover, Inter Valley Trade (IVT) and the Broken Creek loss provision were reviewed but not updated.

Base case modelling results

Reliability is calculated as the percentage of years when February allocations are equal to or greater than 100%. The updated base case model reliability is calculated as 84%. The timeseries of February allocations show that when allocations are less than 100% in February this can persist for multiple years.

In order to examine early season performance, September allocations were also extracted. Under the base case September allocations are constrained by the volume of water that needs to be set aside for operational losses in the allocation calculation. For this reason base case September allocations are rarely above 81% which translates to a very low September reliability of 2% (percentage of years when September allocations are equal to or greater than 100%).

In the base case model losses are split roughly 1/3 upstream and 2/3 downstream of Caseys Weir. There is also 4.3 GL/yr modelled for the Broken Ck loss provision.

Under future climate projections inflows are expected to reduce and hence reliability reduces significantly, falling to 48% under the 2065 high climate change case. Under historic climate and full demand, reliability reduces from 84% to 78%, which is similar to the post 1975 climate case. Under post 1997 climate conditions reliability is 63%, slightly lower than that under 2040 high climate change at 66%.

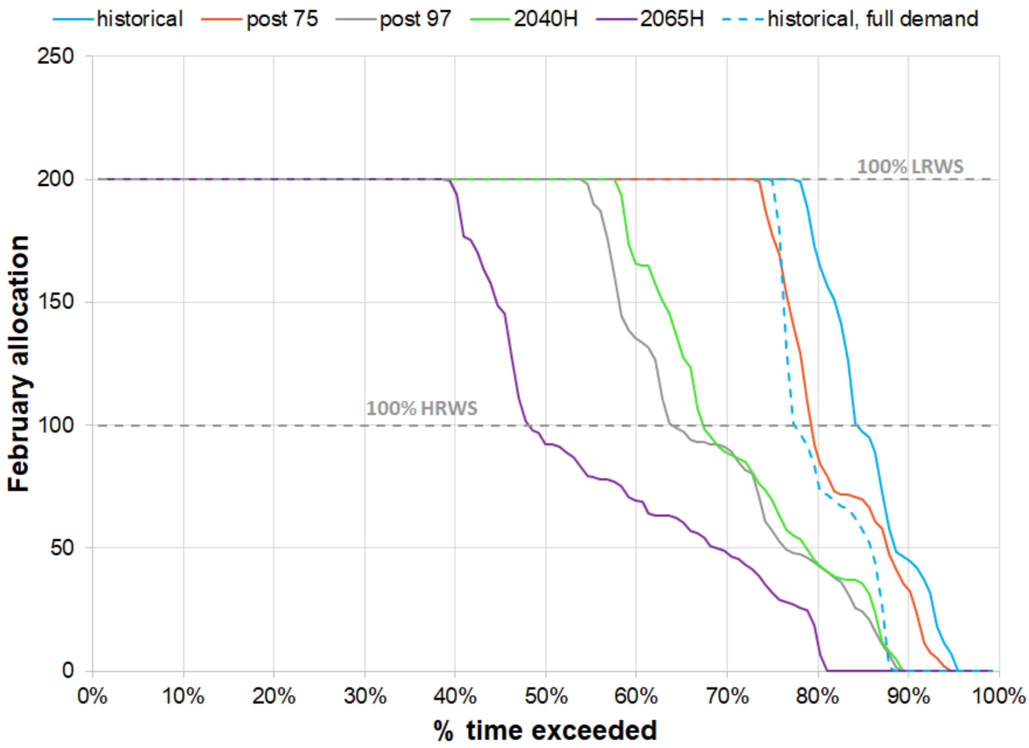


Figure E-1: Base case February allocation (reliability) under future climate and full demand

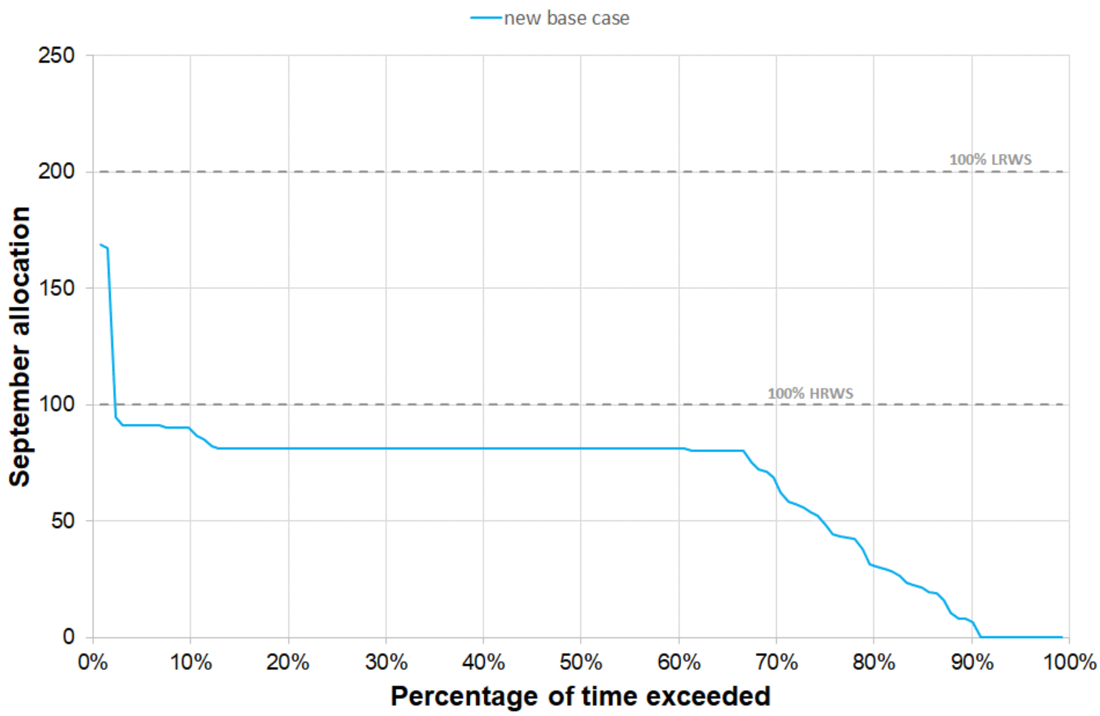


Figure E-2: Base case September allocations, historic climate case

Reconfiguration scenarios

Figure E-3: Reconfiguration zones (Sequana)

Zone based scenarios have been developed by the project team. These are:

Scenario 1: Do nothing (base case)

Scenario 2: Transition out of irrigation (whole system): This scenario has been run to provide a “bookend” to the base case. All irrigation demands are set to zero and D&S demands are retained at current magnitude. Irrigation entitlements are either redistributed to increase reliability of the remaining D&S users or shifted to the environment in a share such that HRWS reliability increases to 90%. This turned out to be 10% retired, 90% to the environment (13,719 ML HRWS).

Scenario 3: Remove or reconnect all services in Zone 5: In this case all Zone 5 irrigation and D&S demands are set to zero. 430 ML of HRWS irrigation entitlements was transferred to Zone 4 and the Zone 4 irrigation demand was increased by the ratio of old and new HRWS (+8%). 50% of the HRWS was redistributed to increase reliability, and 50% was redistributed to the environment.

Scenario 4: Remove or reconnect all services in Zone 3: In this case all Zone 3 irrigation and D&S demands were set to zero. 215 ML of HRWS irrigation entitlements is transferred to Zone 4, and the Zone 4 irrigation demand was increased by the ratio of old and new HRWS (+4%). 50% of the HRWS was redistributed to increase reliability, and 50% was redistributed to the environment.

Scenario 5: Mokoan Pipeline supply channel efficiency improvements: It was estimated that channel losses and seepage in the Mokoan pipeline Channel could be reduced by 90 ML/yr. This was implemented in the model by reducing the "Lake Mokoan" demand in the model by 90 ML/yr.

Scenario 6: All zones reconfiguration opportunities: For this scenario reconfiguration opportunities were explored across all zones. For modelling purposes it was assumed that 50% of unused entitlement (based on the highest recorded use for the last 10 seasons) was relinquished, for zones 1 to 5. 65% of entitlement not linked to land (excluding VEWH, DCCEEW & GMW) was assumed to be relinquished. 50% of the HRWS was redistributed to increase reliability, and 50% was redistributed to the environment.

Scenario 7: Secure access to D&S water: For this scenario a 400 ML D&S reserve is established in Lake Nillahcootie which resets at the start of each water year. This water is then used to top up supply to D&S demands when allocations or unregulated inflows are inadequate.

Scenario 8: Combined Option: Combined Scenario 3, 4, 5, 6 & 7

Scenario 9: Extended combined option: As for Scenario 8 plus Zone 4 irrigation demands set to zero.

Broken Creek loss provision

Broken Creek loss provision impacts the model in two ways. Firstly it is an input to the allocation calculation, where the anticipated loss incurred to deliver demands to Broken Creek needs to be set aside before allocations can be made. Secondly, the actual loss itself is represented in the model as a demand. For scenarios where demands are no longer supplied in Broken Creek this loss provision no longer needs to be set aside and so results in improved allocations.

Scenario modelling

Modelling was undertaken for the reconfiguration scenarios and results compared to the base case.

Table E-1 and Figure E-4 show that only small reliability gains are realised under Scenario 3, 4, 5 & 6. Gains are larger under Scenario 8, 9 and 2 because a greater redistribution of HRWS is assumed. When a D&S reserve is created under Scenario 7 reliability reduces slightly but a very high reliability results for D&S demands.

September allocations increase significantly for scenarios where the volume of consumptive HRWS is substantially reduced and/or when Broken Creek loss provision is not needed (Figure E-5).

Table E-1: Reliability comparison, historic climate and current demand

	Base case	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
reliability	84%	90%	85%	85%	85%	87%	83%	89%	93%
D&S reliability*							99.7%	99.0%	98.7%

* % of D&S demand supplied when using a D&S reserve rule

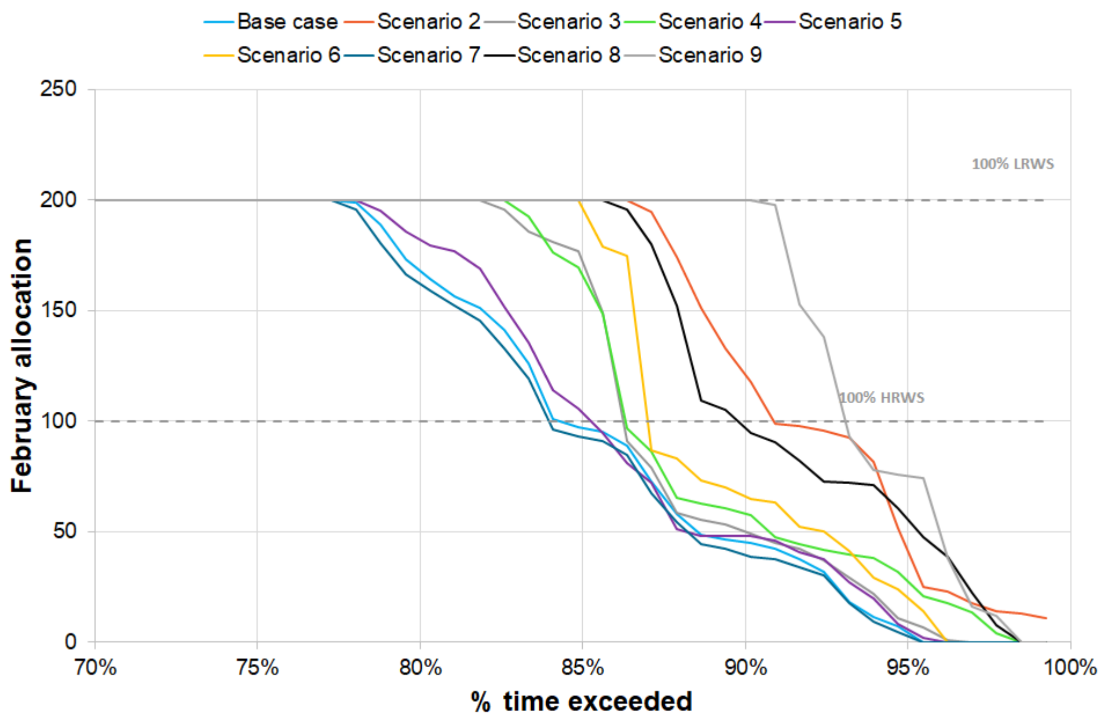


Figure E-4: February allocation (reliability) comparison, historic climate current demand case

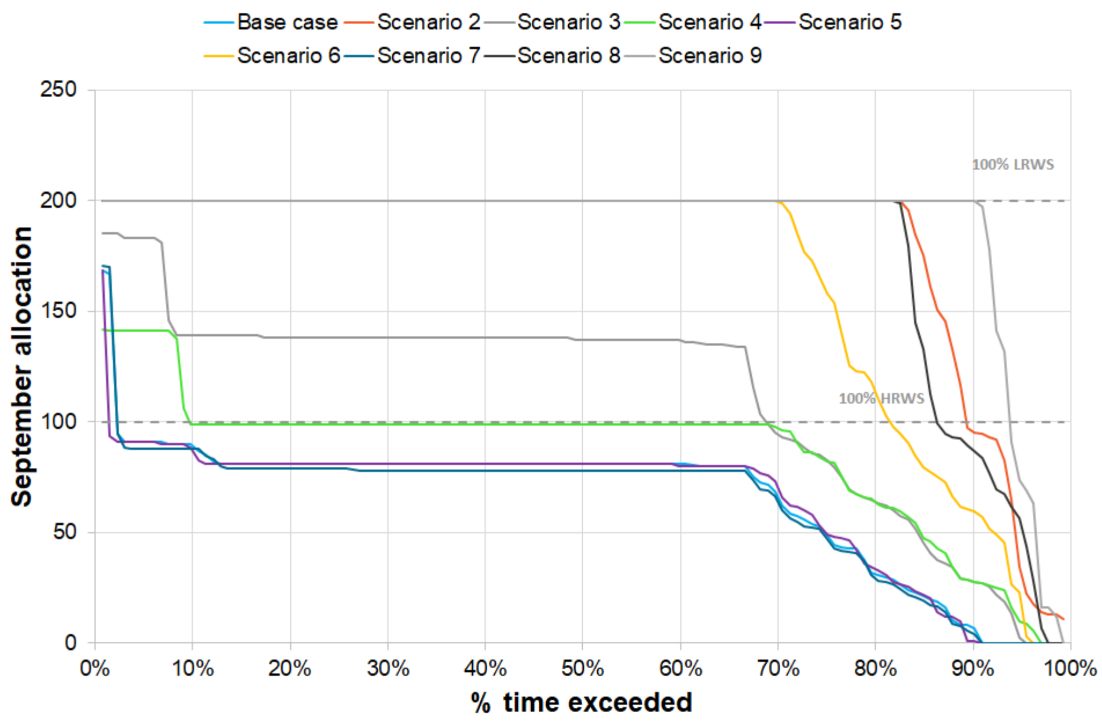


Figure E-5: September allocation (reliability) comparison, historic climate current demand case

Unrestricted demand is defined as the amount of water desired by the customer if there were no constraints to supply. With reference to irrigation, this corresponds to the crop water requirement. For D&S demands this corresponds to the amount that would be supplied unconstrained by allocations and water availability. Scenario performance has examined by comparing the percentage of unrestricted demand supplied for each demand type (Figure E-6).

In terms of demand supplied, there is not a big difference between the base case and the scenarios except for D&S supply in Scenario 2, 7, 8 and 9. For Scenario 2 this is due to the lack of irrigation demand and for Scenario 7, 8 & 9 this is due to the D&S reserve rule.

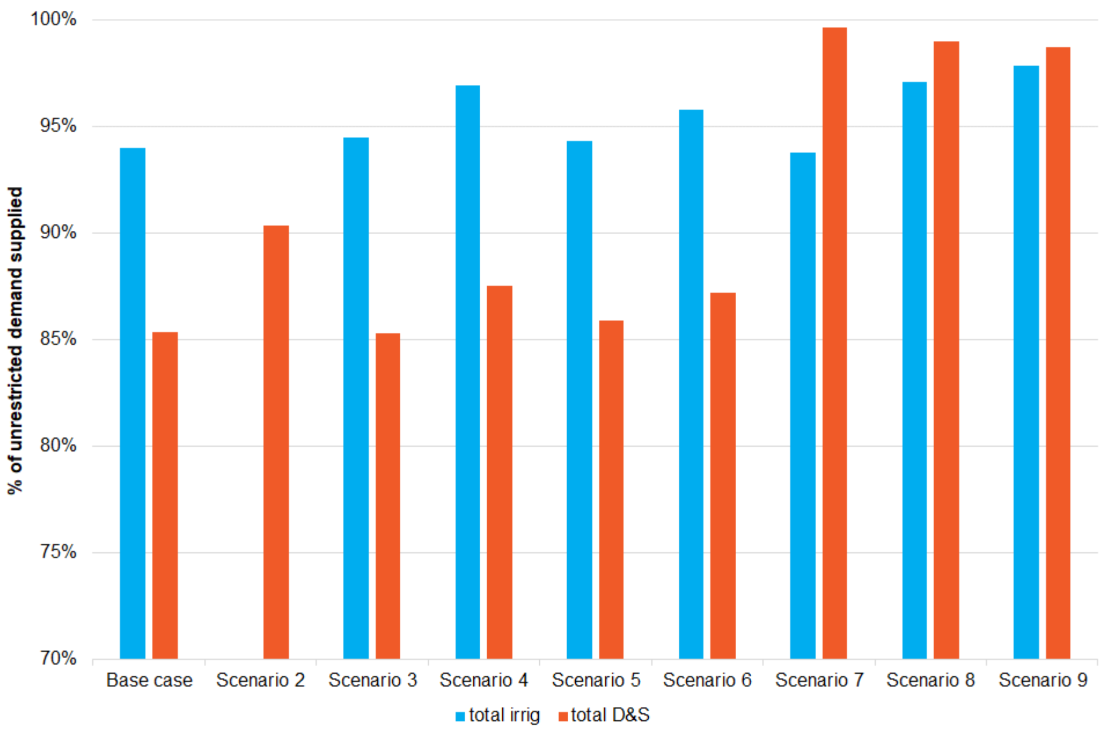


Figure E-6: Percentage of unrestricted demand supplied, historic climate current demand case

Flows down Broken River vary little between scenarios as water redistributed to the environment is still released. There is some difference in flows down Broken Creek for scenarios where the Broken Creek loss provision is reduced or does not need to be provided. For the same reasons, losses are also similar across scenarios, except where Broken Creek loss provision is reduced or does not need to be provided (Figure E-7).

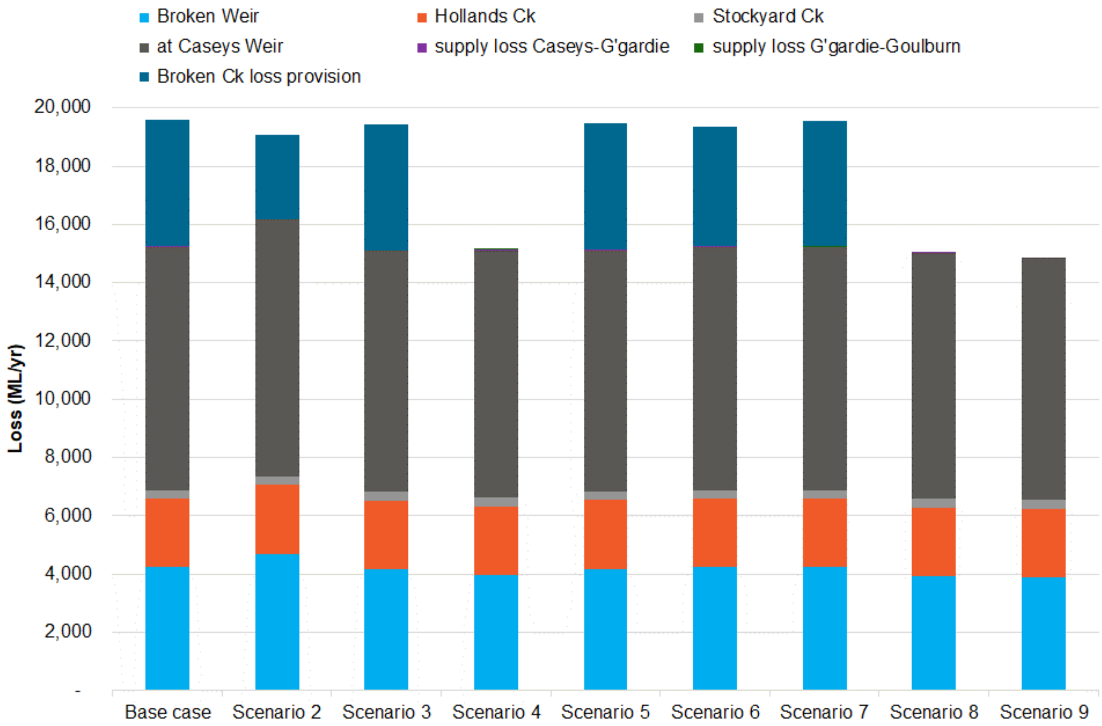


Figure E-7: System loss comparison, historic climate current demand case

The degree to which environmental low flow requirements can be satisfied under each scenario was also examined. Results showed that this did not change substantially across scenarios except where there was a very large volume of stored water held by the environment (for example Scenario 2).

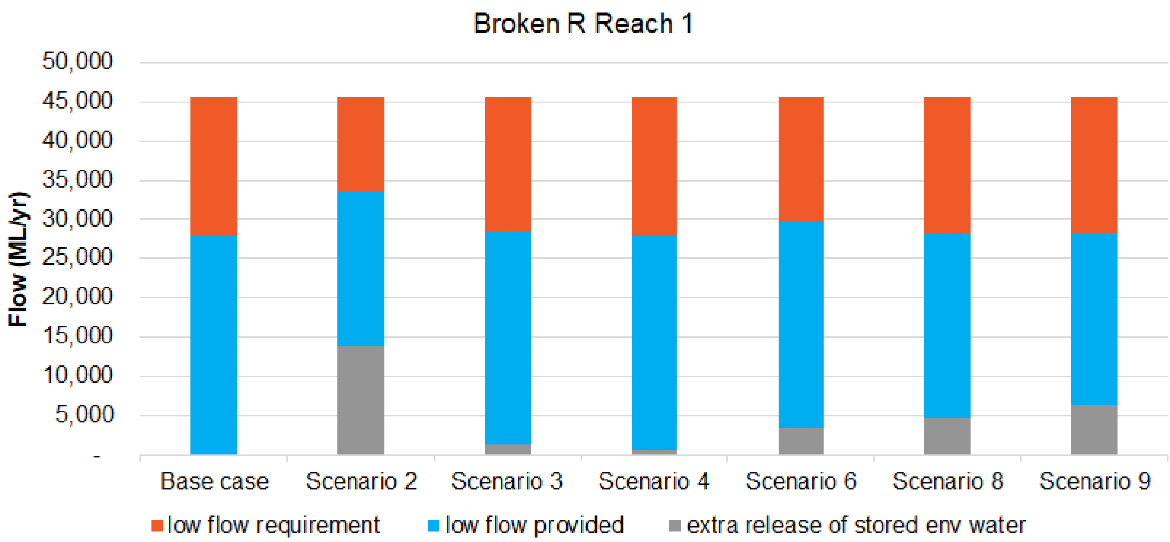


Figure E-8: Environmental low flow comparison, Broken River, historic climate current demand case

Results for Broken Creek showed that low flow requirements are largely being satisfied by the Broken Creek loss provision. In scenarios where water is no longer being sent down Broken Creek (to satisfy demands Scenario 4, 8 & 9) mitigation water is provided.

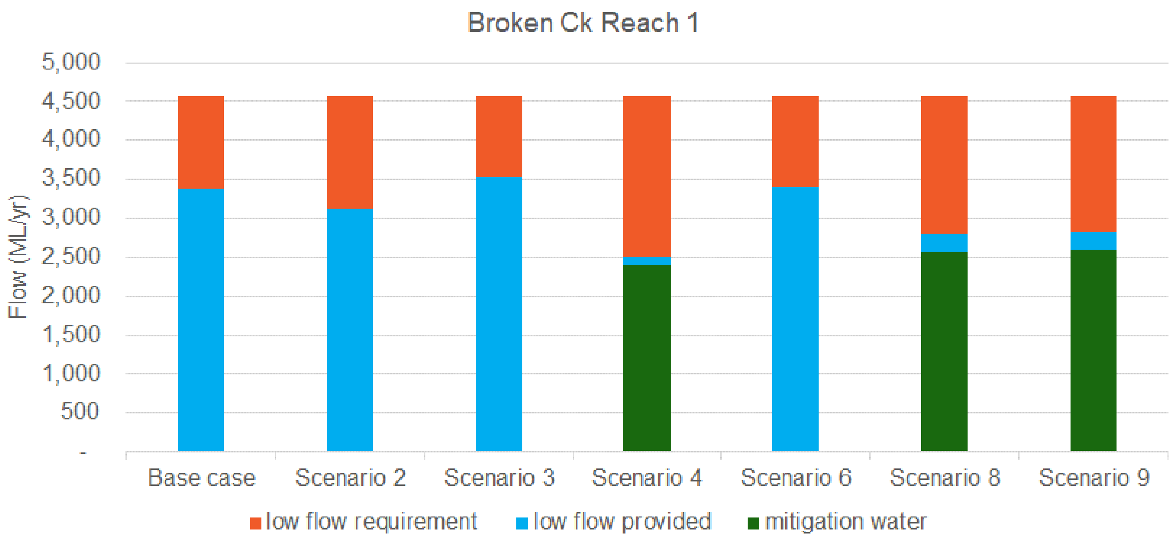


Figure E-9: Environmental low flow comparison, Broken Creek, historic climate current demand case

Conclusions

A new base case model was established and a range of Broken Reconfiguration scenarios run under current and future climate conditions and current and future demand. Redistribution of HRWS was split between the environment and reliability improvement. The performance of a D&S reserve was also tested. Results were compared with base case (do nothing) model results.

Base case modelling showed that current reliability is 84%. While most scenarios resulted in reliability gains, reliability is improved most under cases where a greater redistribution of HRWS is assumed and/or a D&S reserve is in place. A greater redistribution of HRWS means a greater proportion of shares goes to improving reliability for existing users. The D&S reserve rule improves reliability by circumventing constraints due to zero or low reliability.

Early season (September) allocations are constrained by the volume of water that must be set aside in the allocation calculation for river and operational losses and the Broken Creek loss provision. Therefore, September allocations improved substantially for scenarios where consumptive demand magnitude and hence operational losses reduce, especially on Broken Creek.

The proportion of unrestricted demand supplied increased most for scenarios with a significant reduction in consumptive demand or where the D&S reserve rule was introduced.

Due to releases of stored environmental flows, flows and hence river losses vary little between scenarios except for cases where supply is significantly reduced or removed from Broken Creek. Provision of environmental low flow requirements only improved significantly in cases where there was a significant increase in the volume of stored environmental water.

Results showed that that the impacts of climate change on system performance is similar for the base case and for reconfiguration scenarios due to there being a similar impact of climate on water availability. Where the model was run with historic climate and full demand, results showed that the impact of this demand increase on reliability is similar to the impact of running the model over the full period of record but with inputs prior to 1975 adjusted to have the characteristics of post 1975 climate.

Table E-2: Scenario performance comparison

	Base case	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
February reliability*	84%	90%	85%	85%	85%	87%	83%	89%	93%
D&S reliability with reserve							99.7%	99.0%	98.7%
September reliability^	2%	89%	69%	9%	1%	82%	2%	86%	94%
Unrestricted demand supplied	92%	90%	93%	95%	93%	95%	95%	98%	98%
Losses compared to base case	19,584	-523	-137	-4,432	-107	-228	-24	-4,565	-4,728
Provision of low flows compared to base case, ML/yr (scenarios with stored environmental water only)									
Broken River reach 1	27,983	+5,547	+462	-108	n/a	+1,558	n/a	+231	+326
Broken Creek reach 1	3,390	-265	+139	-887#	n/a	+10	n/a	-583#	-558#

*February reliability is calculated as the percentage of years over the whole model run when HRWS allocation is 100% or greater by February.

^September reliability is calculated as the percentage of years over the whole model run when HRWS allocation is 100% or greater by September.

Modelled flow results post processed as described in Section 5.1.5.

1. Introduction

HARC was engaged by Sequana to provide water resources support and advice for the Broken Reconfiguration Feasibility Study (BRFS) project.

As a result of meeting discussions the following findings were made:

a) **A better understanding of Broken River reach losses** is required under current conditions and under reconfiguration under current and future climate, and current and full demand. The representation of reach losses in the existing GSM REALM model is coarse and based on losses relationships derived many years ago (pre Millennium Drought). Improved loss relationships should exist in the recently developed daily Goulburn, Broken, Campaspe, Coliban and Loddon (GBCCL) Source model.

b) There would be benefit in understanding **how reliability of supply changes** under these scenarios

It was understood that a full GBCCL Source model is not available at this time. However, there appeared to be an opportunity to examine loss relationship, inflow and demand data already in the GBCCL model to build a spreadsheet-based daily mainstem model. The intention was to investigate the best available information to accurately determine losses and reliability under the required scenarios. On review of data provided from the GBCCL model, and in consideration of the level of verification needed before it could be used for the intended purpose, the investigation confirmed the GBCCL model is not yet ready for use in this kind of assessment.

It was intended that some data from the GBCCL model (daily local catchment inflows, loss relationships) be used to improve the representation of losses and inflows in the existing monthly REALM model, in particular D&S and irrigator access to within-month unregulated flows. Initial base case model runs however showed that the losses taken from Source produced a different distribution of losses to those in the REALM model and those expected by GMW. Due to this the base case losses in REALM were retained.

This report summarises the modelling approach, key assumption and outputs.

2. Creating the base case REALM model

2.1 Background

The Goulburn Simulation Model is a monthly timestep water resources model that represents the connected Goulburn-Broken-Campaspe-Loddon water supply system. The GSM was developed by the (then) Rural Water Corporation in 1990/91 representing 1990/91 level of development. The model was progressively updated over a number of years, and in 1998 work was done to change the demands from 1990/91 levels of development to 1993/94 level of development (the Murray-Darling Basin Cap version of the GSM). Information from this model was required annually to audit the annual Cap on diversions from the Goulburn, Broken, Loddon and Campaspe basins. Annual diversions are now assessed against the Sustainable Diversion Limits models.

Since 1998 other versions of the GSM have been created for other purposes. Model versions relevant to this project are described below (definitions adapted from DELWP, 2019):

- **Baseline Diversion Limit** (BDL): The long-term average annual take under historical climate conditions (i.e. for the period July 1895 – June 2009) at the baseline level of development (30 June 2009 for Northern Victoria). BDLs are further defined in Schedule 3 of the Basin Plan.
- **Sustainable Diversion Limit** (SDL): The long-term average annual take under historical climate conditions at the sustainable level of development. Calculated as BDL minus required water recovery.
- **Water Resource Plan** (WRP): A requirement of the Murray Darling Basin Plan, WRPs present the water resource management mechanisms and strategies that support collaborative management of Murray-Darling Basin.
- **BDL model**: Model representing baseline conditions as at 30 June 2009. Has average annual diversions equal to the BDL under historical climate conditions.
- **SDL model**: As per BDL model, but with Basin Plan water recovery. Has average annual diversions equal to the SDL under historical climate conditions.
- **WRP model**: Model representing WRP conditions post-30 June 2019, including full Basin Plan water recovery and its use for achieving environmental outcomes. Has average annual diversions equal to the SDL under historical climate conditions. Can be used to determine annual permitted take.

2.2 Base case model changes for Broken Review modelling (2021)

In 2020 HARC was provided with a copy of the Water Resource Plan (WRP) version of the GSM which best represented current system operations. This model was updated to represent current conditions (HARC, 2020) and used for scenario modelling to support the Broken Review (HARC, 2021). Modelling was undertaken over a model run period of July 1891 to June 2019.

Table 2-1: Summary of model changes made to create the base case for Broken Review modelling (HARC, 2020)

Item	Change
High reliability water share (HRWS) and low reliability water share (LRWS) volumes	Updated to current volumes in limit curves and elsewhere in the model
Irrigation demand magnitude	Factored down from WRP to current level
Irrigation demand split	Re-split to better match current split
SHEPPARTON waterworks district (WWD) demand	Factored down to represent D&S volume only (518 ML). Limit curve and allocation calculation adjusted accordingly.
Allocation calculation – Shepparton WWD and domestic and stock (D&S) demands	Included Shepparton WWD 830 ML in HRWS entitlement. Edited allocation calculation to remove D&S volume from HRWS and adjusted volume of "Broken urban" allowance. Adjusted HRWS and LRWS volumes for limit curves on split irrigation demands.
Carryover	Turned off carryover of LRWS. Allowed for carryover in allocation calculation but was not made available to active irrigators.
Broken Creek loss provision	Allowed Broken Creek loss provision to increase with allocation
Allocation calculation – Transmission and operational losses	Changed loss allowance to correspond with GMW estimates and updated loss provision
Long term inter-valley trade (IVT)	Derived using relationship between IVT and in-valley use
Hollands Creek passing flow	Turned off
Rain rejection storage	Updated capacity to 379 ML to include capacity of Broken Weir
Passing flow calculation in allocation	Error found in model, changed to reference passing flow downstream of Caseys Weir rather than a switched off arc
Broken deliveries	Error found in model where Broken deliveries were double counting Lake Mokoan PDs. Error fixed

2.3 Base case model changes for D&S reserve modelling (2023)

In 2023 HARC was engaged to carry out further water resource modelling to investigate the creation of a D&S reserve in Lake Nillahcootie. As part of that project further changes were made to the base case model to support this analysis.

Table 2-2: Summary of model changes made to create the base case for D&S reserve modelling (HARC, 2023)

Item	Change
Extending the model run period to June 2022	Adopting / creating extended input files suitable for the WRP model version
Explicit representation of critical D&S demands	Adding critical D&S demand nodes to the system file Creating critical D&S demand time series Adjusting down PD demand time series

2.4 Base case model changes for this project

Existing base case model assumptions were reviewed. Model changes are summarised below.

Table 2-3: Summary of model changes made to create the base case for D&S reserve modelling (HARC, 2023)

Item	Change
D&S split out	Change volume from critical D&S to total D&S (from 1 ML per user to 2 ML per user). Make corresponding adjustments to HRWS and limit curves in the model Make corresponding adjustments to PD demands and functions referring to demand
Shepparton WWD	Set demand to zero. Retain volume in allocation calculation
Tungamah urban	Set demand to zero. Retain volume in allocation calculation
Model reaches / subcatchments	Split lower Broken and water shares upstream and downstream of Gowangardie weir to accommodate reconfiguration zones Make corresponding adjustments to PD demands and functions referring to demand

3. Review and update of existing base case model settings

A range of existing base case model settings were reviewed as part of this project.

3.1 Carryover

The current base case version of the GSM REALM model allows for a carryover volume in its calculation of available water and hence allocation, but access to carryover is turned off at the demand nodes so it is not available at times of zero allocation. This assumption is based on advice from GMW in 2021 that while substantial volumes are carried over each year (taking up airspace in Lake Nillahcootie) these volumes are generally held by inactive users and are therefore not available to active irrigators. This setting was discussed and it was decided that the current setting is ok to retain.

3.2 D&S split out

The current Broken REALM model used to evaluate the D&S reserve has "critical" D&S demands split out at 1 ML per user or syndicate member. For this project the split was re-done to separate out total rather than critical D&S (2 ML per user / syndicate member). A within-year pattern was applied to D&S use consistent with urban usage (see Figure 3-1).

Reach / location (REALM demand node)	D&S demand (ML/yr)
Lake Nillahcootie to Broken Weir (UP BROKEN PD1)	118
Broken Weir to Caseys Weir (UP BROKEN PD2)	236
from Winton wetland (LK MOKOAN PD)	132
Broken Creek between Caseys Weir and Waggarandall Weir (BROKEN CK PD)	88
Major Ck (MAJOR CK PD)	12
Downstream Caseys Weir (LOW BROKEN PD)	204
Total	790

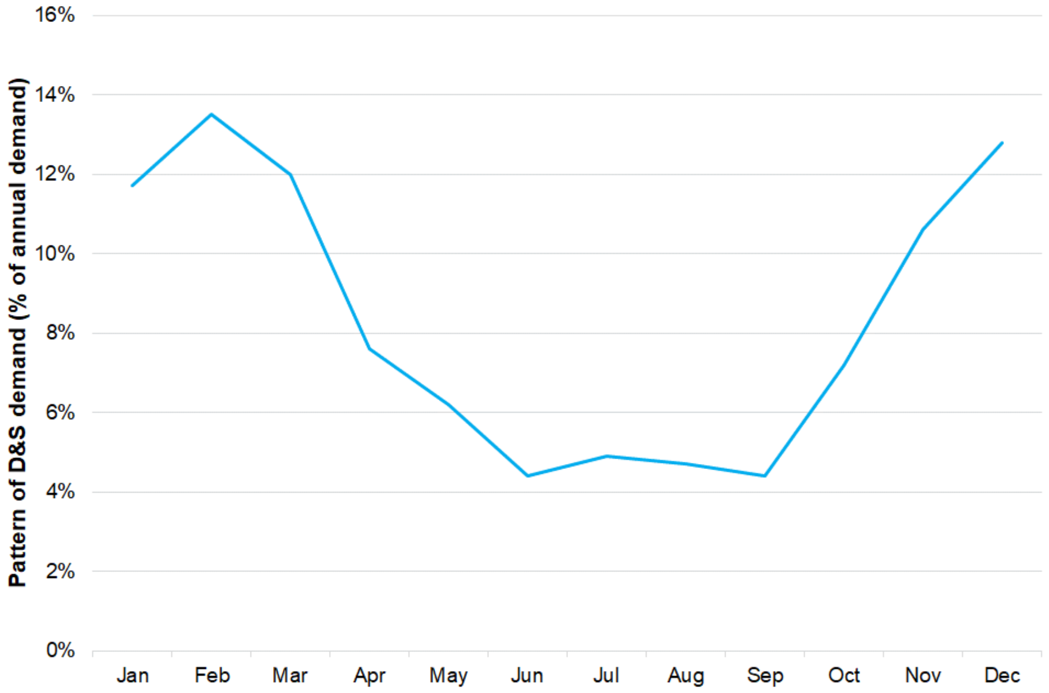


Figure 3-1: Within-year pattern of D&S demand

3.3 Shepparton WWD

In the original WRP REALM model provided by DEECA, SHEPPARTON WWD was represented as a repeating demand of 590 ML/yr spread over December to March. An allowance of 1,348 ML/yr was made for Shepparton WWD in the allocation calculation as part of the Broken Urban commitment.

As part of the REALM model review for the Broken Review project (HARC, 2020) GMW advised that 830 ML of the HRWS in the system corresponded to Shepparton WWD. DEECA advised that 518 ML of the 830 ML is D&S. Therefore the base case model was changed as follows:

- Shepparton WWD allowance in the Broken Urban part of allocation calculation was reduced to 518 ML
- 830 ML Shepparton WWD entitlement included in the HRWS volume for the purposes of allocation calculation
- The limit curve for the LOWER BROKEN PD demand was adjusted to include the 830 ML HRWS for Shepparton WWD
- The limit curve for the SHEPPARTON WWD demand was reduced to 518 ML
- SHEPPARTON WWD demand time series was factored down to be 518 ML/yr

Shepparton WWD has been supplied from Cosgrove pipeline since 2014, however the corresponding water shares still exist. On this basis, and in line with the Tungamah urban assumption, the SHEPPARTON WWD demand in the model was set to zero, but the allowance for HRWS retained in the allocation calculation.

3.4 Tungamah urban

Examination of the current BE, BE amendments and recent Vic Water Accounts showed that the 135 ML/yr for Tungamah urban corresponds to the BE volume post Tungamah Pipelining, however it is currently not being used by NEW (only traded). The 2019-20 water account has the following comment:

> *North East Water transferred its offtake for this bulk entitlement to upstream of Benalla Weir in October 2009, but it does not have infrastructure in place to supply water under this entitlement. In 2018–19, Tungamah, Devenish and St. James continued to be supplied with water via a pipeline from Yarrawonga in the Murray system.*

On this basis it was decided that the Tungamah Urban volume should continue to be allowed for in the entitlement calculation, but the demand was set to zero in the base case and for scenario modelling.

3.5 Broken Creek loss provision (Tungamah etc)

This demand node in REALM represents the Goulburn Murray Water (GMW) Bulk Entitlement loss provision for Broken Creek. Some GSM documentation suggests that it includes an allowance for water passed downstream of Waggarandall Weir.

The GMW BE includes a Broken Creek loss provision of 1,850 ML/yr. The Broken Creek loss allowance as documented in the Victorian Water Account is in general greater than the Broken Creek loss provision, as shown below. This occurs when GMW report that losses from Broken Creek during regulated conditions are greater than the loss provision in the BE.

Table 3-1: Recent Broken Creek loss allowance and allocation

	2014/15	2015/16	2016/17	2017/18	2018/19
Broken Creek loss allowance^	4,455	2,066	6,526	4,181	2,978
February allocation*	200%	26%	200%	200%	32%

^ from Victorian Water Accounts
* provided by GMW

As part of the Broken Review project the Broken Creek loss provision was updated to better match actual losses as reported in the Vic Water Accounts:

*Broken Ck loss provision (ML/mth) = (0.3 * Broken allocation * old demand pattern) + 230*

This was able to produce a better fit to the annual loss provision reported in the Victorian Water Accounts, as seen in Figure 7-1.

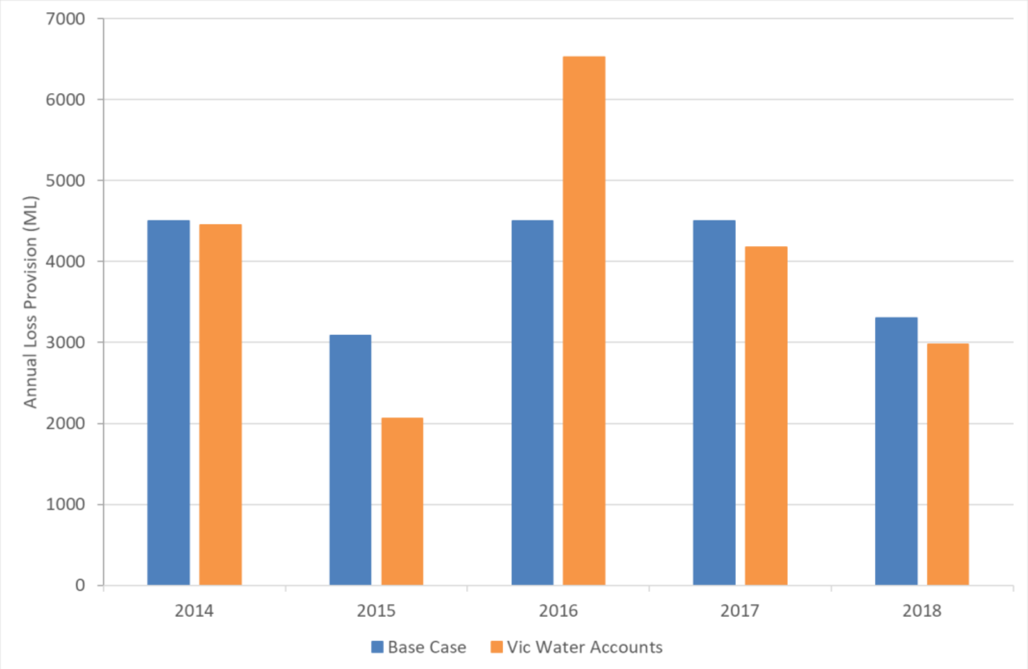


Figure 3-2: Historic and modelled annual loss provision

This is represented in the model as a demand node from Broken Creek d/s of Caseys Weir. It is allowed for in the allocation calculation as a demand delivered to date (factored by 0.5) and may also be included in the forecast overall transmission loss (63 ML/d) and operational loss (42 ML/d).

3.6 Inter-valley trade (IVT)

As part of the Broken Review project IVT was estimated as a function of in-valley use and Broken allocation. This assumption was discussed and retained in the base case model.

IVT is calculated as the previous months in-valley irrigation delivery multiplied by the previous months allocation for the months of November to April, and set to zero for other months.

The plots below in Figure 3-3 and Figure 3-4 show historic IVT and IVT predicted as a function of in-valley use and Broken allocation. This relationship was implemented in the model.

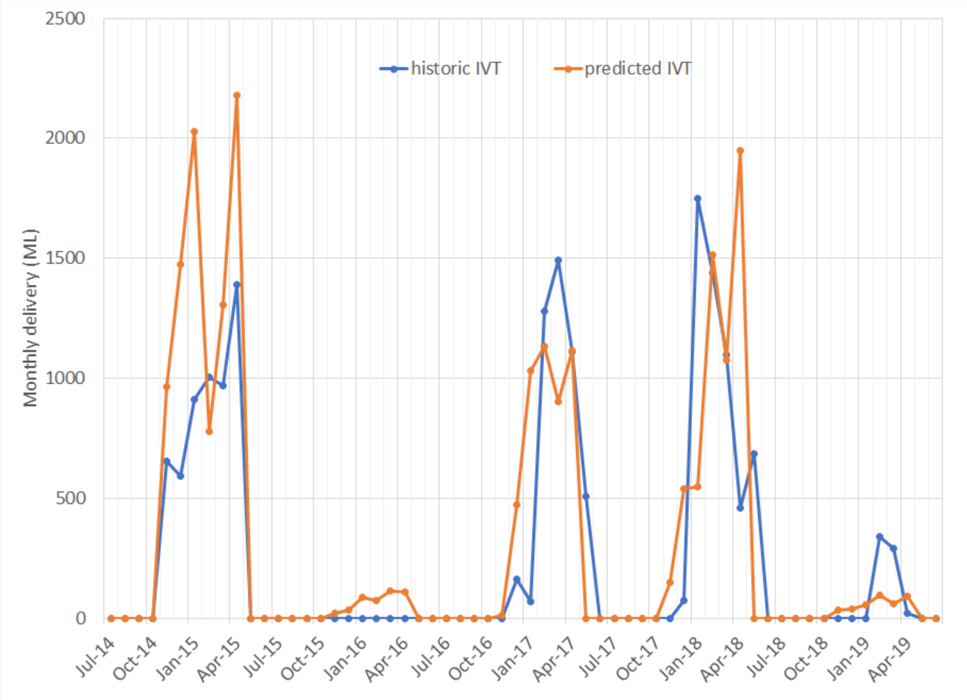


Figure 3-3: Predicted and historic IVT (monthly)

Figure 3-4: Modelled and historic IVT (water year)

3.7 Model reaches / subcatchments

Potential reconfiguration zones have been defined for this project as shown in Figure 3-5. To accommodate these zones Lower Broken demands in the model were split upstream and downstream of Gowangardie Weir (Zone 4 and 5). Water shares were split on the basis of the ratio of HRWS and LRWS in the respective zones, while demand inputs were split based on the ratio of recent usage.

Table 3-2: Split of lower Broken demands

	HRWS	LRWS	10 yr avg annual use	Ratio for split between zones HRWS	LRWS	10 yr avg annual use
Zone 4	3,827	908	1,228	56%	60%	60%
Zone 5	3,031	603	809	44%	40%	40%

It was decided that there was no need to split demands and inflows upstream and downstream of Benalla (Zone 1 and 2) as there were no scenarios with changes just to either of these zones and Benalla is not an environmental flow compliance point.

Figure 3-5: Reconfiguration zones

3.8 Environmental flows

3.8.1 Base case environmental flow assumptions

The base case model implements environmental minimum flows as required by the Bulk Entitlement.

Table 3-3: Summary of environmental minimum flows represented in REALM

Location	In REALM
d/s Nillahcootie	30 ML/d or natural Jun-Nov
d/s Broken Weir	22 ML/d or natural Dec-May
d/s of Caseys Weir	25 ML/d or natural Dec-May

3.8.2 Environmental flow compliance points

For modelling purposes, environmental flow compliance points are assumed at the following locations:

Table 3-4: Environmental flow compliance points

Reach	Description	Compliance point
Broken R Reach 1	Lake Nillahcootie to Holland Creek	Broken River d/s of Back Ck Junction
Broken R Reach 2	Hollands Creek to Caseys Weir	Broken River u/s of Caseys Weir
Broken R Reach 3	Caseys Weir to Goulburn River	Broken River d/s of Gowangardie Weir
Broken Ck Reach 1	Caseys Weir to Waggarandall Weir	Broken Creek d/s of Caseys Weir

3.9 Full uptake demands for scenario modelling

REALM demands are available at Water Resource Plan level of development. WRP demands have average annual diversions equal to the Sustainable Diversion limit under historical climate conditions. These demands were adopted for the full uptake case for scenario modelling. This assumption also required re-splitting out D&S demands, applying limit curves, allocations, etc.

3.10 Climate cases for scenario modelling

REALM model inputs already exist for the following climate cases:

- Historic climate
- Inputs adjusted via decile scaling to match post 1975 climate conditions
- Inputs adjusted via decile scaling to match post 1997 climate conditions
- Inputs adjusted according to 2040 low climate change projections using the RCP 8.5 emissions scenario
- Inputs adjusted according to 2040 medium climate change projections using the RCP 8.5 emissions scenario
- Inputs adjusted according to 2040 high climate change projections using the RCP 8.5 emissions scenario

To support scenario modelling for this project inputs were derived for an additional climate case:

- Inputs adjusted according to 2065 high climate change projections using the RCP 8.5 emissions scenario

These inputs were derived in accordance with the DEECA 2020 Climate Change Guidelines.

4. Base case modelling

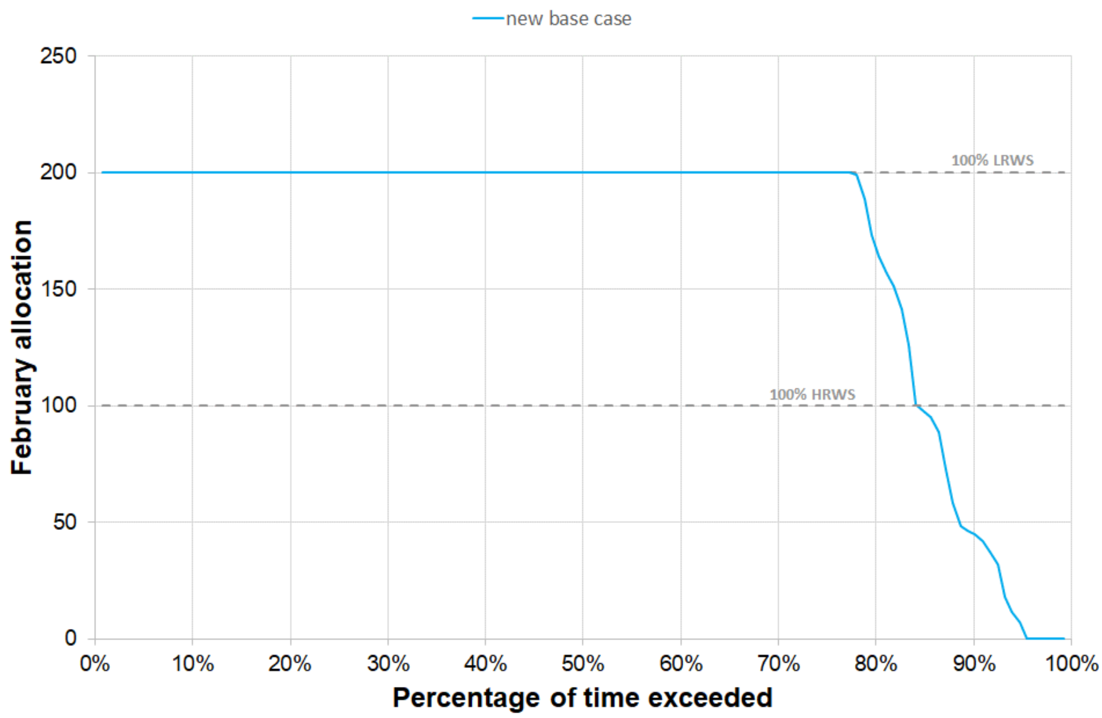
4.1 Results, historic climate case

Reliability is calculated as the percentage of years when February allocations are equal to or greater than 100%. The updated base case model reliability is calculated as 84%. The timeseries of February allocations show that when allocations are less than 100% in February this can persist for multiple years (Figure 4-1).

In order to examine early season performance, September allocations were also extracted from the model as shown in Figure 4-2. It can be seen from this figure that September allocations rarely rise above 81%. This is to do with the way that allocations are calculated. At the start of each month a volume of water available for allocation is calculated based on

- water in storage
- plus a conservative “useful inflow” forecast for the remainder of the season
- plus delivery year to date
- minus allowances over the rest of the season for net evaporation from storage, river losses (including Broken Creek loss provision, transmission losses and operational losses)
- minus passing flows (in excess of operational losses)
- minus urban commitments,
- minus carryover

So to understand why values are pretty constant for September you need to look at the values used in the calculation. At the end of August forecast inflow is 6,880 ML, delivery to date is small at around 300 ML, net evap is around 6,000 ML, river loss is mostly 20,000 ML but sometimes 15,000 ML, and carryover is mostly 7,500 ML but sometimes 6,000 ML. Combining all these numbers with a full Lake Nillahcootie at the end of August gives a volume of around 12,300 ML which translates to a September allocation of 81%. This only varies in years where a lower carryover of 6,000 ML is assumed due to a low allocation the preceding February instead of the usual 7,500 ML, or when Nillahcootie is not full at the end of August.



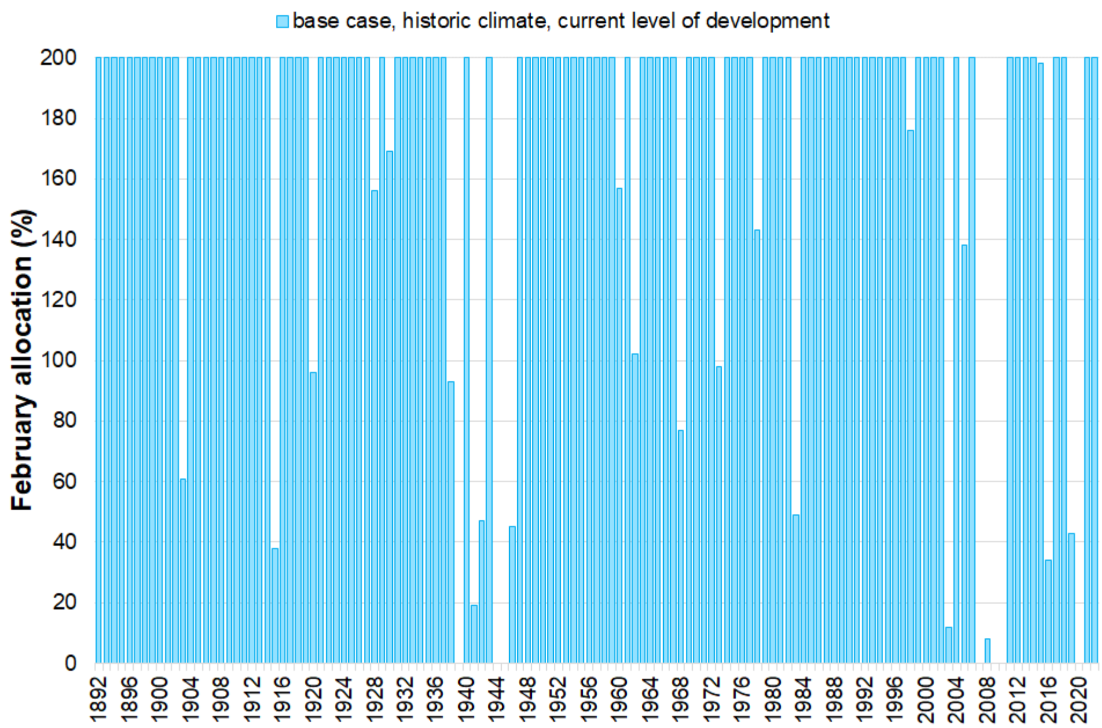
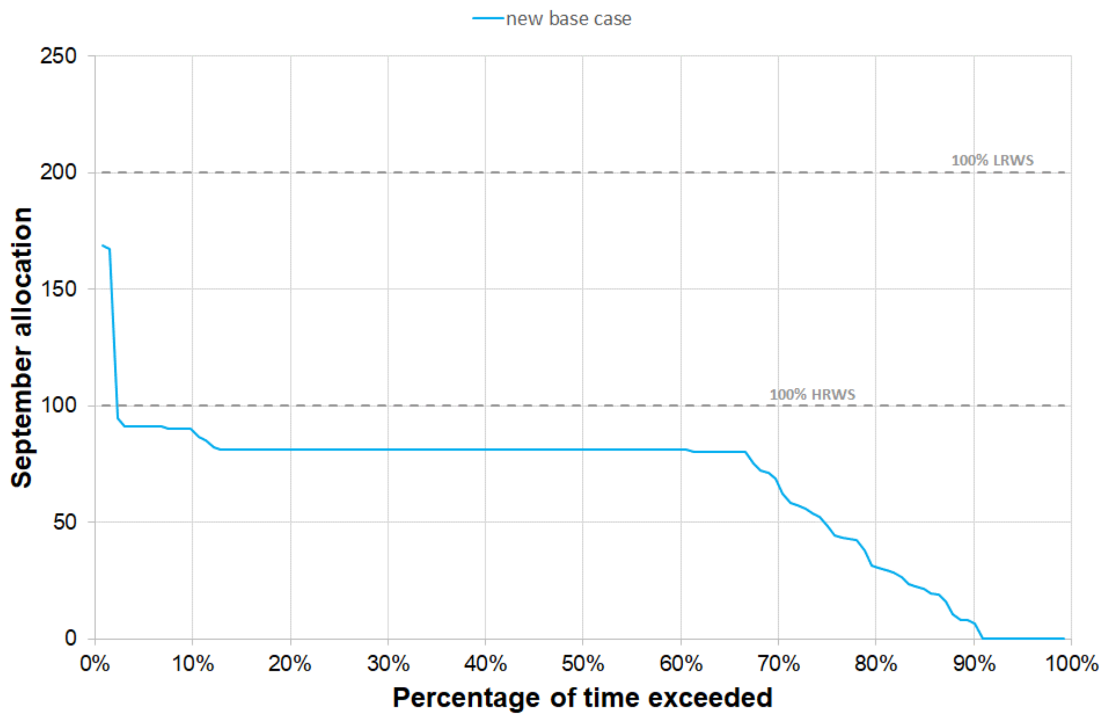


Figure 4-1: Updated base case February allocation (reliability) historic climate case



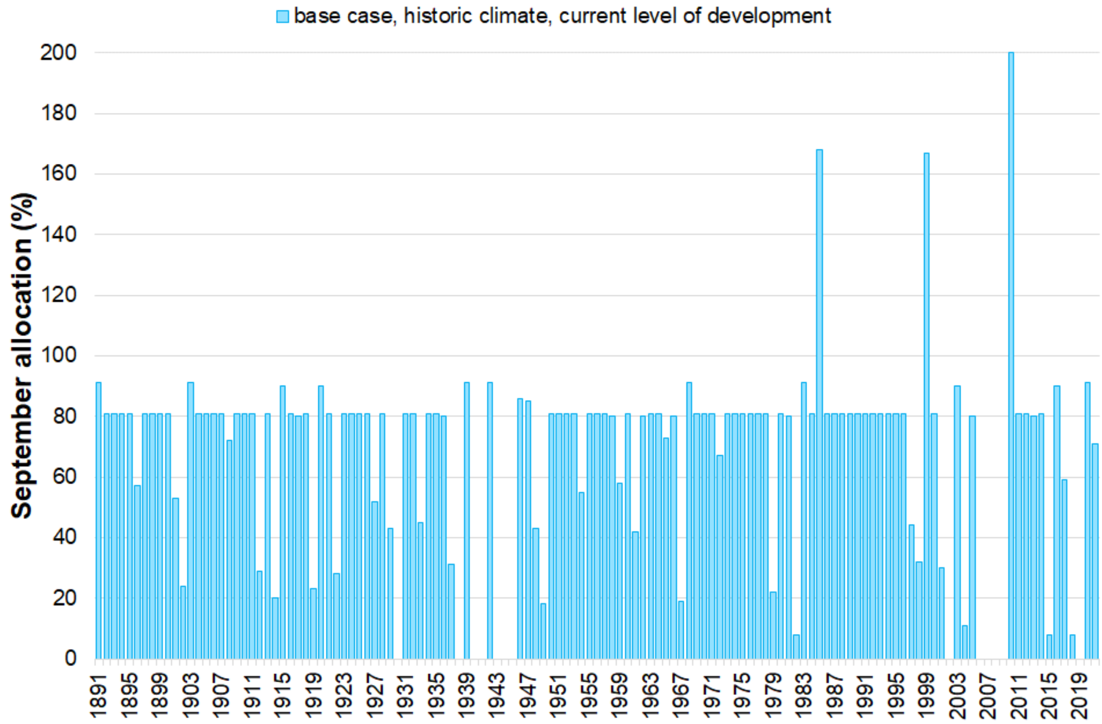


Figure 4-2: Updated base case September allocations, historic climate case

Other key results extracted were unrestricted, restricted and suppled demands, mean annual flow at compliance points and modelled losses.

Table 4-1: Demand results, base case, historic climate, current demands

	unrestricted	restricted	supplied
Irrigation demands (ML/yr)	3,683	3,462	3,462
D&S demands (ML/yr)	793	677	677

Table 4-2: Mean annual flow at compliance points, base case, historic climate, current demands

	Compliance point	Mean annual flow (ML/yr)
Broken R reach 1	Broken River d/s of Back Ck Junction	69,367
Broken R reach 2	Broken River u/s of Caseys Weir	199,532
Broken R reach 3	Broken River d/s of Gowangardie Weir	225,757
Broken Ck reach 1	Broken Creek d/s of Caseys Weir	5,015

Table 4-3: Mean annual loss, base case, historic climate, current demands

Zone	Reach / location	Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236
Zone 1	Hollands Creek	2,359
Zone 2	Stockyard Creek	292
	Total upstream of Caseys Weir	**6,887**
	Total downstream of Caseys Weir	**8,374**
Zone 3	Broken Ck loss provision	4,323

4.2 Results, future climate and full demand

The base case model was run under a number of future climate cases and with full demand. Figure 4-3 shows the impact this has on February allocations and hence reliability (Table 4-4) and demand supplied (Table 4-5). The magnitude of flows at eflow compliance points (as defined in the relevant FLOWS studies) is also impacted (Table 4-6), as is the magnitude of losses. In general results show that future climate has a much greater impact on the system than an increase in demands. It also shows the contribution that the underutilisation of available resources has to system reliability.

Table 4-4: Base case reliability under future climate and demand

	Climate case					Historic climate, full demand
	Historic	Post 75	Post 97	2040 high	2065 high	
Current demand	84%	79%	63%	66%	48%	78%

Table 4-5: Base case supplied demand under future climate and demand

	Climate case					Historic climate, full demand
	Historic	Post 75	Post 97	2040 high	2065 high	
Irrigation demand	3,462	3,422	3,219	3,251	2,963	7,797
D&S demand	677	657	593	603	522	624

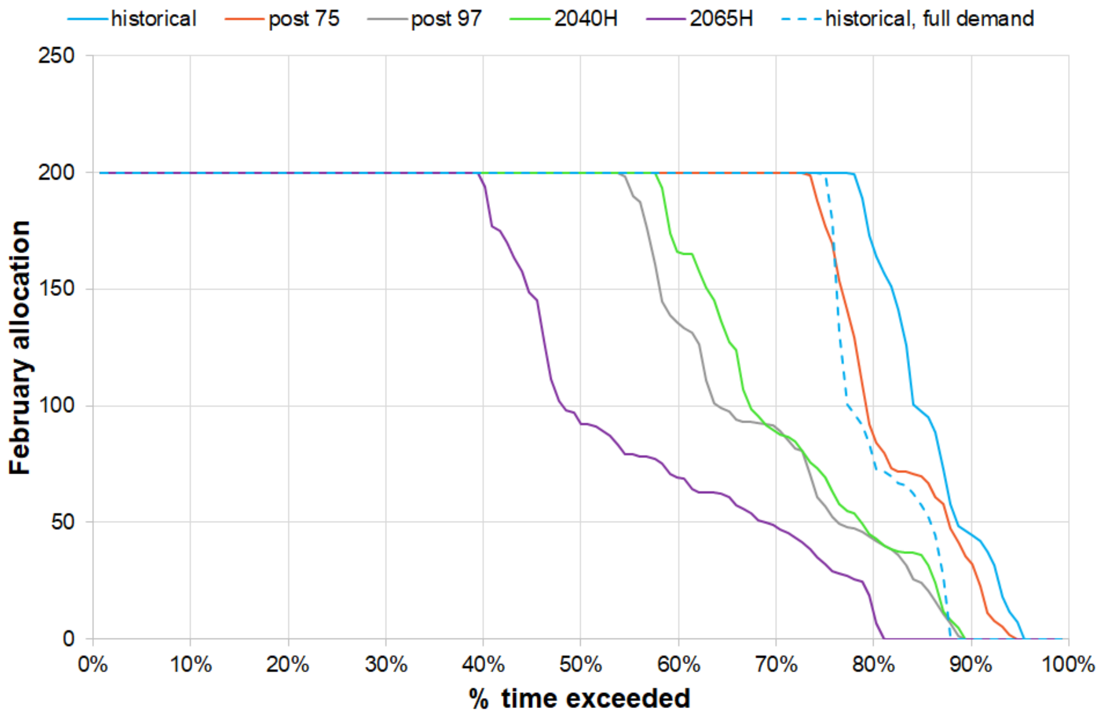


Figure 4-3: Base case February allocation (reliability) under future climate and full demand

Table 4-6: Base case mean annual flow at compliance points under future climate and full demand

Reach	Climate case Historic	Post 75	Post 97	2040 high	2065 high	Historic climate, full demand
Broken R reach 1	69,367	59,505	39,505	38,193	28,373	69,374
Broken R reach 2	199,532	178,252	115,133	113,403	86,832	198,005
Broken R reach 3	225,757	200,161	123,956	122,075	89,288	219,973
Broken Ck reach 1	5,015	4,957	4,746	4,781	4,506	5,645

Table 4-7: Base case losses under future climate and demand

Reach / location	Climate case Historic	Post 75	Post 97	2040 high	2065 high	Historic climate, full demand
Broken Weir	4,236	4,298	3,798	3,399	2,766	5,016
Hollands Ck	2,359	2,027	1,610	1,298	1,012	2,359
Stockyard Ck	292	286	257	182	142	292
Total u/s Caseys	**6,887**	**6,612**	**5,665**	**4,880**	**3,920**	**7,667**
Total d/s Caseys	**8,374**	**8,194**	**7,449**	**7,402**	**6,666**	**9,143**
Broken Ck loss provision	4,323	4,277	4,116	4,143	3,931	4,284

5. Scenario modelling

5.1 Broken Reconfiguration zone based scenarios

Proposed zone based scenarios have been developed by the project team. These are:

- Scenario 1: Do nothing (base case).
- Scenario 2: Transition out of irrigation (whole district).
- Scenario 3: Remove or reconnect all services in Zone 5.
- Scenario 4: Remove or reconnect all services in Zone 3.
- Scenario 5: Mokoan Pipeline supply channel efficiency improvements.
- Scenario 6: All zones reconfiguration opportunities.
- Scenario 7: Improving D&S Reliability
- Scenario 8: Combined Scenario 3, 4, 5, 6 & 7
- Scenario 9: Combined Scenario 3, 4, 5, 6 & 7 plus remove or reconnect all services from Zone 4

Figure 5-1: Reconfiguration zones (Sequana)

5.1.1 Use of new environmental shares

Environmental minimum flows are specified in the model as required by the GMW Broken Bulk Entitlement. For scenarios where water shares are transferred to the environment an assumption needed to be made about how that extra water would be used.

For this project it was agreed in consultation with Goulburn Broken CMA that if additional water was available baseflows and freshes would be supplied as summarised below:

- Summer autumn low flow requirement on all Broken River reaches to be modelled as 100 ML/d, no or natural case (1st priority)
- Winter spring low flow requirement on all Broken River reaches to be modelled as 150 ML/d, no or natural case (2nd priority)
- Broken Creek low flow requirements to be modelled, 10 ML/d summer-autumn, 15 ML/d winter-spring.
- April fresh to be added to deliver 450 ML/d for 2 days Broken River Reach 1 only (3rd priority)
- November fresh to be added to deliver 4500 ML/d for 2 days on all Broken R reaches (4th priority)

This was approximated in the model by imposing the Reach 1 low flow requirement downstream of Lake Nillahcootie and the Broken Creek low flow requirement downstream of Caseys Weir, and gradually increasing the duration it was required in order to use up the volume of new HRWS held by the environment. This was an iterative process.

5.1.2 Summary of model assumptions for scenario modelling

The key assumptions made in the model for each scenario are summarised below. Each scenario is discussed in more detail in the following sections.

Table 5-1: Summary of model assumptions for scenario modelling

Model element	Scenario 2 – no irrigation	Scenario 3 – no zone 5	Scenario 4 – no Zone 3
Irrigation HRWS	Set to zero	Zone 5 set to zero. Transfer 430 ML to Zone 4	Zone 3 set to zero. Transfer 215 ML to Zone 4
D&S HRWS	No change from base case	Zone 5 set to zero	Zone 3 set to zero
Irrigation demand	Set to zero	Zone 5 set to zero. Factor up Zone 4 demand by ratio of old and new HRWS (+8%)	Zone 3 set to zero. Factor up Zone 4 demand by ratio of old and new HRWS (+4%)
D&S demand	No change from base case	Zone 5 set to zero	Zone 3 set to zero
Volume of HRWS redistributed	15,215 ML	2,968 ML	1,302 ML
Share of HRWS to environment	90% (13,719 ML) determined by targeting reliability of 90%	50% (1,484 ML)	50% (651 ML)
Broken Ck loss provision	2,920 ML	No change from base case	Set to zero
IVT	Set to zero	No change (function of in-valley use)	No change (function of in-valley use)
Allocation calculation	Reduce transmission and operating loss allowance by the ratio of old and new consumptive HRWS (95%)	Reduce transmission and operating loss allowance by ratio of old and new consumptive HRWS (20%)	Reduce transmission and operating loss allowance by ratio of old and new consumptive HRWS (15%)
Changes under climate change runs (post 97, 2065H)	none	Recalculate additional eflow release from storage	Recalculate additional eflow release from storage
Changes under full demand run	The same as the current case	Divide irrig demands by 0.4 Recalculate additional eflow release from storage	Divide irrig demands by 0.4 Recalculate additional eflow release from storage
Prioritised additional eflow release from storage	Historic, Post 97, 2065 High climate cases Broken River summer-autumn low 100 ML/d (Dec-May applied) Broken Creek summer-autumn low 10 ML/d (Dec-May applied) Broken River winter-spring low 150 ML/d (15 days in Nov applied) Broken Creek winter-spring low 15 ML/d (15 days in Nov applied)	Historic climate case Broken River summer-autumn low 100 ML/d (Jan applied) Broken Creek summer-autumn low 10 ML/d (Jan applied) Post 97 climate case Broken River summer-autumn low 100 ML/d (Jan applied) Broken Creek summer-autumn low 10 ML/d (Jan applied) Full demand, historic climate Broken River summer-autumn low 100 ML/d (Jan, Feb, Dec applied) Broken Creek summer-autumn low 10 ML/d (Jan, Feb Dec applied) 2065 High climate case Broken River summer-autumn low 100 ML/d (Jan, Feb applied) Broken Creek summer-autumn low 10 ML/d (Jan, Feb applied)	Historic climate case Broken River summer-autumn low 100 ML/d (Jan applied) Broken Creek summer-autumn low 10 ML/d (Jan applied) 2065 H, Post 97 climate cases Broken River summer-autumn low 100 ML/d (23 days in Jan applied) Broken Creek summer-autumn low 10 ML/d (23 days in Jan applied) Full demand, historic climate Broken River summer-autumn low 100 ML/d (22 days in Jan applied) Broken Creek summer-autumn low 10 ML/d (22 days in Jan applied)
Model element	**Scenario 5 - Lake Mokoan pipeline channel savings**	**Scenario 6 – systemwide reduction**	**Scenario 7 – Improving D&S Reliability**
Irrigation HRWS	No change from base case	Reduce irrig HRWS as per the table provided (see below). Reduction in unallocated HRWS spread across reaches in ratio of existing HRWS	No change from base case
D&S HRWS	No change from base case	No change from base case	No change from base case
Irrigation demand	Reduce Lake Mokoan demands by 90 ML/yr	No change from base case	No change from base case
D&S demand	No change from base case	No change from base case	Allow D&S demand to access 400 ML reserve in Nillahcootie if demand cannot be fully supplied due to low/zero allocations or inadequate unregulated inflows downstream of Nillahcootie. 400 ML resets at the start of each water year
Volume of HRWS redistributed	n/a	6,692 ML	n/a
Share of HRWS to environment	n/a	50% (3,364 ML)	n/a
Broken Ck loss provision	No change from base case	factor by ratio of old and new Broken Ck irrig demand (60%)	No change from base case
IVT	No change (function of in-valley use)	No change (function of in-valley use)	No change (function of in-valley use)
Allocation calculation	No change from base case	Reduce transmission and operating loss allowance by ratio of old and new consumptive HRWS (50%)	Reduce available water by volume remaining in the D&S reserve
Changes under climate change	No change from base case	Recalculate additional eflow release from storage	Check if 400 ML reserve is big enough, change if required

Changes under full demand	Pick up full demands derived for base case Subtract 90 ML/yr from Lake Mokoan demands using same approach as for current case	Divide irrig demands by 0.4 Recalculate additional eflow release from storage	Divide irrig demands by 0.4 Check if 400 ML reserve is big enough, change if required
Prioritised additional eflow release from storage	n/a	Historic climate case Broken River summer-autumn low 100 ML/d (Dec-Feb and 23 days in March applied) Broken Creek summer-autumn low 10 ML/d ((Dec-Feb and 23 days in March applied) 2065 H climate case Broken River summer-autumn low 100 ML/d (Dec-Feb and 23 days in March applied) Broken Creek summer-autumn low 10 ML/d ((Dec-Feb and 23 days in March applied) Post 97 climate case Broken River summer-autumn low 100 ML/d (Dec-Feb and 10 days in March applied) Broken Creek summer-autumn low 10 ML/d ((Dec-Feb and 10 days in March applied) Full demand, historic climate Broken River summer-autumn low 100 ML/d (60% Nov, Dec-Mar) Broken Creek summer-autumn low 10 ML/d ((60% Nov, Dec-Mar)	n/a

Model element	Scenario 8 ; Combined Scenario 3, 4, 5, 6 & 7
Irrigation HRWS	Zone 5 set to zero. Transfer 430 ML to Zone 4, Zone 3 set to zero. Transfer 215 ML to Zone 4 Zone 1 reduced by 1079 ML, Zone 2 reduced by 1051 ML, Zone 4 reduced by 1301 ML Reduction in unallocated HRWS spread across reaches in ratio of existing HRWS
D&S HRWS	Zone 5 set to zero, Zone 3 set to zero All other zones unchanged
Irrigation demands	Zone 5 set to zero. Factor up Zone 4 demand by ratio of old and new HRWS (+8%) Zone 3 set to zero. Factor up Zone 4 demand by ratio of old and new HRWS (+4%) Reduce Lake Mokoan demands by 90 ML/yr All other zones reduce by ratio of old and new HRWS
D&S demand	Zone 5 set to zero, Zone 3 set to zero Allow D&S demand to access 400 ML reserve in Nillahcootie if demand cannot be fully supplied due to low/zero allocations or inadequate unregulated inflows downstream of Nillahcootie. 400 ML resets at the start of each water year
Volume of HRWS redistributed	9,112 ML
Share of HRWS to environment	50% (4,556.2 ML)
Broken Ck loss provision	Set to zero
IVT	No change (function of in-valley use)
Allocation calculation	Reduce transmission and operating loss by ratio of old and new consumptive HRWS
Changes under climate change	Check if 400 ML reserve is big enough, change if required Recalculate additional eflow release from storage
Changes under full demand	Divide irrig demands by 0.4 Check if 400 ML reserve is big enough, change if required Recalculate additional eflow release from storage
Prioritised additional eflow release from storage	Historic climate case Broken River summer-autumn low 100 ML/d (15 days in Dec and Jan and Feb applied) Broken Creek summer-autumn low 10 ML/d (15 days in Dec and Jan and Feb applied) Post 97 climate case Broken River summer-autumn low 100 ML/d (15 days in Dec and Jan and Feb applied) Broken Creek summer-autumn low 10 ML/d (15 days in Dec and Jan and Feb applied) 2065 High climate case Broken River summer-autumn low 100 ML/d (Dec- Feb applied) Broken Creek summer-autumn low 10 ML/d (Dec- Feb applied) Full climate case

	Broken River summer-autumn low 100 ML/d (20% of Nov, Dec- Feb applied) Broken Creek summer-autumn low 10 ML/d (20% of Nov, Dec- Feb applied)
Model element	**Scenario 9 - Combined Scenario 3, 4, 5, 6 & 7 plus no Zone 4 demand**
Irrigation HRWS	Zone 3, 4 & 5 set to zero Zone 1 reduced by 1,079 ML, Zone 2 reduced by 1,051 ML Reduction in unallocated HRWS spread across reaches in ratio of existing HRWS
D&S HRWS	Zone 3, 4 & 5 set to zero All other zones unchanged
Irrigation demands	Zone 3, 4 & 5 set to zero Reduce Lake Mokoan demands by 90 ML/yr All other zones reduce by ratio of old and new HRWS
D&S demand	Zone 3, 4 & 5 set to zero Allow D&S demand to access 400 ML reserve in Nillahcootie if demand cannot be fully supplied due to low/zero allocations or inadequate unregulated inflows downstream of Nillahcootie. 400 ML resets at the start of each water year
Volume of HRWS redistributed	12,674 ML
Share of HRWS to environment	50% (6,337 ML)
Broken Ck loss provision	Set to zero
IVT	No change (function of in-valley use)
Allocation calculation	Reduce transmission and operating loss by ratio of old and new consumptive HRWS
Changes under climate change	Check if 400 ML reserve is big enough, change if required Recalculate additional eflow release from storage
Changes under full demand	Divide irrig demands by 0.4 Check if 400 ML reserve is big enough, change if required Recalculate additional eflow release from storage
Prioritised additional eflow release from storage	<u>Historic climate case</u> Broken River summer-autumn low 100 ML/d (Dec, Jan and 25 days in Feb applied) Broken Creek summer-autumn low 10 ML/d (Dec, Jan and 25 days in Feb applied) <u>2065 High climate case</u> Broken River summer-autumn low 100 ML/d (Dec- 26 April applied) Broken Creek summer-autumn low 10 ML/d (Dec- 26 April applied) <u>Full climate case</u> Broken River summer-autumn low 100 ML/d (Dec- 7 May applied) Broken Creek summer-autumn low 10 ML/d (Dec- 7 May applied)

5.1.3 Scenario 2 – Transition out of irrigation

This scenario has been run to provide a "bookend" to the base case and does not reflect a realistic scenario to be implemented.

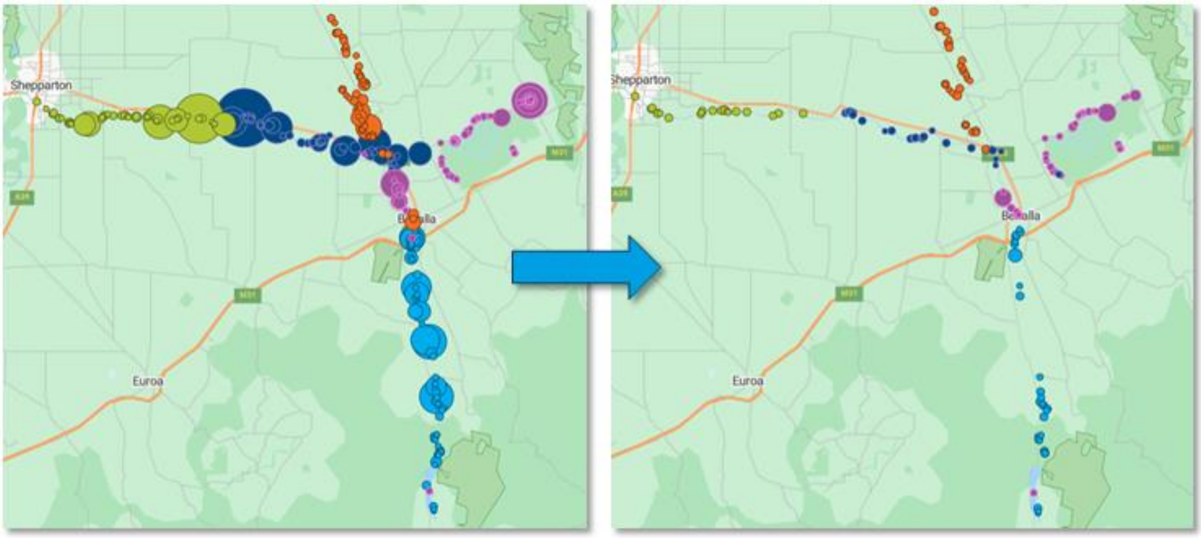


Figure 5-2: Scenario 2: Transition out of irrigation (Sequana)

For this scenario all irrigation demands are set to zero and D&S demands are retained at current magnitude. Irrigation entitlements are either redistributed to increase reliability of the remaining D&S users or shifted to the environment in a share such that HRWS reliability increases to 90%. This turned out to be 10% retired, 90% to the environment (13,719 ML HRWS).

Table 5-2: Scenario 2 redistribution of water shares

	Irrigation entitlement relinquished (ML)	Redistribution to the environment (ML)	Redistribution to reliability (ML)
HRWS	15,215	13,719	1,496
LRWS	3,254	2,929	325

Changes in the model are summarised in Table 5-1. Broken Ck loss provision was reduced to 2,920 ML/yr. This is based on the volume needed to supply remaining D&S demand remains on the creek, assuming an average flow of around 8 ML/d. This was distributed across the year as 5 ML/d in winter, 8 ML/d in spring and autumn and 10 ML/d in summer. Inter Valley Trade (IVT) is set to zero, and the transmission and operating loss allowance in the allocation calculation is reduced by the ratio of old and new consumptive HRWS (95%).

The new environmental entitlement was used to supply low flows downstream of Nillahcootie until the volume of HRWS redistributed to the environment is used. Under historic climate this required the supply of summer-autumn low flow of 100 ML/d all summer and autumn, and supply of the winter-spring low flow of 150 ML/d for 15 days in November. Corresponding low flows in Broken Creek were also supplied (10 ML/d in summer-autumn and 15 ML/d in winter spring).

Results show that reliability (percentage of years with 100% HRWS in February) increases from 84% to 90% under this scenario (Figure 5-3). September allocations are also substantially higher than the base case (Figure 5-4).

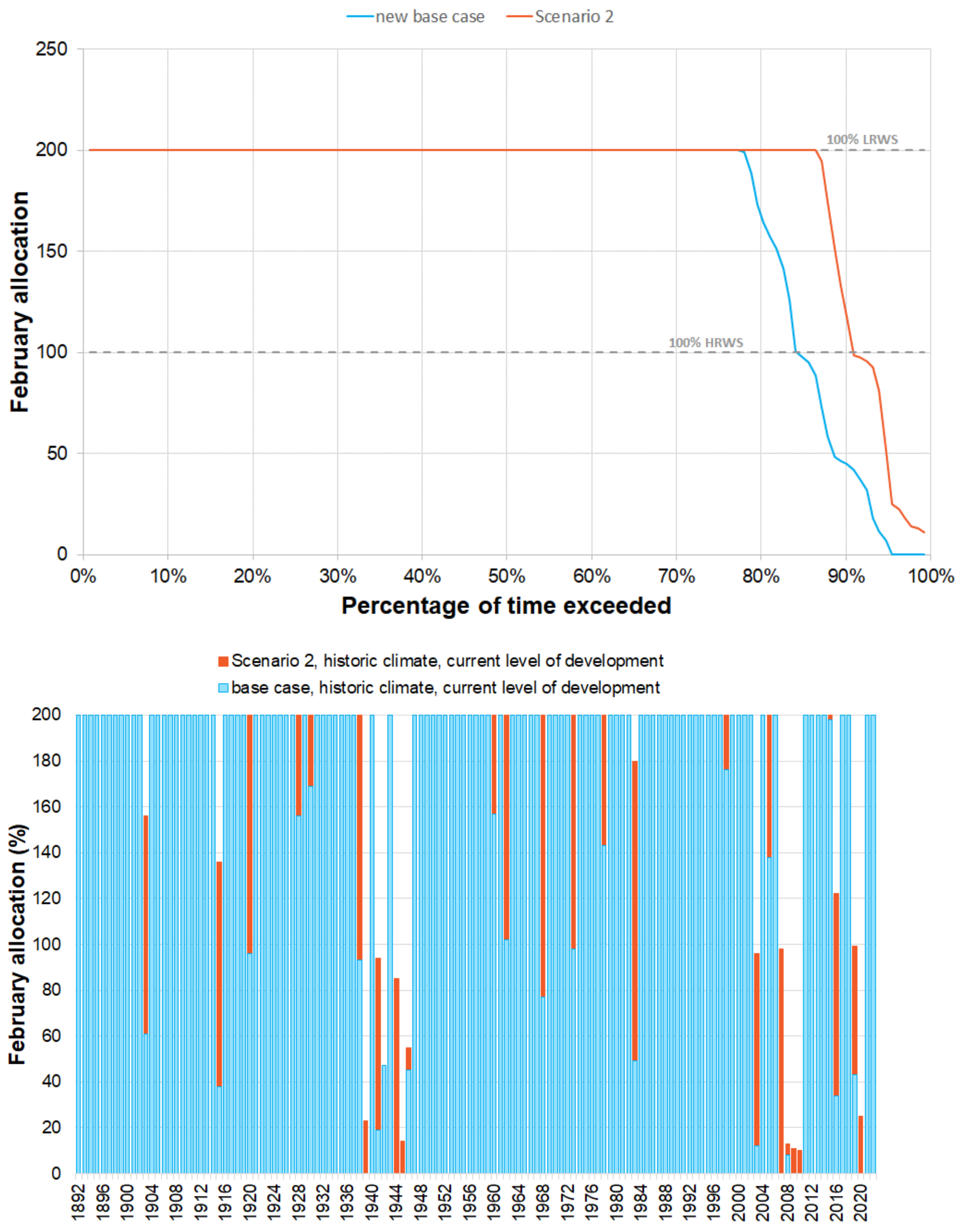


Figure 5-3: Scenario 2: February allocation (reliability) compared to the base case, historic climate

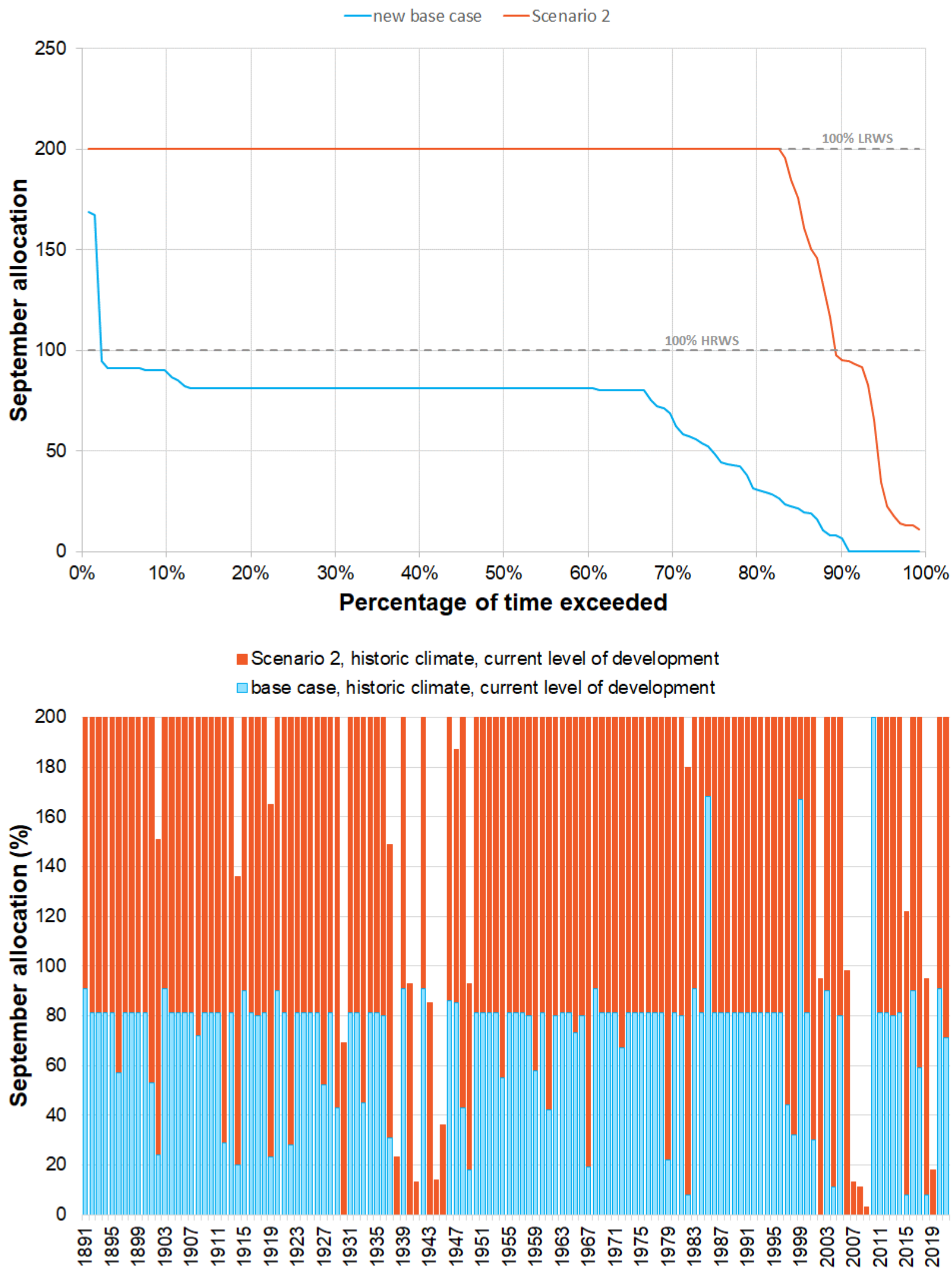


Figure 5-4: Scenario 2: September allocation (reliability) compared to the base case, historic climate

Results show that more D&S demand can be supplied under this scenario because of greater allocations, and that river flows are not significantly different, this is because water that is now owned by the environment is still released down the river to satisfy environmental flow requirements. As a result losses are also not significantly different with the exception of the Broken creek loss provision which is reduced as irrigation demand no longer needs to be supplied.

Table 5-3: Demand results, Scenario 2, historic climate, current demands

	Base case supplied	Scenario 2 supplied
Irrigation demands (ML/yr)	3,462	0
D&S demands (ML/yr)	677	716

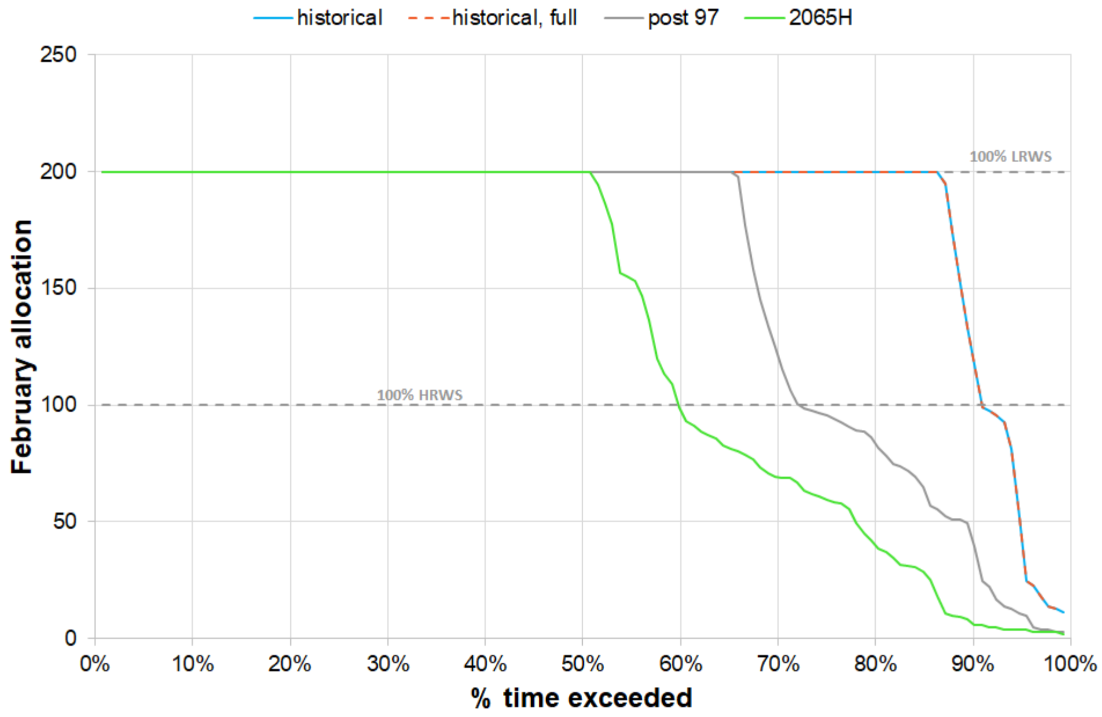
Table 5-4: Mean annual flow at compliance points, Scenario 2, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 2 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,480
Broken R reach 2	199,532	199,764
Broken R reach 3	225,757	228,096
Broken Ck reach 1	5,015	4,704

Table 5-5: Mean annual loss, Scenario 2, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 2 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	4,699
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**7,350**
Zone 4	at Caseys Weir	8,340	8,818
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	0
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	0
	Total downstream of Caseys Weir	**8,374**	**8,818**
Zone 3	Broken Creek loss provision	4,323	2,894

Scenario results under climate change and full demand show that similar to the base case allocations reduce significantly under climate change.



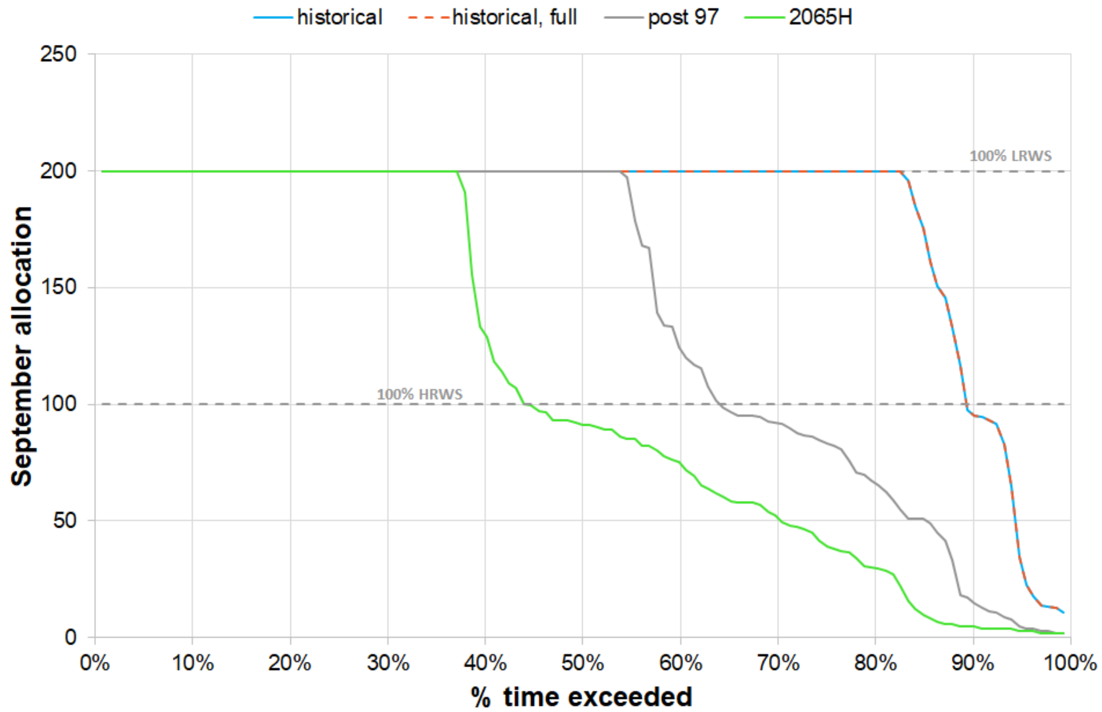


Figure 5-5: Scenario 2 February and September allocations under future climate and full demand

5.1.4 Scenario 3 – Remove or reconnect all services in Zone 5

For this scenario all demands in Zone 5 are set to zero or reconnected elsewhere.

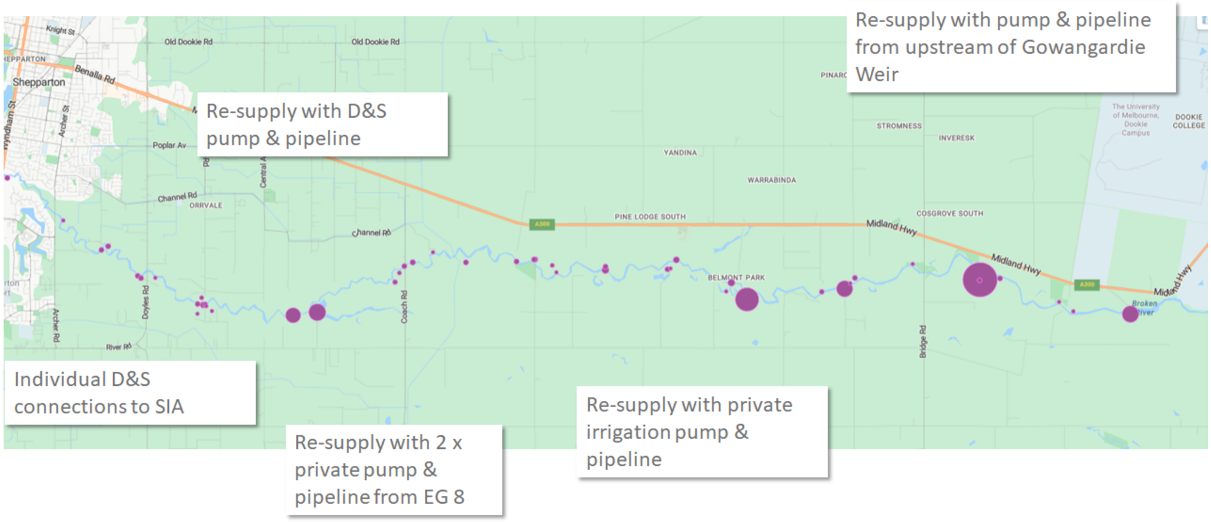


Figure 5-6: Scenario 3: Remove or reconnect all services in Zone 5 (Sequana)

In this case all Zone 5 irrigation and D&S demands are set to zero. 430 ML of HRWS irrigation entitlements was transferred to Zone 4 and the Zone 4 irrigation demand was increased by the ratio of old and new HRWS (+8%). 50% of the HRWS was redistributed to increase reliability, and 50% was redistributed to the environment.

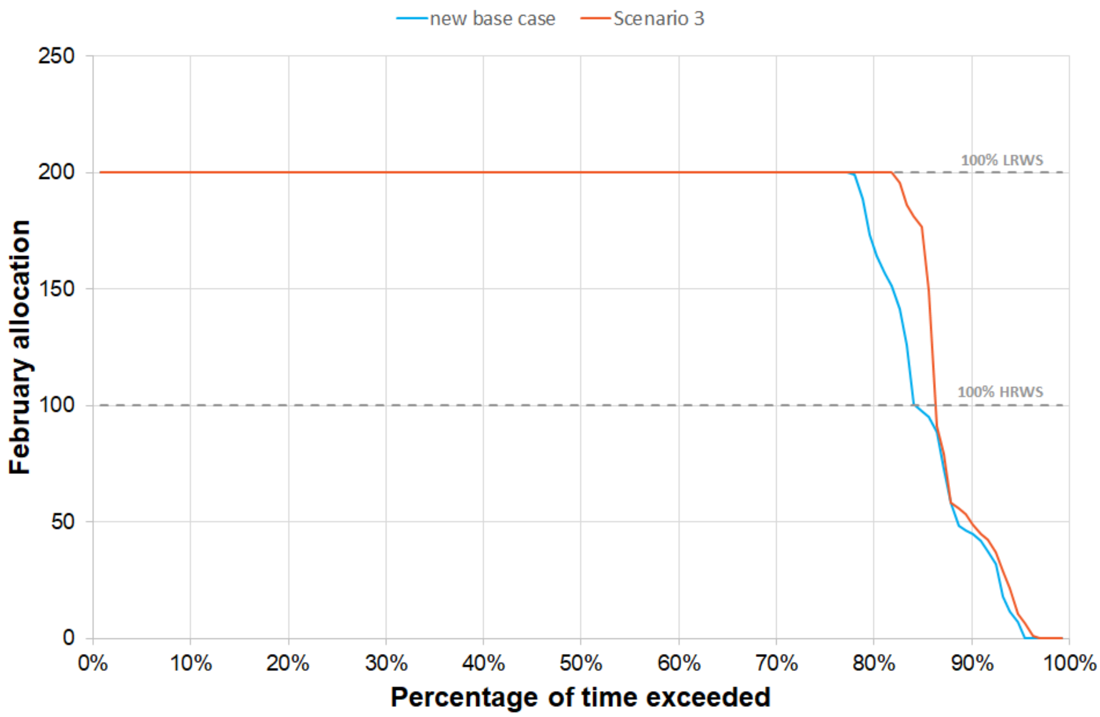
Table 5-6: Scenario 3 redistribution of water shares

	Irrigation entitlement relinquished (ML)	Redistribution to the environment (ML)	Redistribution to reliability (ML)
HRWS	2,968	1,484	1,484
LRWS	709	354	354

Changes in the model are summarised in Table 5-1. Transmission and operating loss assumptions used in the allocation calculation were reduced by the ratio of old and new consumptive HRWS (-20%).

The new environmental entitlement was used to supply low flows downstream of Nillahcootie until shares are used. Under historic climate and current demand this required the supply of summer-autumn low flow of 100 ML/d during January. Corresponding low flows in Broken Creek were also supplied (10 ML/d in summer-autumn).

Results show that reliability (percentage of years with 100% HRWS in February) increases slightly from 84% to 85% under this scenario (Figure 5-7). September allocations are also substantially higher than the base case (Figure 5-8).



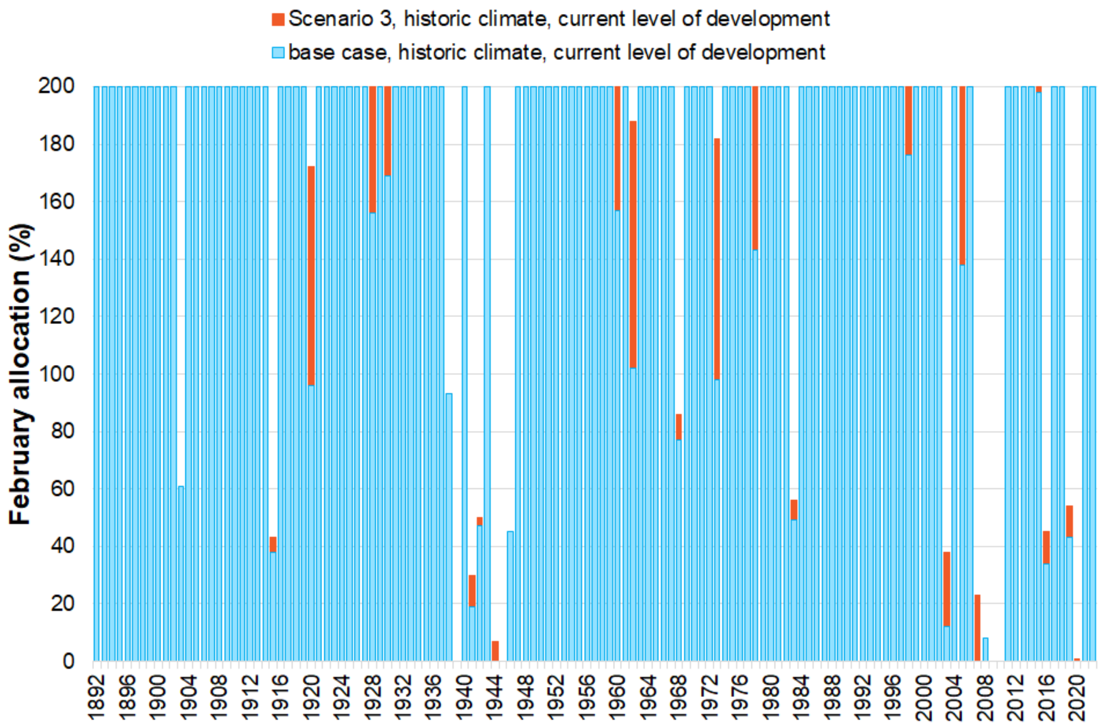


Figure 5-7: Scenario 3: February allocation (reliability) compared to the base case, historic climate

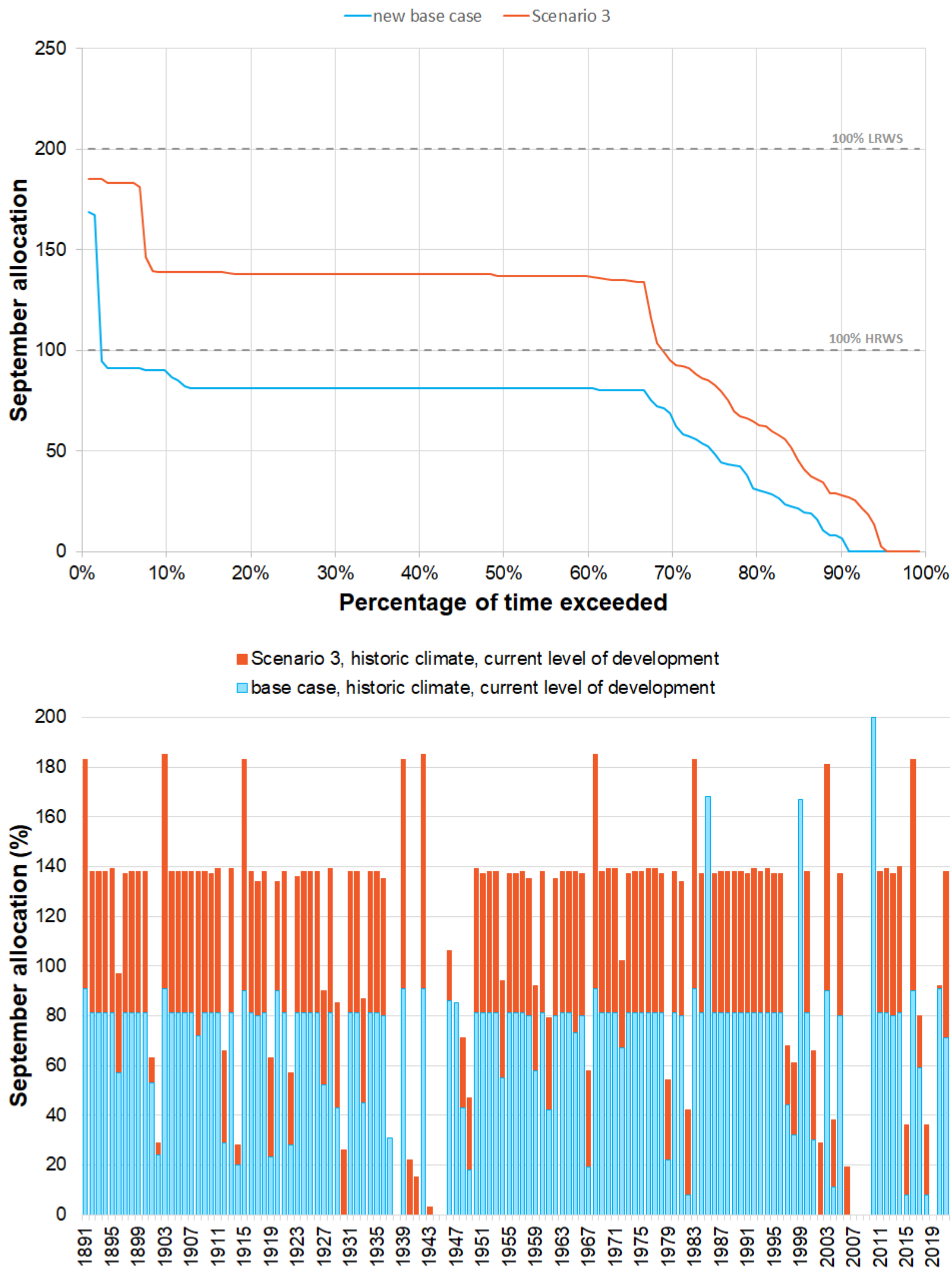


Figure 5-8: Scenario 3: September allocation (reliability) compared to the base case, historic climate

Results show that less irrigation and D&S demand exist in the system and hence less is supplied under this scenario. Again river flows are very similar to the base case because water that is now owned by the environment is still released down the river to satisfy environmental flow requirements. As a result losses are also are not significantly different.

Table 5-7: Demand results, Scenario 3, historic climate, current demands

	Base case supplied	Scenario 3 supplied
Irrigation demands (ML/yr)	3,462	2,767
D&S demands (ML/yr)	677	606

Table 5-8: Mean annual flow at compliance points, Scenario 3, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 3 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,397
Broken R reach 2	199,532	199,622
Broken R reach 3	225,757	226,592
Broken Ck reach 1	5,015	5,125

Table 5-9: Mean annual loss, Scenario 3, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 3 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	4,170
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**6,821**
Zone 4	at Caseys Weir	8,340	8,269
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	24
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	0
	Total downstream of Caseys Weir	**8,374**	**8,292**
Zone 3	Broken Creek loss provision	4,323	4,334

Scenario results under climate change and full demand show that similar to the base case, allocations reduce significantly under climate change.

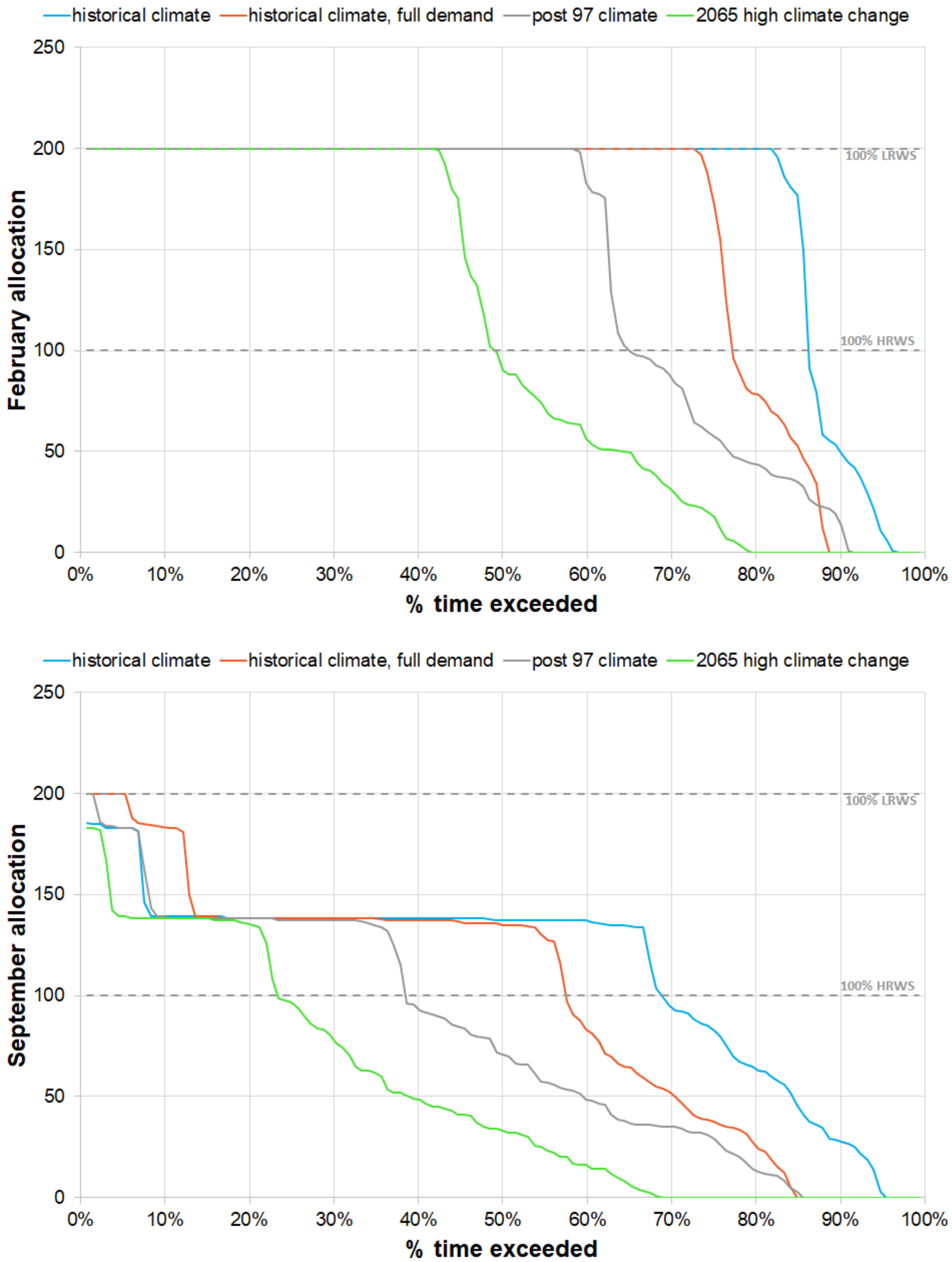


Figure 5-9: Scenario 3 February and September allocations under future climate and full demand

5.1.5 Scenario 4 – Remove or reconnect all services in Zone 3

For this scenario all demands in Zone 3 are set to zero or reconnected elsewhere.

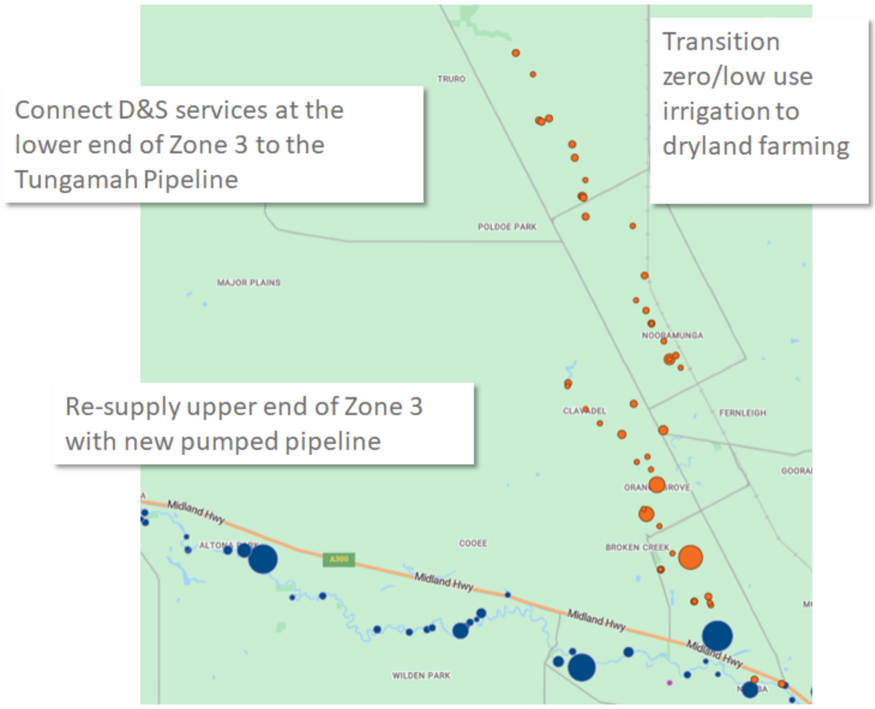


Figure 5-10: Scenario 4: Remove or reconnect all services in Zone 3 (Sequana)

In this case all Zone 3 irrigation and D&S demands were set to zero. 215 ML of HRWS irrigation entitlements is transferred to Zone 4, and the Zone 4 irrigation demand was increased by the ratio of old and new HRWS (+4%). 50% of the HRWS was redistributed to increase reliability, and 50% was redistributed to the environment.

Table 5-10: Scenario 4 redistribution of water shares

	Irrigation entitlement relinquished (ML)	Redistribution to the environment (ML)	Redistribution to reliability (ML)
HRWS	1,302	651	651
LRWS	304	152	152

Changes in the model are summarised in Table 5-1. Broken Creek loss provision was set to zero, and transmission and operating loss assumptions used in the allocation calculation were reduced by the ratio of old and new consumptive HRWS (-15%).

The new environmental entitlement was used to supply low flows downstream of Nillahcootie until the volume of HRWS redistributed to the environment is used. This required the supply of summer-autumn low flow of 100 ML/d during January. Corresponding low flows in Broken Creek were also supplied (10 ML/d in summer-autumn).

Results show that reliability (percentage of years with 100% HRWS in February) increases slightly from 84% to 85% under this scenario (Figure 5-11). September allocations are also substantially higher than the base case (Figure 5-12).

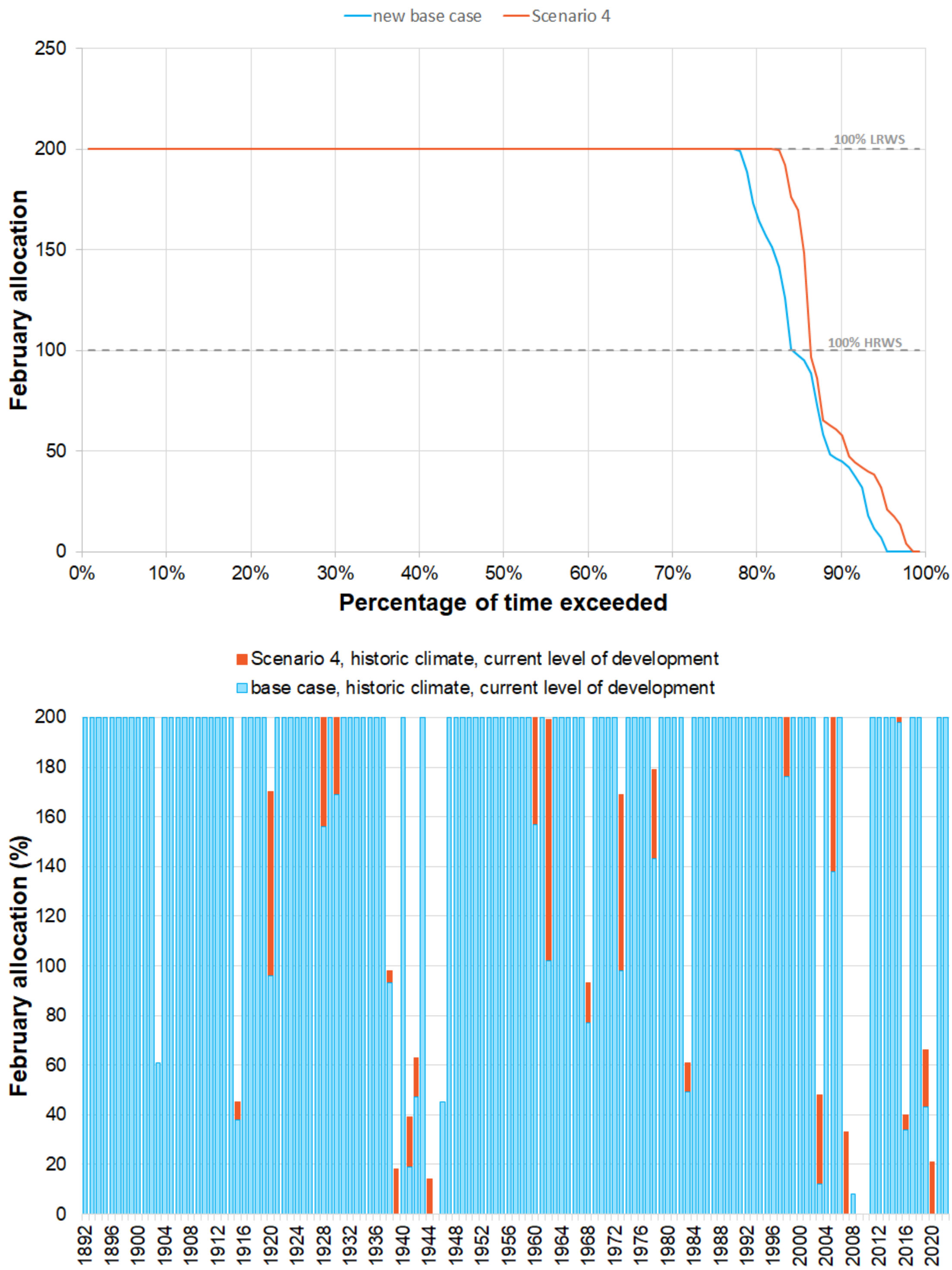


Figure 5-11: Scenario 4: February allocation (reliability) compared to the base case, historic climate

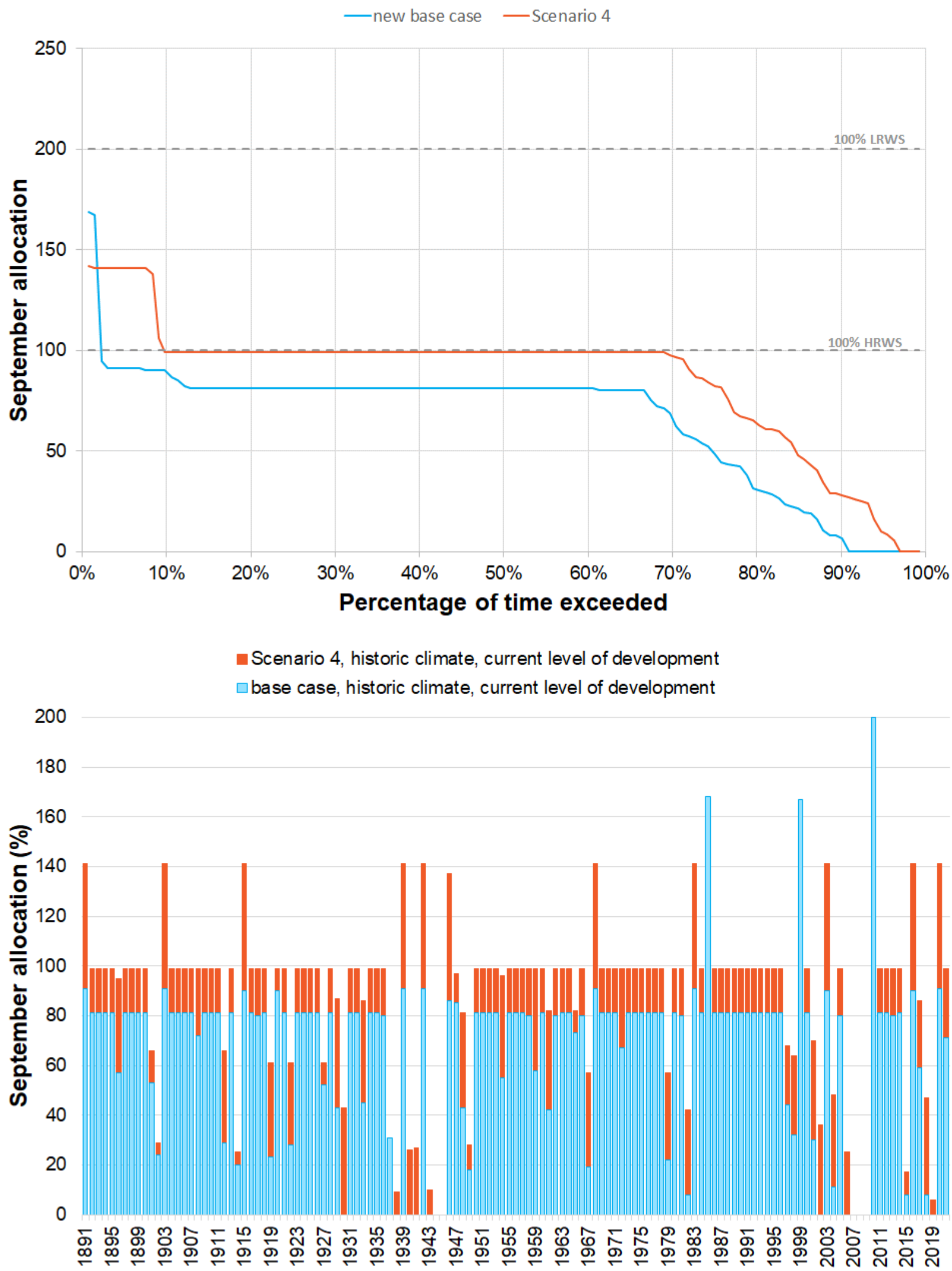


Figure 5-12: Scenario 4: September allocation (reliability) compared to the base case, historic climate

Results show that less irrigation and D&S demand exist in the system and hence less is supplied under this scenario. Again river flows are very similar to the base case because water that is now owned by the environment is still released down the river to satisfy environmental flow requirements. As a result Broken River losses are also not significantly different but Broken Creek loss provision is now zero.

Table 5-11: Demand results, Scenario 4, historic climate, current demands

	Base case supplied	Scenario 4 supplied
Irrigation demands (ML/yr)	3,462	2,991
D&S demands (ML/yr)	677	606

Following completion of modelling it was decided that for scenarios where there are no services in Zone 3 (scenarios 4, 8 and 9) it would be desirable to provide mitigation water in addition to the environmental low flows provided. Instead of re-running these scenarios, modelled flows in Broken River Reach 3 and Broken Creek Reach 1 were adjusted (post processed) to allow for mitigation water sent down Broken Creek. The volume of mitigation water allowed was calculated for each model timestep as follows:

> *If Broken River Reach 3 flow for the scenario is greater than reach 3 flow under the base case then the excess will be sent down Broken Creek as mitigation water, a a volume not exceeding the flow down Broken Creek under the base case.*

Modelled flows in Broken River Reach 3 and Broken Creek Reach1 were then reduced and increased accordingly.

Table 5-12: Mean annual flow at compliance points, Scenario 4, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 4 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,387
Broken R reach 2	199,532	199,791
Broken R reach 3	225,757	227,683*
Broken Ck reach 1	5,015	3,068*

* Modelled flow results post processed

Table 5-13: Mean annual loss, Scenario 4, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 4 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	3,971
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**6,621**
Zone 4	at Caseys Weir	8,340	8,495
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	23
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	13
	Total downstream of Caseys Weir	**8,374**	**8,531**
Zone 3	Broken Creek loss provision	4,323	0

Scenario results under climate change and full demand show that similar to the base case, allocations reduce significantly under climate change.

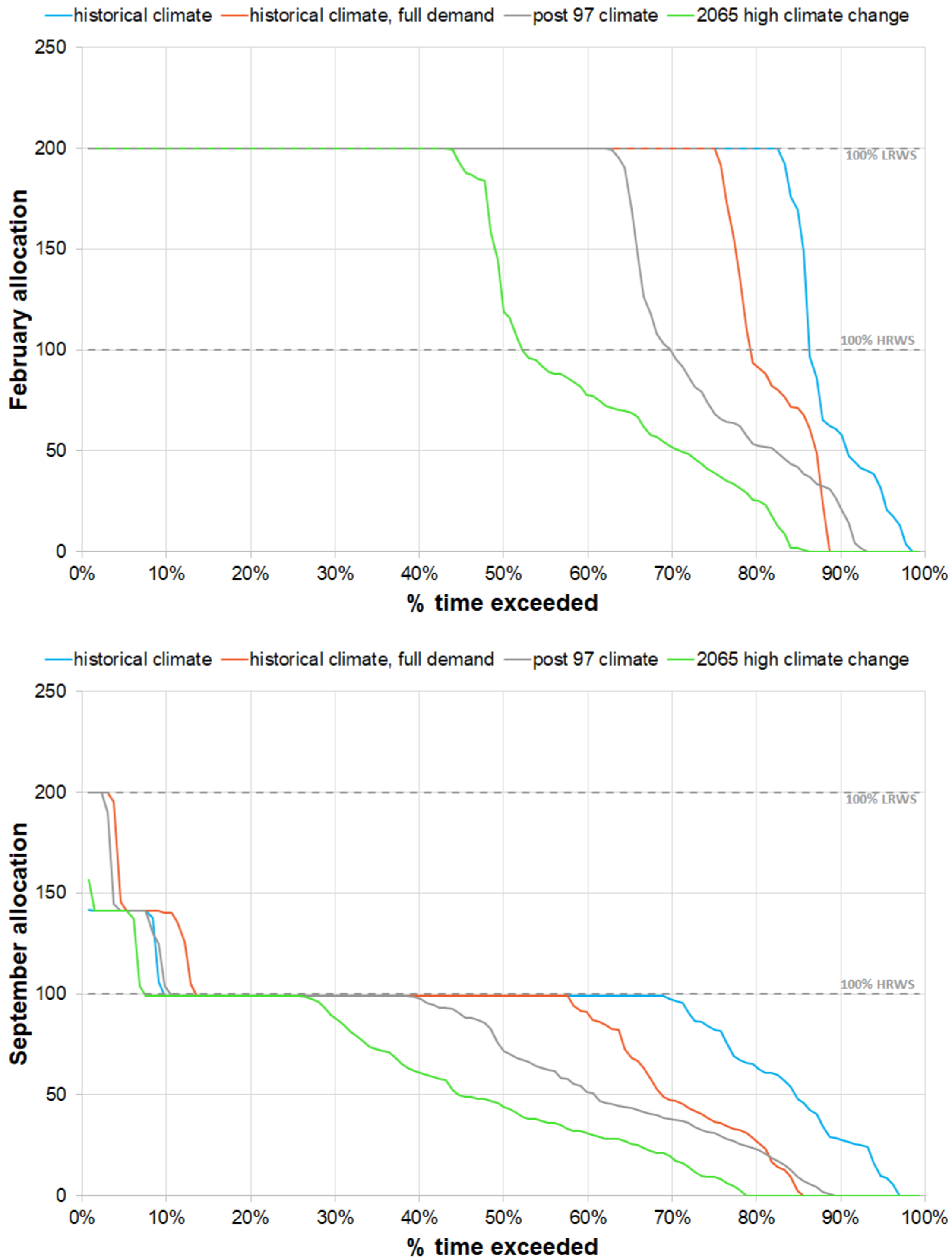


Figure 5-13: Scenario 4 February and September allocations under future climate and full demand

5.1.6 Scenario 5 – Reduce losses in Mokoan pipeline channel

It was estimated that channel losses and seepage in the Mokoan pipeline channel could be reduced by 90 ML/yr. This was implemented in the model by reducing the Lake Mokoan demand by 90 ML/yr.

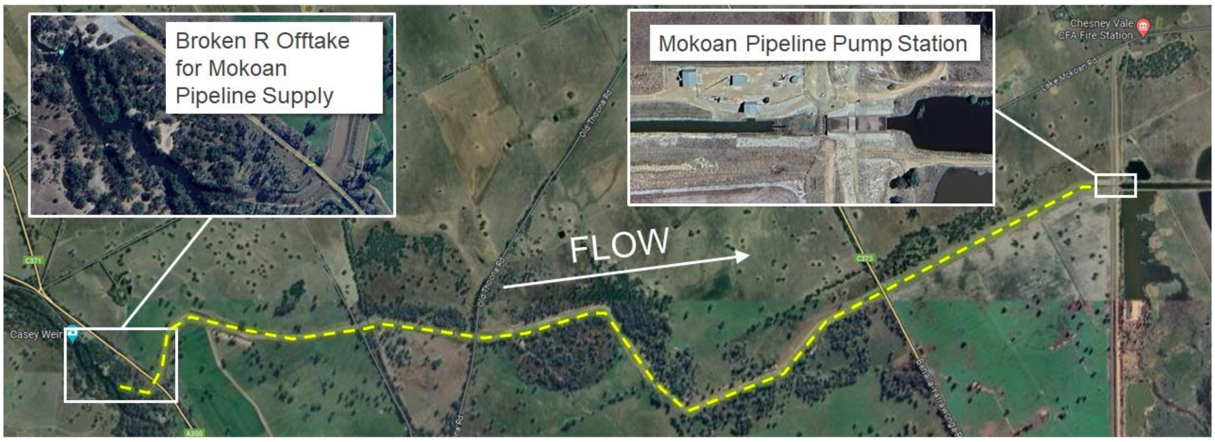
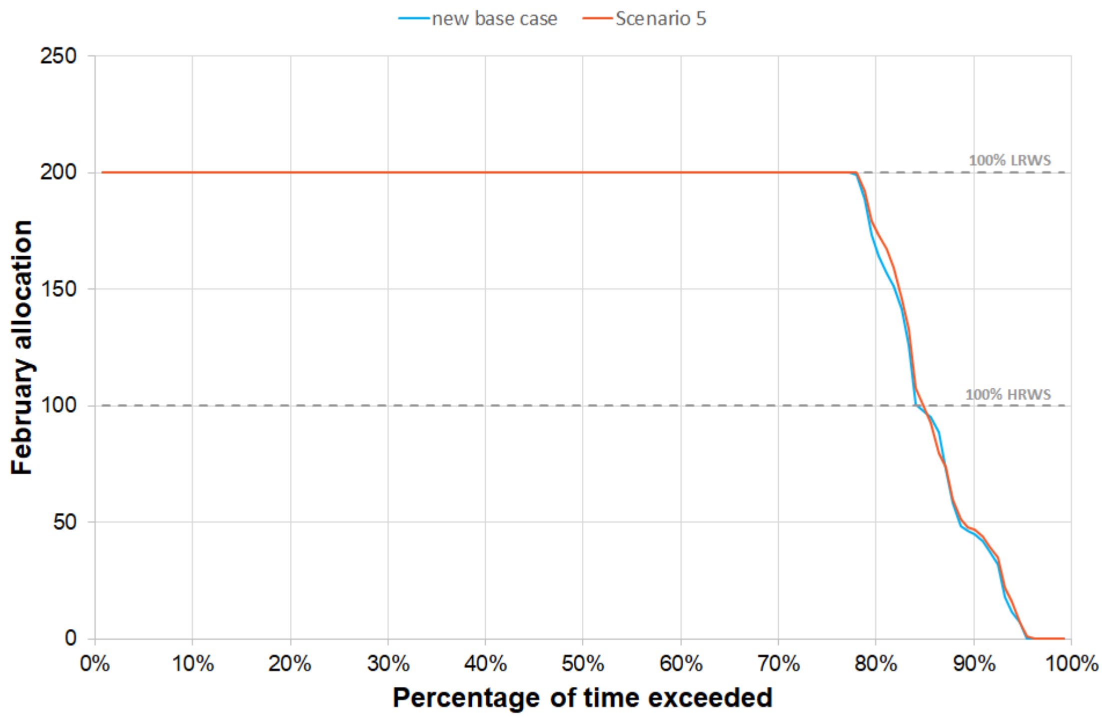


Figure 5-14: Scenario 5: Reduce losses in Mokoan pipeline channel (Sequana)

In this case redistribution of water shares was not required.

Results show that reliability (percentage of years with 100% HRWS in February) increases slightly from 84% to 85% under this scenario (Figure 5-15). September allocations are also slightly higher than the base case (Figure 5-16).



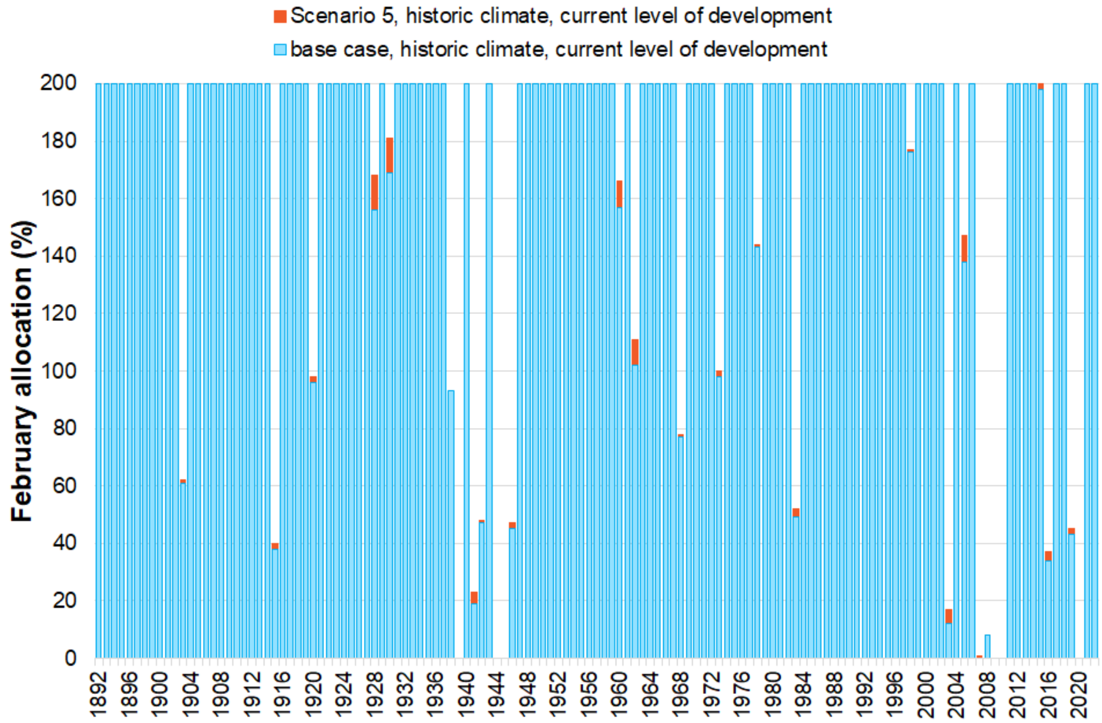
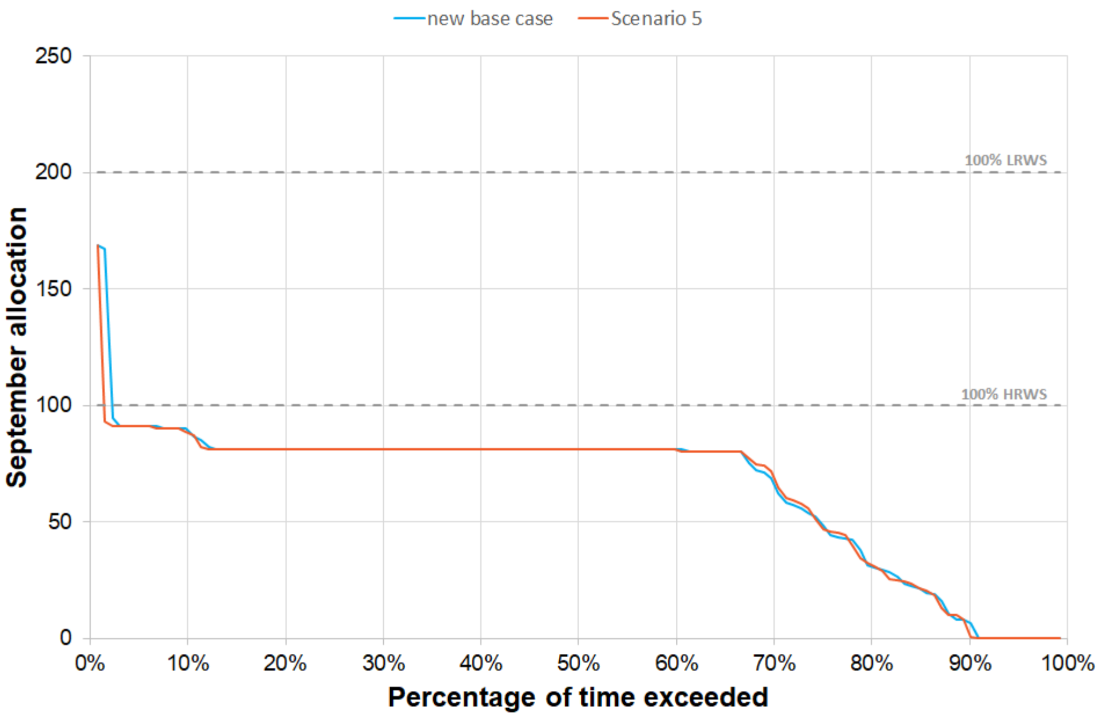


Figure 5-15: Scenario 5: February allocation (reliability) compared to the base case, historic climate



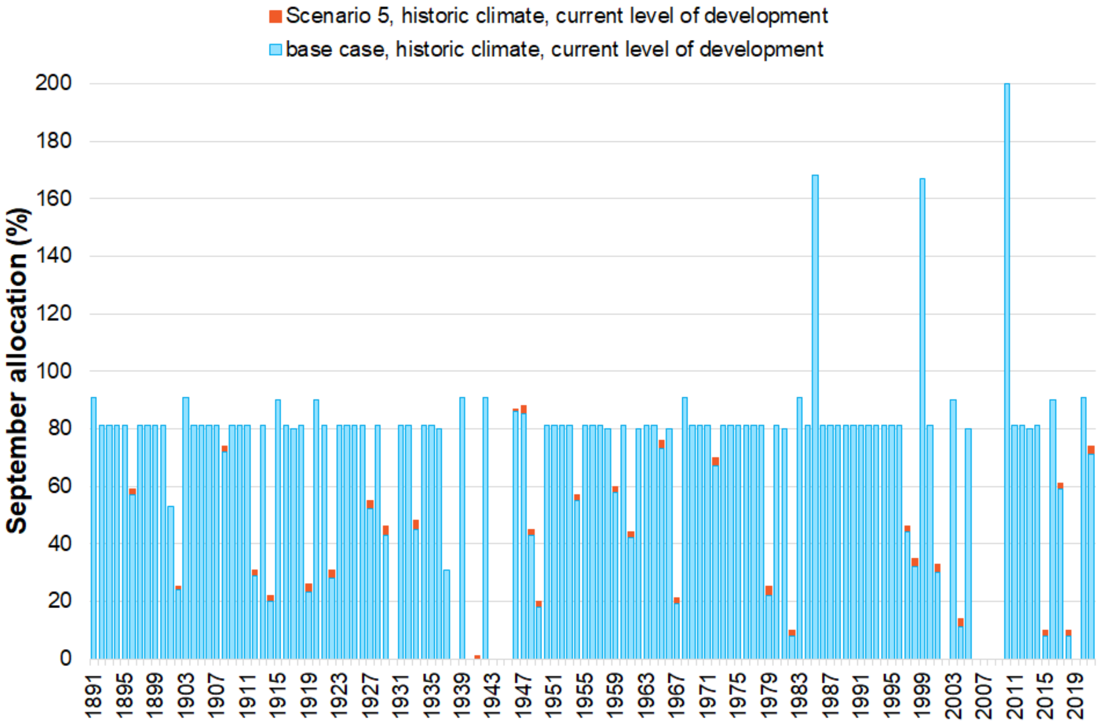


Figure 5-16: Scenario 5: September allocation (reliability) compared to the base case, historic climate

Results show that less demand exists in the system and hence less is supplied under this scenario. River flows and losses are very similar to the base case.

Table 5-14: Demand results, Scenario 5, historic climate, current demands

	Base case supplied	Scenario 5 supplied
Irrigation demands (ML/yr)	3,462	3,396
D&S demands (ML/yr)	677	610

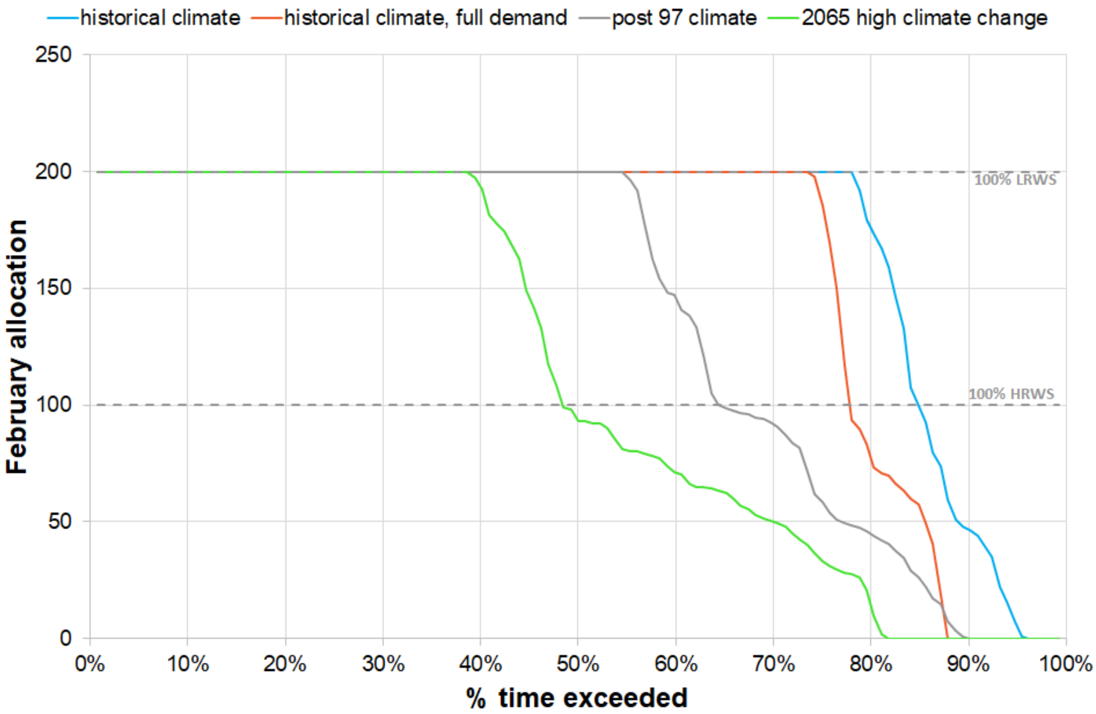
Table 5-15: Mean annual flow at compliance points, Scenario 5, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 5 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,369
Broken R reach 2	199,532	199,583
Broken R reach 3	225,757	225,999
Broken Ck reach 1	5,015	5,020

Table 5-16: Mean annual loss, Scenario 5, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 5 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	4,183
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**6,833**
Zone 4	at Caseys Weir	8,340	8,284
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	21
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	13
	Total downstream of Caseys Weir	**8,374**	**8,319**
Zone 3	Broken Creek loss provision	4,323	4,325

Scenario results under climate change and full demand show that similar to the base case, allocations reduce significantly under climate change.



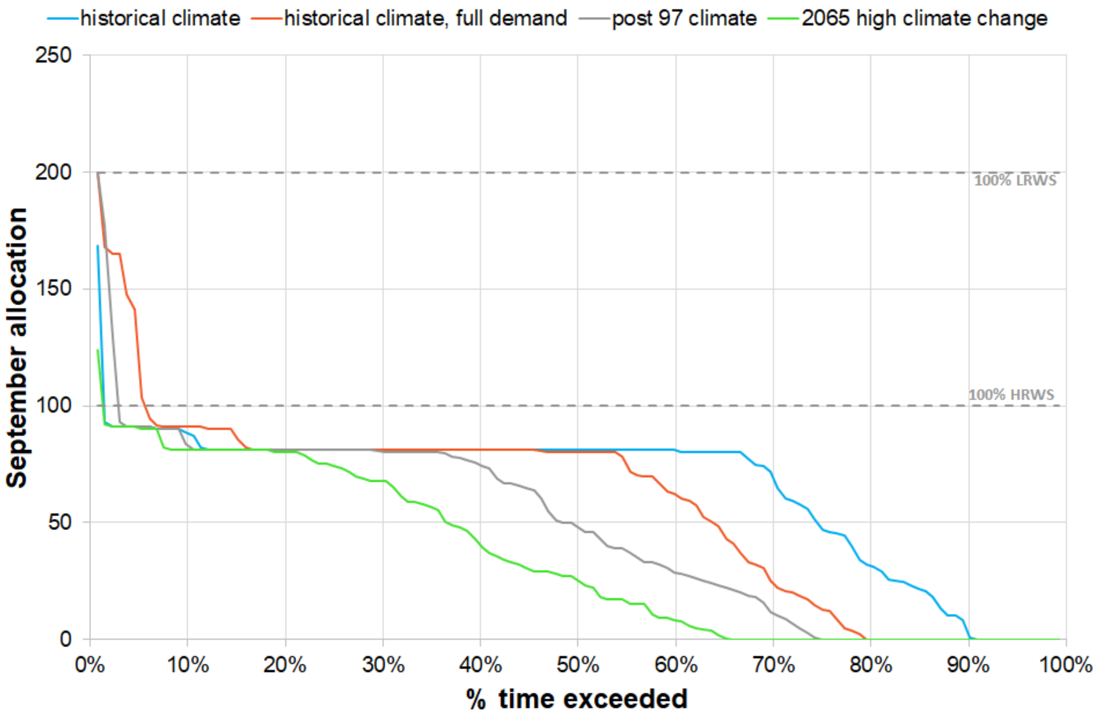


Figure 5-17: Scenario 5 February and September allocations under future climate and full demand

5.1.7 Scenario 6 – Reconfiguration opportunities in all zones

For this scenario reconfiguration opportunities were explored across all zones. For modelling purposes it was assumed that 50% of unused entitlement (based on the highest recorded use for the last 10 seasons) was relinquished, for zones 1 to 5. 65% of entitlement not linked to land (excluding VEWH, DCCEEW & GMW) was assumed to be relinquished.

Table 5-17: Scenario 6 reconfiguration assumptions

Zone	Reduction in irrigation HRWS*
Zone 1	1,226
Zone 2	1,480
Zone 3	708
Zone 4	1,822
Zone 5	1,453
total	6,690

* Unallocated reductions spread across zones in ratio of irrig HRWS

In this case irrigation HRWS in each zone was reduced according to the table above. Irrigation demands were left unchanged. 50% of the HRWS was redistributed to increase reliability, and 50% was redistributed to the environment.

Table 5-18: Scenario 6 redistribution of water shares

	Irrigation entitlement relinquished (ML)	Redistribution to the environment (ML)	Redistribution to reliability (ML)
HRWS	6,692	3,346	3,346
LRWS	0	0	0

Changes in the model are summarised in Table 5-1. Broken Creek loss provision was factored by the ratio of old and new Broken Creek irrigation demand (60%), and transmission and operating loss assumptions used in the allocation calculation were reduced by the ratio of old and new consumptive HRWS (-50%).

The new environmental entitlement was used to supply low flows downstream of Nillahcootie until until the volume of HRWS redistributed to the environment is used. Under historic climate and current demands this required the supply of summer-autumn low flow of 100 ML/d during December, February and 23 days in January. Corresponding low flows in Broken Creek were also supplied (10 ML/d in summer-autumn).

Results show that reliability (percentage of years with 100% HRWS in February) increases from 84% to 87% under this scenario (Figure 5-18). September allocations are also substantially higher than the base case (Figure 5-19).

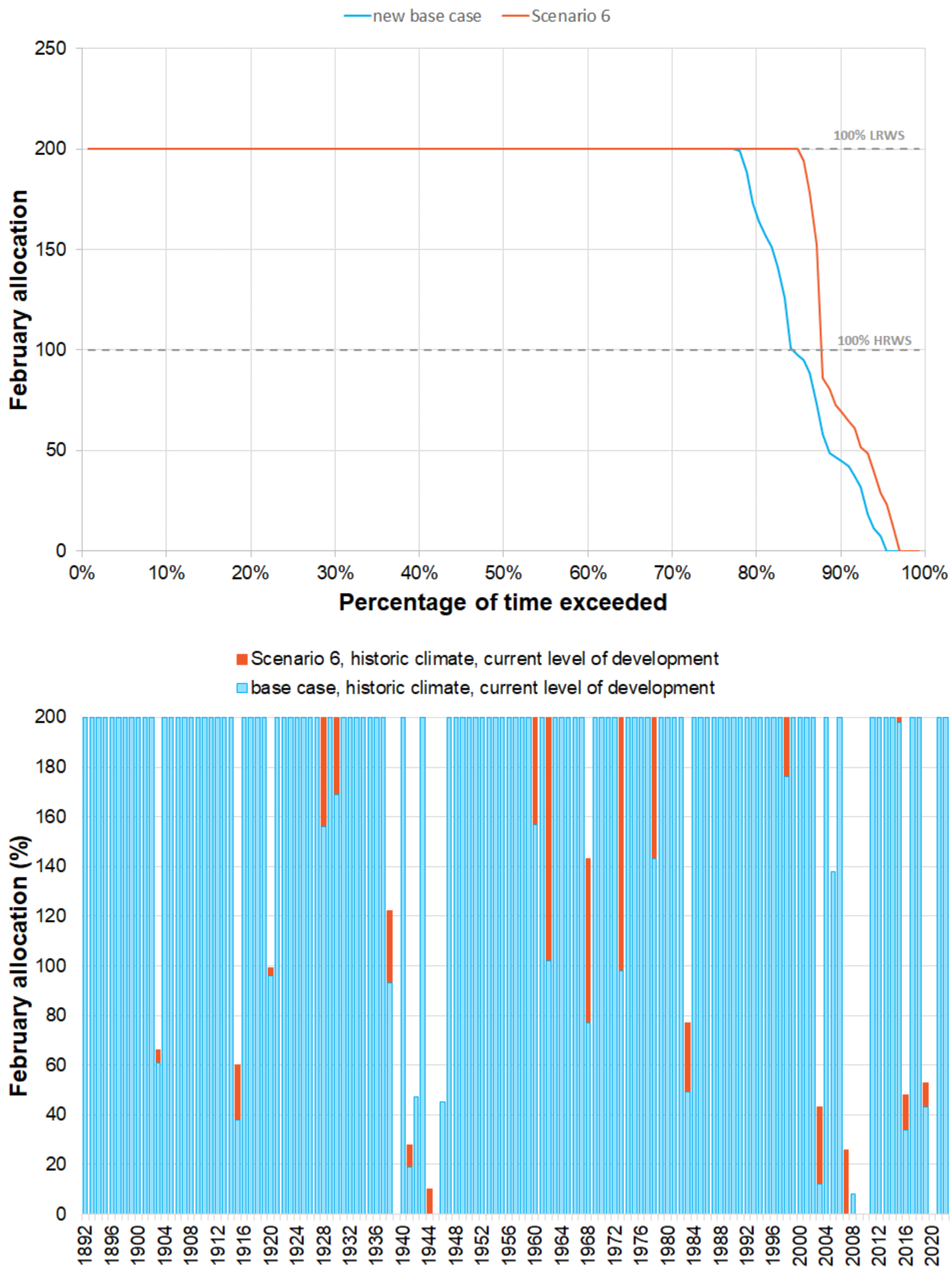


Figure 5-18: Scenario 6: February allocation (reliability) compared to the base case, historic climate

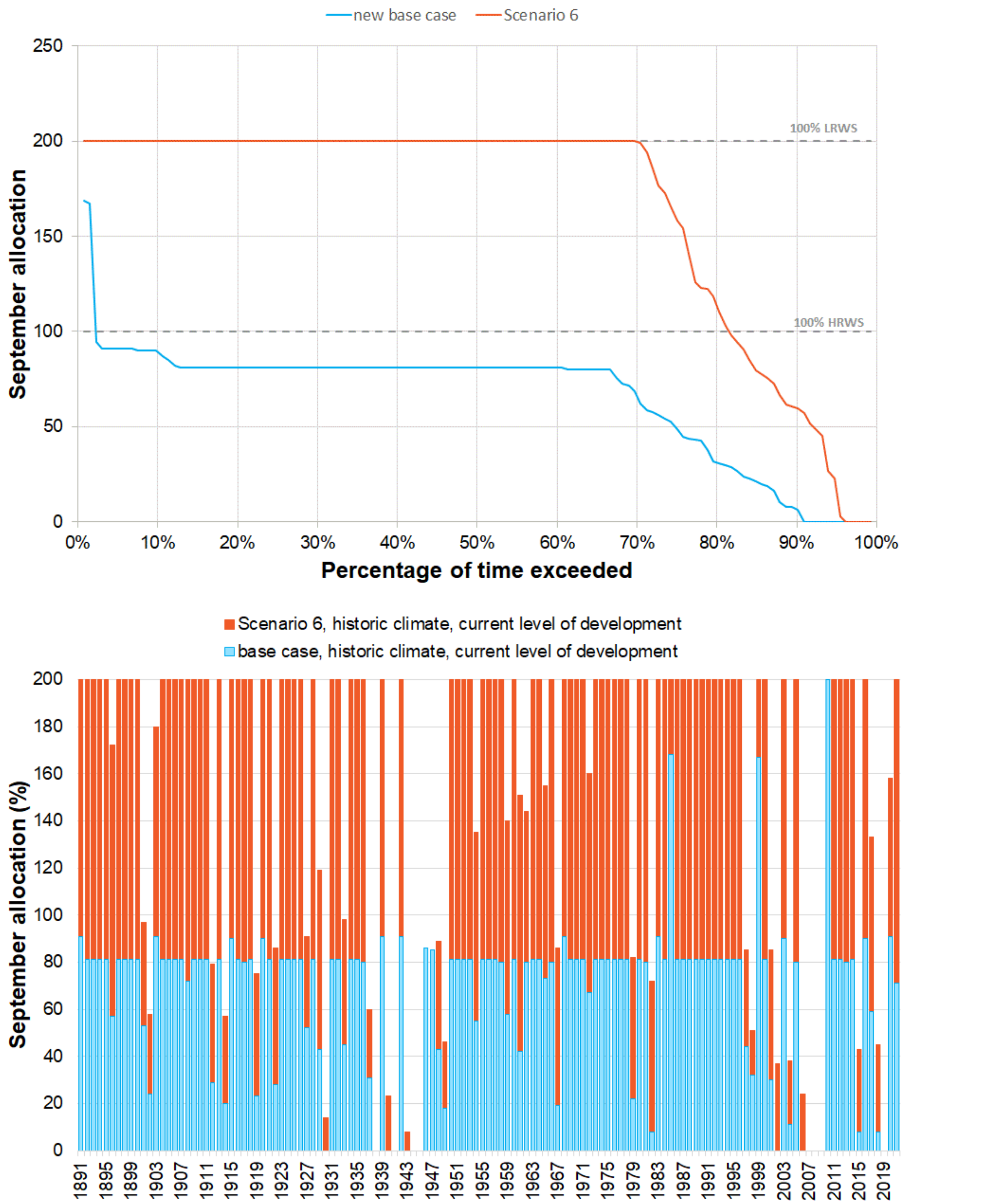


Figure 5-19: Scenario 6: September allocation (reliability) compared to the base case, historic climate

Results show that less irrigation exists in the system and hence less is supplied under this scenario. Again river flows are very similar to the base case because water that is now owned by the environment is still released down the river to satisfy environmental flow requirements. As a result Broken River losses are also not significantly different.

Table 5-19: Demand results, Scenario 6, historic climate, current demands

	Base case supplied	Scenario 6 supplied
Irrigation demands (ML/yr)	3,462	1,982
D&S demands (ML/yr)	677	692

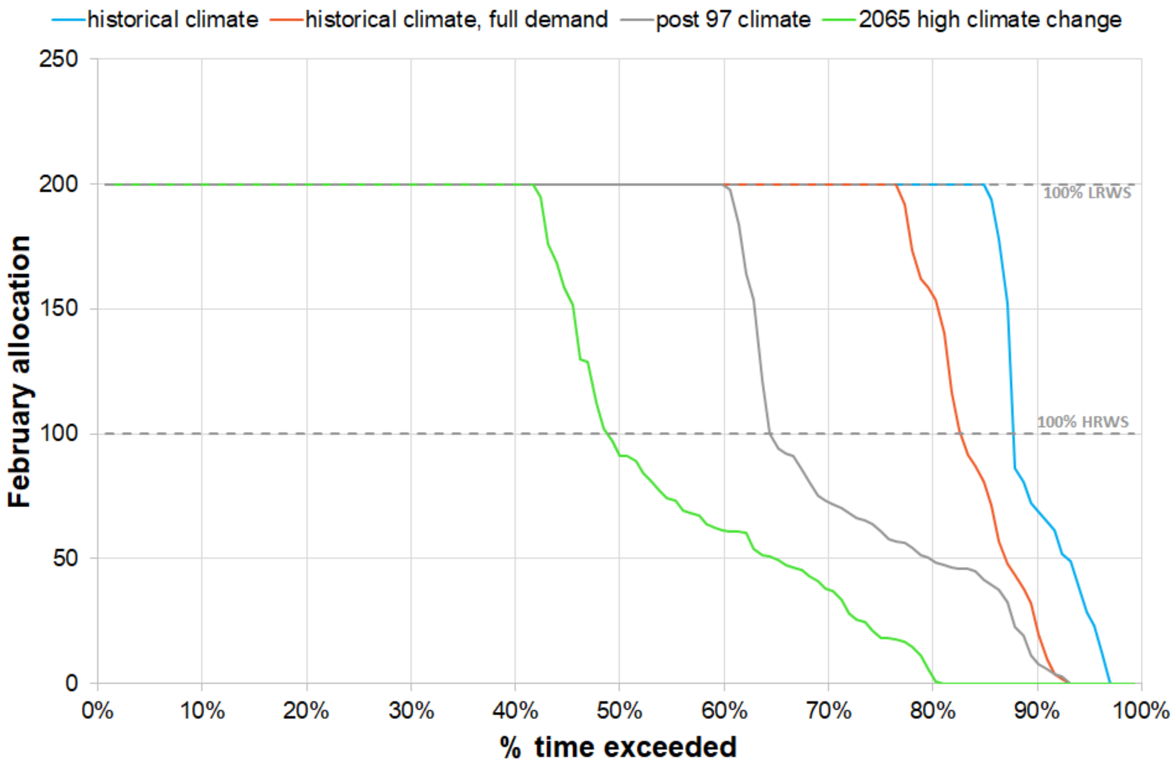
Table 5-20: Mean annual flow at compliance points, Scenario 6, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 6 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,460
Broken R reach 2	199,532	199,928
Broken R reach 3	225,757	224,259
Broken Ck reach 1	5,015	4,790

Table 5-21: Mean annual loss, Scenario 6, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 6 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	4,232
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**6,883**
Zone 4	at Caseys Weir	8,340	8,326
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	21
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	13
	Total downstream of Caseys Weir	**8,374**	**8,360**
Zone 3	Broken Creek loss provision	4,323	4,317

Scenario results under climate change and full demand show that similar to the base case, allocations reduce significantly under climate change.



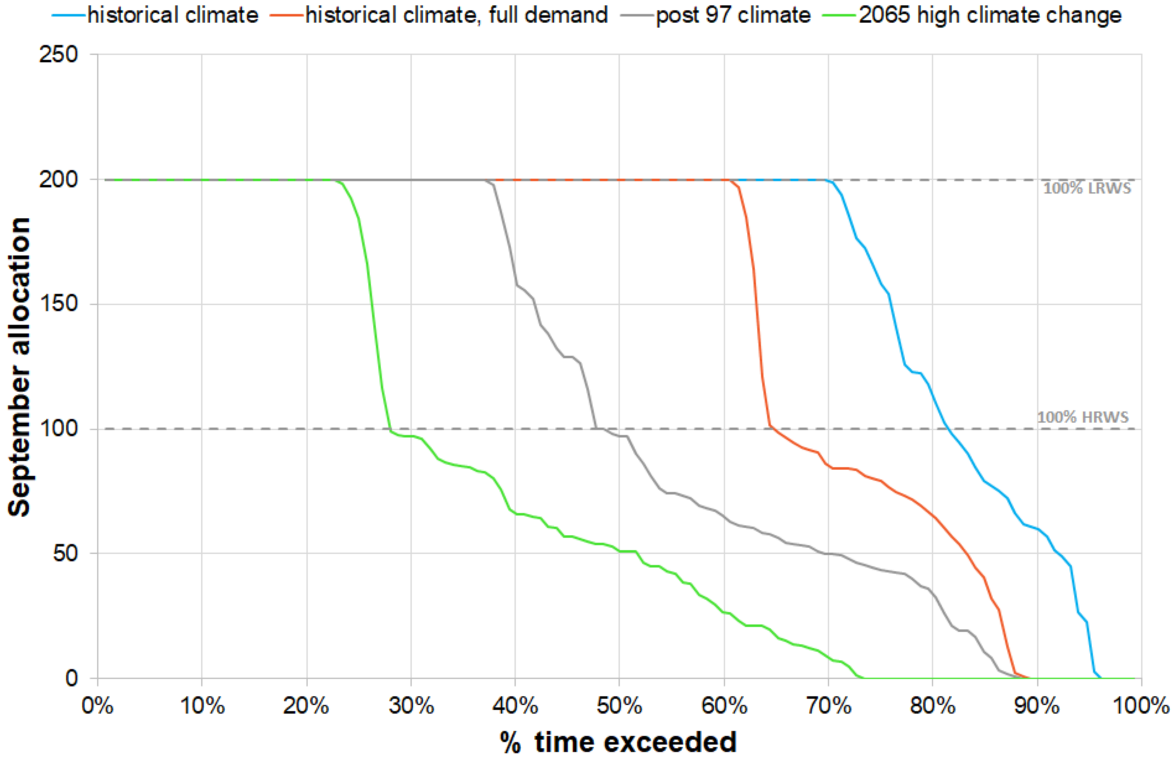


Figure 5-20: Scenario 6 February and September allocations under future climate and full demand

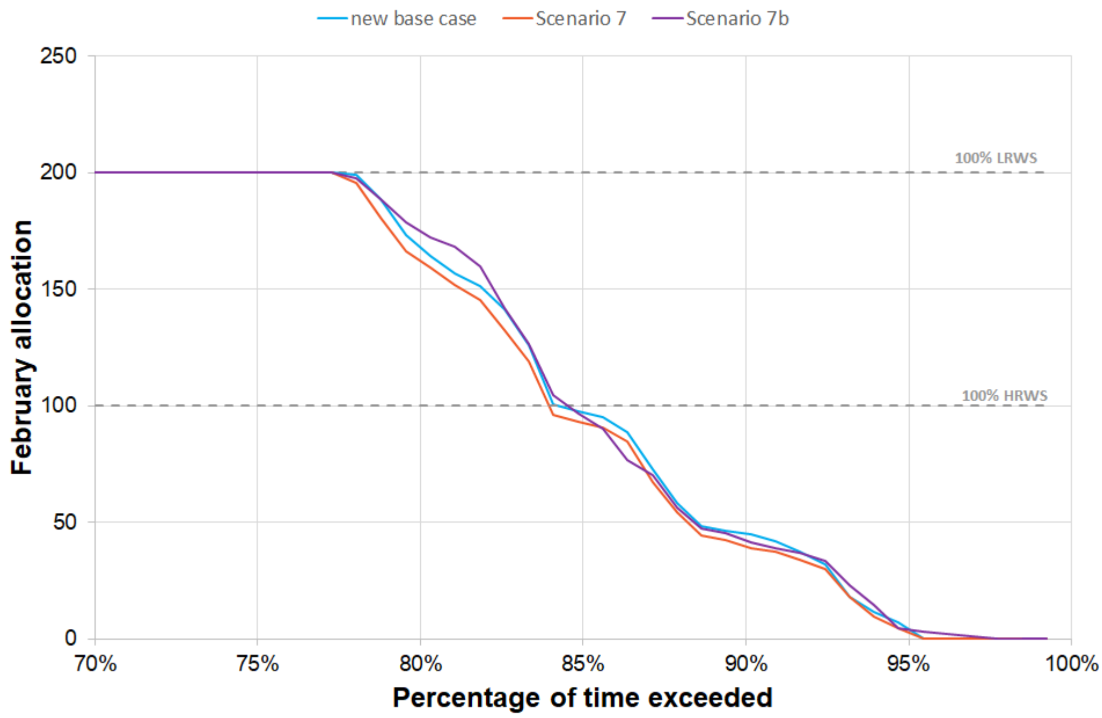
5.1.8 Scenario 7 – Improving D&S reliability

For this scenario a D&S reserve rule was created outside of the allocation system. A 400 ML D&S reserve is established in Lake Nillahcootie which resets at the start of each water year. This water is then used to top up supply to D&S demands when allocations or unregulated inflows are inadequate.

In this case the available water used in the allocation calculation in the model was reduced by the volume of water in the D&S reserve. Changes in the model are summarised in Table 5-1.

Results show that reliability for irrigation users (percentage of years with 100% HRWS in February) reduces slightly to 83% (Figure 5-21). September allocations are also slightly lower than the base case (Figure 5-22). In the case of D&S demands 99.7% of unrestricted demand can now be supplied.

Additional modelling (Scenario 7b) showed that allocations could be restored to the base case level by reducing HRWS across the system by 5%.



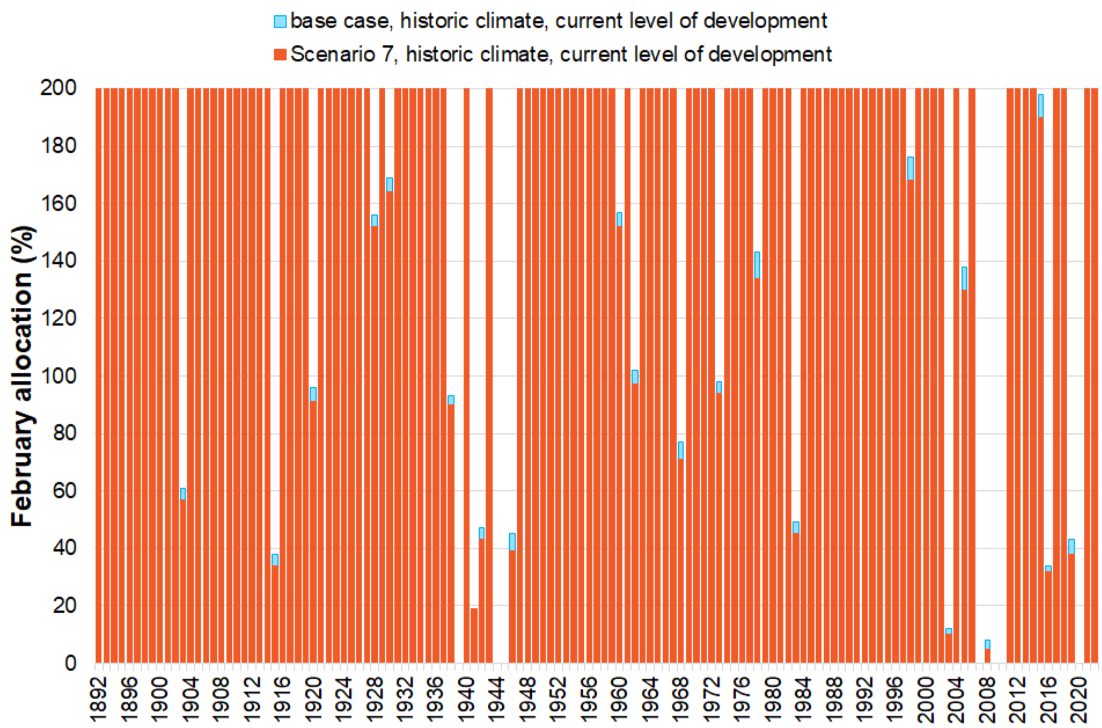
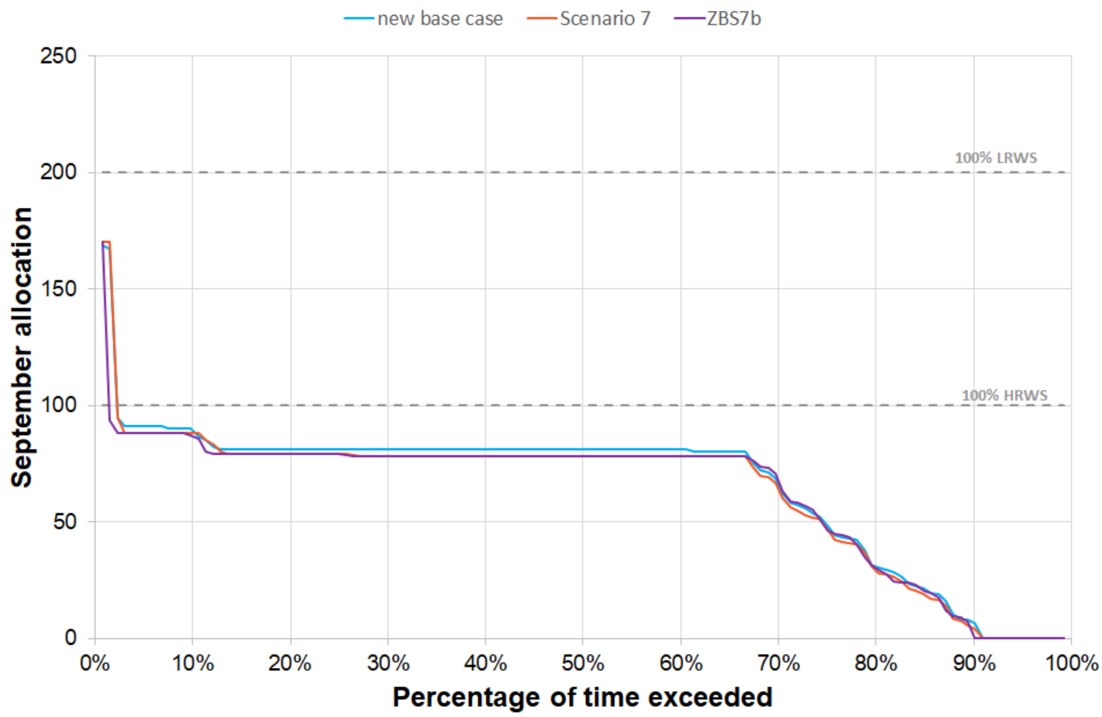


Figure 5-21: Scenario 7: February allocation (reliability) compared to the base case, historic climate



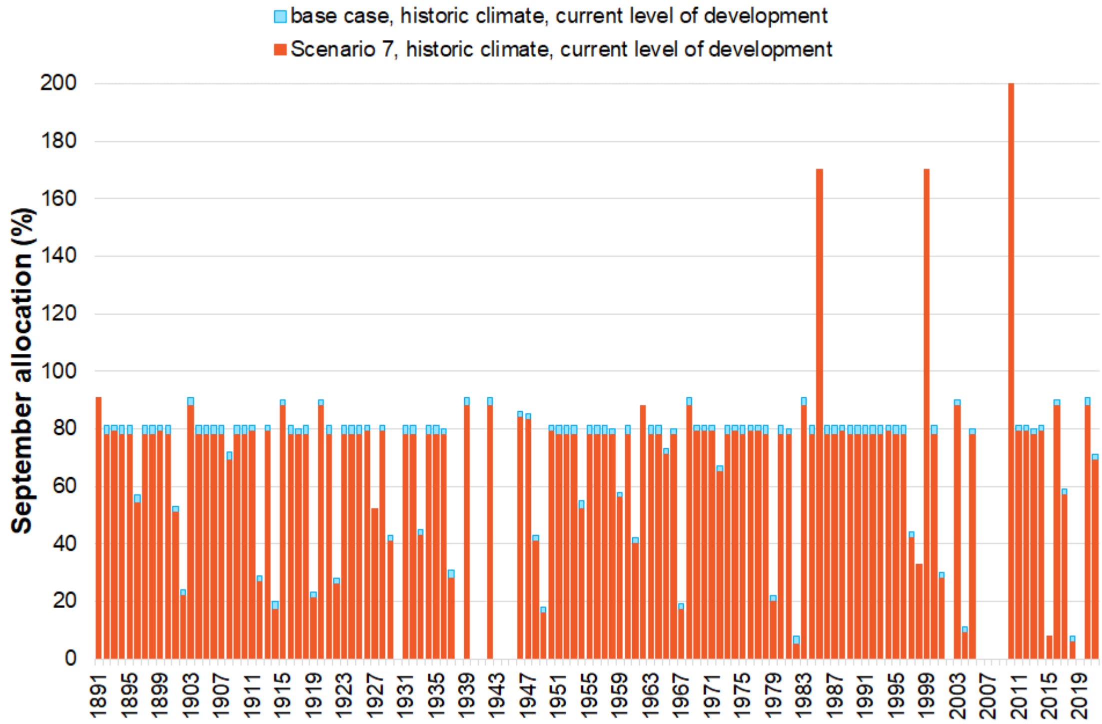


Figure 5-22: Scenario 7: September allocation (reliability) compared to the base case, historic climate

Results show that slightly less irrigation demand but much more D&S demand is supplied under this scenario. River flows are very similar to the base case and as a result, losses are also very similar.

Table 5-22: Demand results, Scenario 7, historic climate, current demands

	Base case supplied	Scenario 7 supplied
Irrigation demands (ML/yr)	3,462	3,455
D&S demands (ML/yr)	677	790

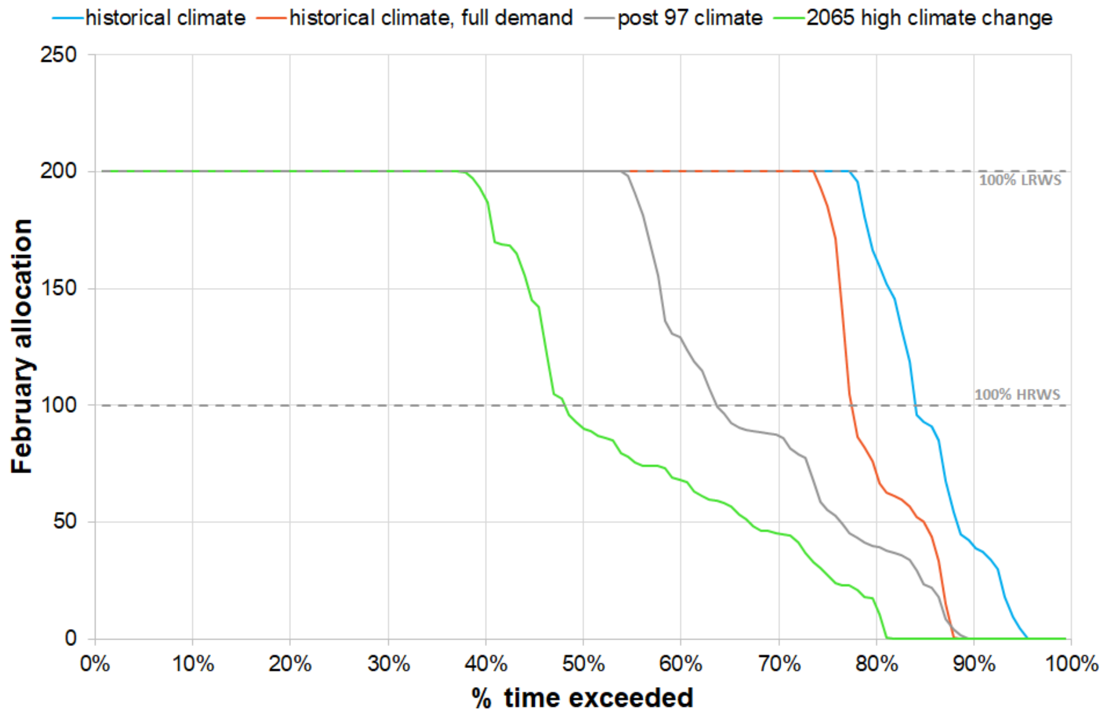
Table 5-23: Mean annual flow at compliance points, Scenario 7, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 7 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,369
Broken R reach 2	199,532	199,489
Broken R reach 3	225,757	225,677
Broken Ck reach 1	5,015	5,021

Table 5-24: Mean annual loss, Scenario 6, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 7 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	4,232
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**6,883**
Zone 4	at Caseys Weir	8,340	8,326
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	21
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	13
	Total downstream of Caseys Weir	**8,374**	**8,360**
Zone 3	Broken Creek loss provision	4,323	4,317

Scenario results under climate change and full demand show that similar to the base case, allocations reduce significantly under climate change.



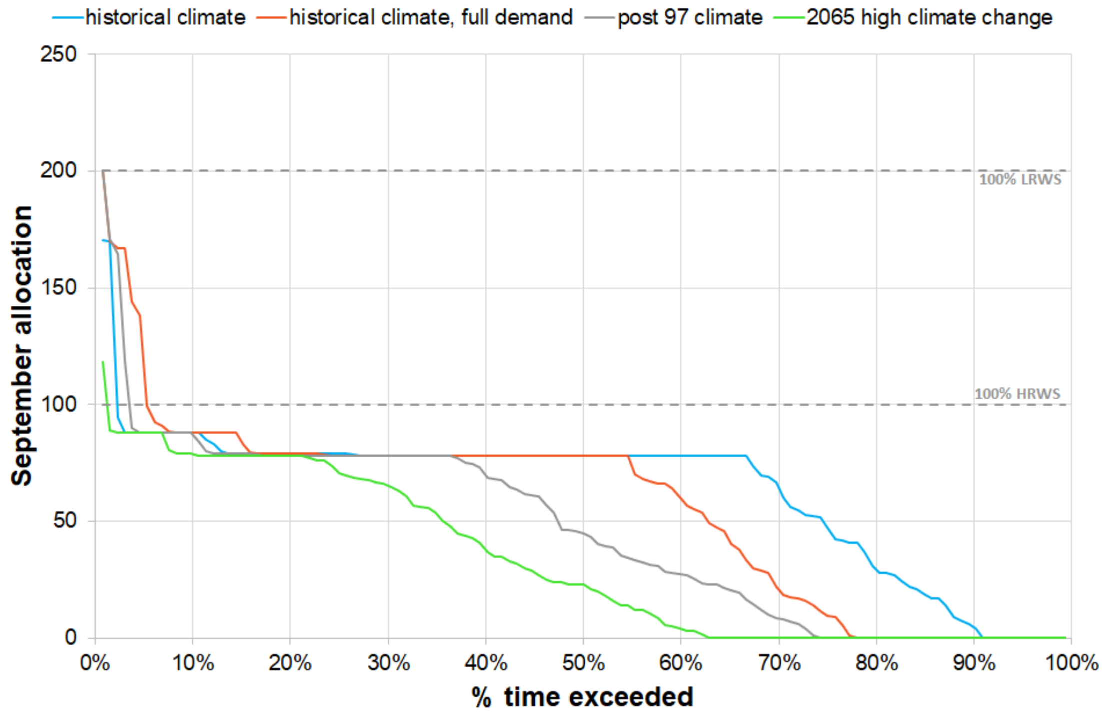


Figure 5-23: Scenario 7 February and September allocations under future climate and full demand

5.1.9 Scenario 8 – Combined option

This scenario combines the assumptions of Scenario 3, 4, 5, 6, and 7.

In terms of irrigation HRWS Zone 5 was set to zero and 430 ML transferred to Zone 4. Zone 3 was set to zero and 215 ML transferred to Zone 4. Irrigation HRWS was reduced by 1079 ML in Zone 1, 1050 ML in Zone 2, 1301 ML in Zone 4. D&S HRWS was set to zero in Zone 3 & 5.

Irrigation demands were set to zero in zones 3 & 5 and factored up to account for transfers in Zone 4. Lake Mokoan demands were reduced by 90 ML/yr to account for savings, and demands in all other zones were factored by the ratio of old and new HRWS.

Table 5-25: Scenario 8 redistribution of water shares

	Irrigation entitlement relinquished (ML)	Redistribution to the environment (ML)	Redistribution to reliability (ML)
HRWS	9,112	4,556	4,556
LRWS	1,012	506	506

Changes in the model are summarised in Table 5-1. Broken Creek loss provision was set to zero, and transmission and operating loss assumptions used in the allocation calculation were reduced by the ratio of old and new consumptive HRWS.

The new environmental entitlement was used to supply low flows downstream of Nillahcootie until the volume of HRWS redistributed to the environment is used. For the historic climate and current demand case this required the supply of summer-autumn low flow of 100 ML/d for 15 days in December and all of January and February. Corresponding low flows in Broken Creek were also supplied (10 ML/d in summer-autumn).

Results show that irrigation reliability (percentage of years with 100% HRWS in February) increases from 84% to 89% under this scenario (Figure 5-11). September allocations are also substantially higher than the base case (Figure 5-12). In the case of D&S demands 99.0% of unrestricted demand can now be supplied.

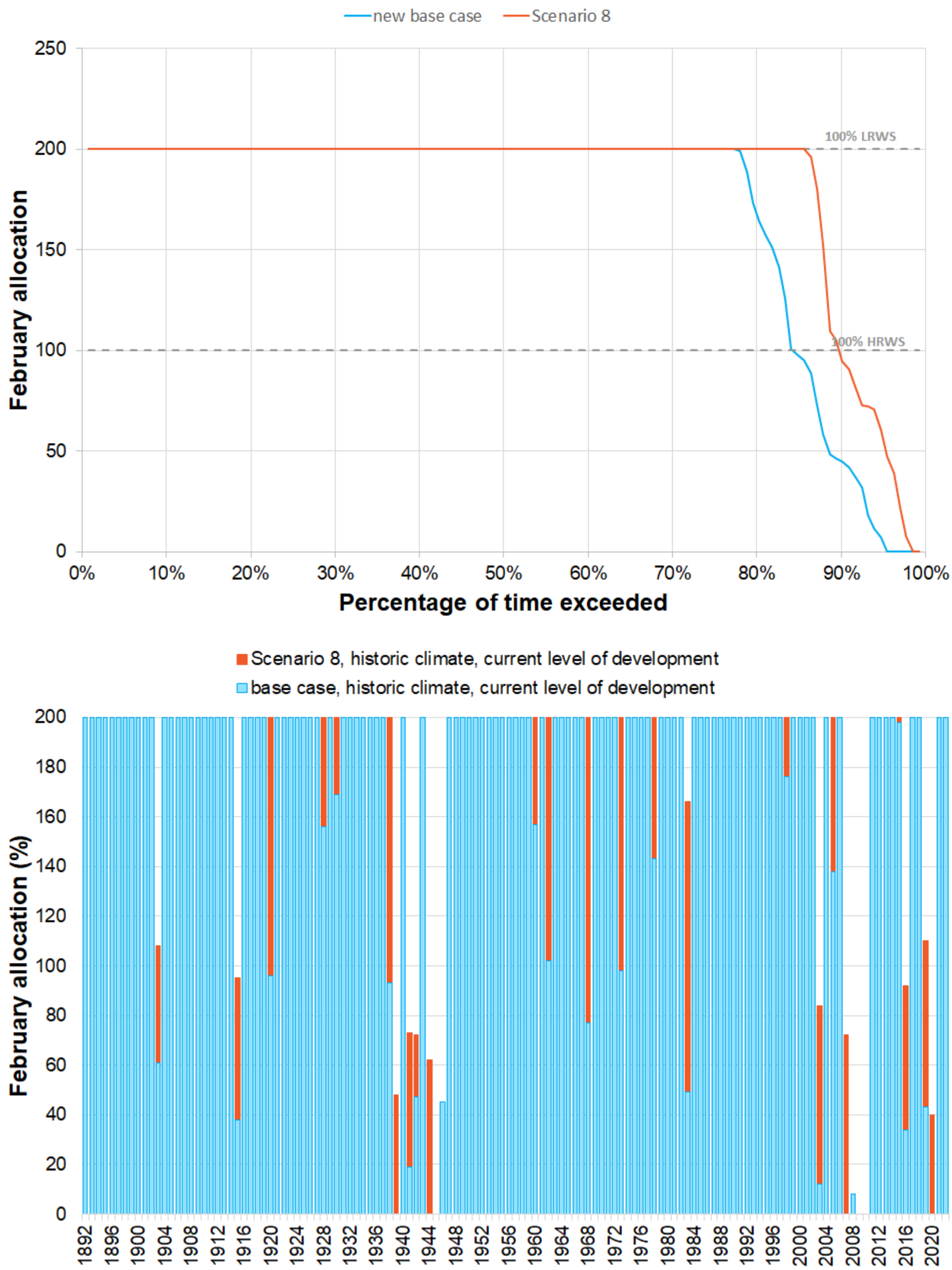


Figure 5-24: Scenario 8: February allocation (reliability) compared to the base case, historic climate

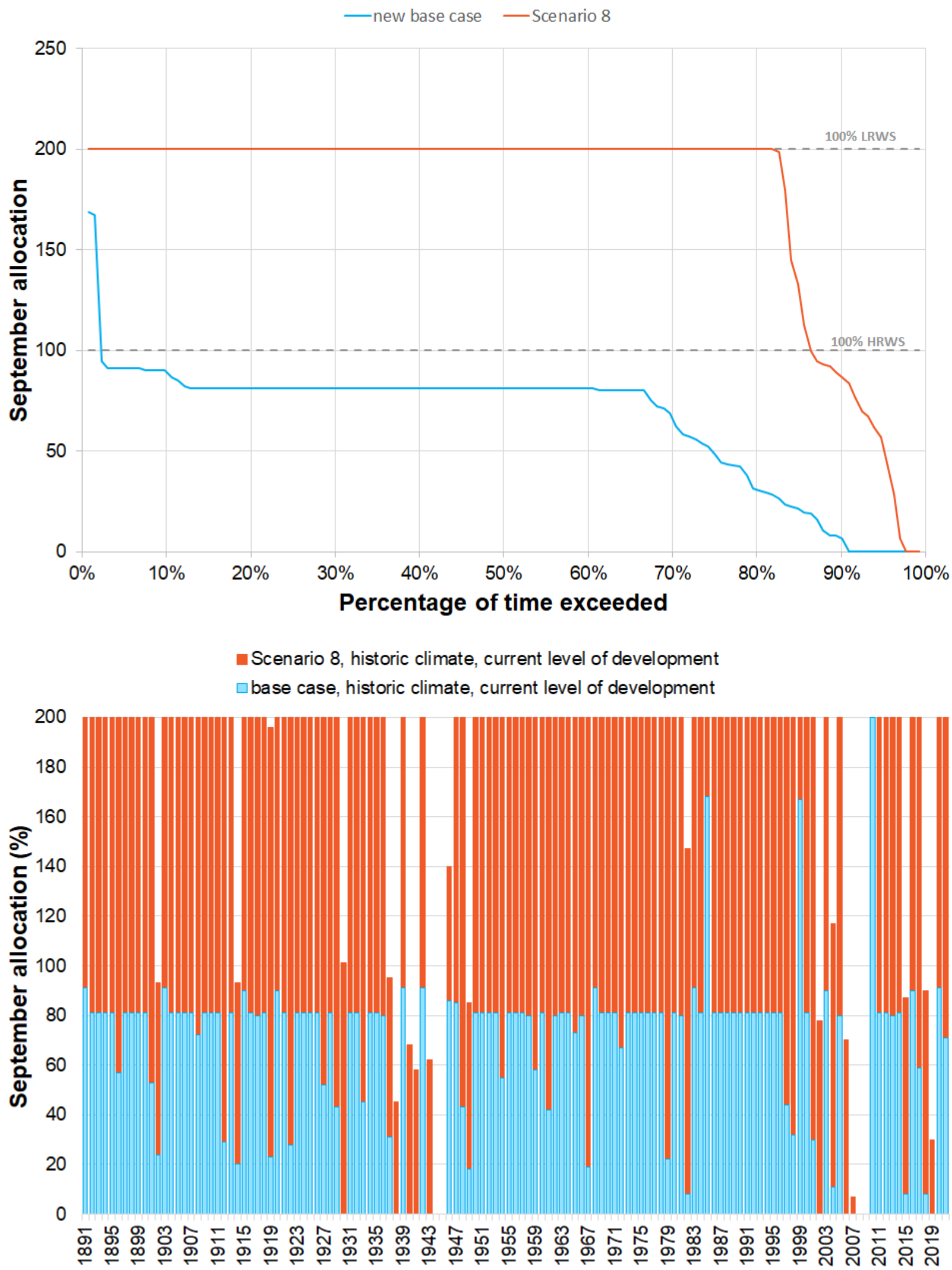


Figure 5-25: Scenario 8: September allocation (reliability) compared to the base case, historic climate

Results show that less irrigation and D&S demand exist in the system and hence less is supplied under this scenario. Again river flows are very similar to the base case because water that is now owned by the environment is still released down the river to satisfy environmental flow requirements. As a result Broken River losses are also are not significantly different but Broken Creek loss provision is now zero.

Table 5-26: Demand results, Scenario 8, historic climate, current demands

	Base case supplied	Scenario 8 supplied
Irrigation demands (ML/yr)	3,462	1,246
D&S demands (ML/yr)	677	521

Table 5-27: Mean annual flow at compliance points, Scenario 8, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 8 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,438
Broken R reach 2	199,532	200,199
Broken R reach 3	225,757	228,870*
Broken Ck reach 1	5,015	3,896*

* Modelled flow results post processed as described in Section 5.1.5.

Table 5-28: Mean annual loss, Scenario 8, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 8 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	3,931
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	**6,582**
Zone 4	at Caseys Weir	8,340	8,422
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	15
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	0
	Total downstream of Caseys Weir	**8,374**	**8,437**
Zone 3	Broken Creek loss provision	4,323	0

Scenario results under climate change show that similar to the base case, allocations reduce significantly under climate change.

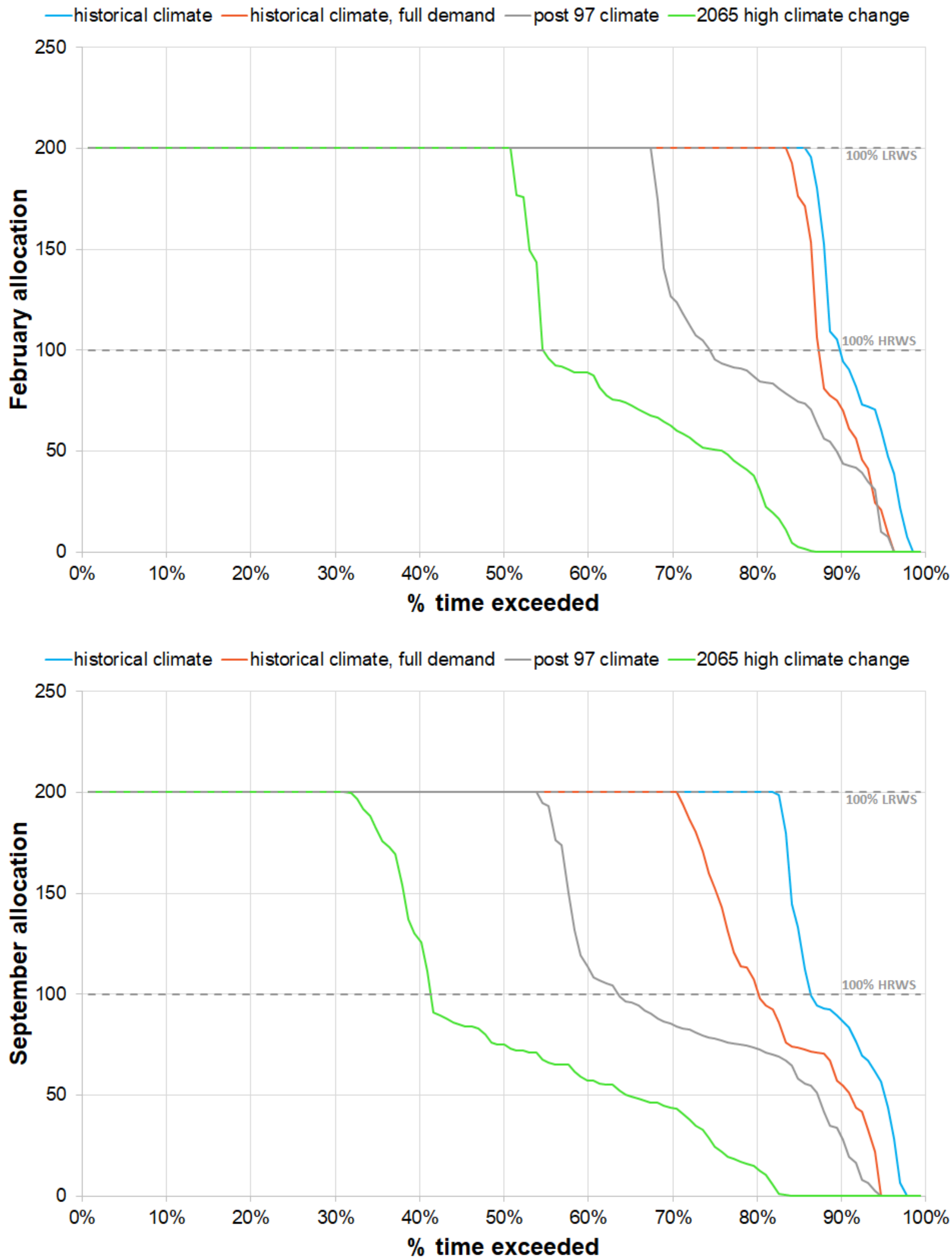


Figure 5-26: Scenario 4 February and September allocations under future climate and full demand

5.1.10 Scenario 9 – Extended combined option

This scenario is the same as Scenario 8 but with demands in Zone 4 also set to zero.

In terms of irrigation HRWS in zones 3, 4 and 5 was set to zero. Irrigation HRWS was reduced by 1079 ML in Zone 1 and 1050 ML in Zone 2. D&S HRWS was set to zero in Zones 3, 4 & 5.

Irrigation demands were set to zero in zones 3, 4 & 5. Lake Mokoan demands were reduced by 90 ML/yr to account for savings, and demands in all other zones were factored by the ratio of old and new HRWS.

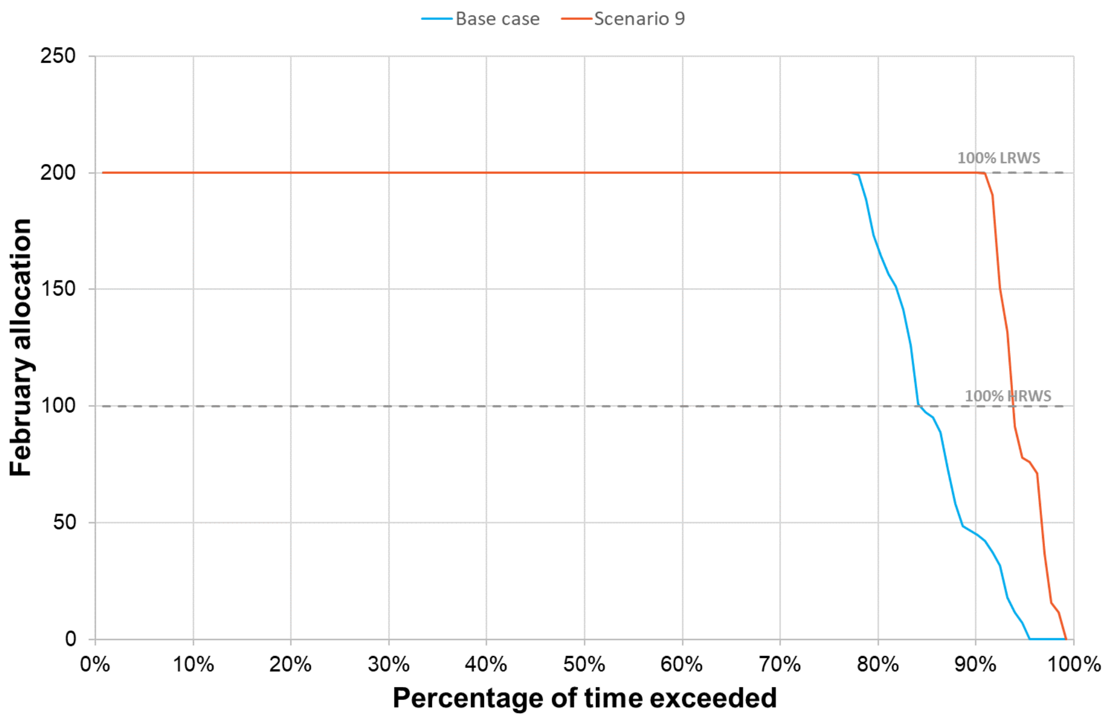
Table 5-29: Scenario 9 redistribution of water shares

	Irrigation entitlement relinquished (ML)	Redistribution to the environment (ML)	Redistribution to reliability (ML)
HRWS	12,675	6,337	6,337
LRWS	2,076	1,038	1,038

Changes in the model are summarised in Table 5-1. Broken Creek loss provision was set to zero, and transmission and operating loss assumptions used in the allocation calculation were reduced by the ratio of old and new consumptive HRWS.

The new environmental entitlement was used to supply low flows downstream of Nillahcootie until the volume of HRWS redistributed to the environment is used. For the historic climate and current demand case this required the supply of summer-autumn low flow of 100 ML/d for December, January 25 days in February. Corresponding low flows in Broken Creek were also supplied (10 ML/d in summer-autumn).

Results show that irrigation reliability (percentage of years with 100% HRWS in February) increases from 84% to 93% under this scenario (Figure 5-29). September allocations are also substantially higher than the base case (Figure 5-30). In the case of D&S demands 98.7% of unrestricted demand can now be supplied.



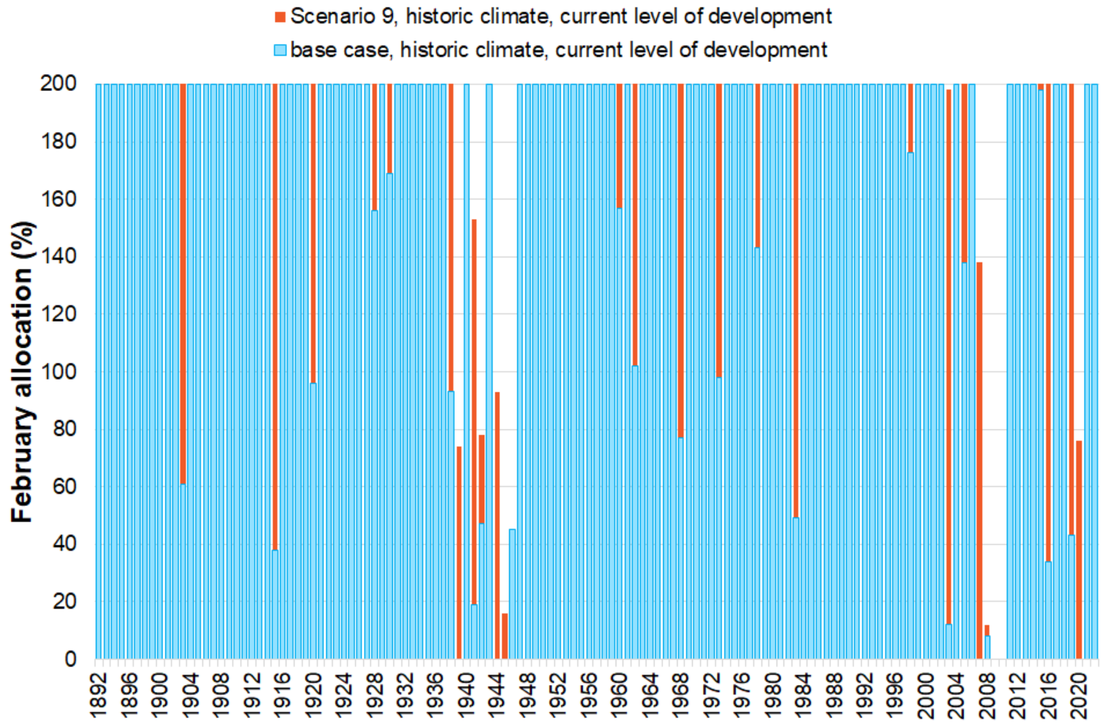


Figure 5-27: Scenario 9: February allocation (reliability) compared to the base case, historic climate

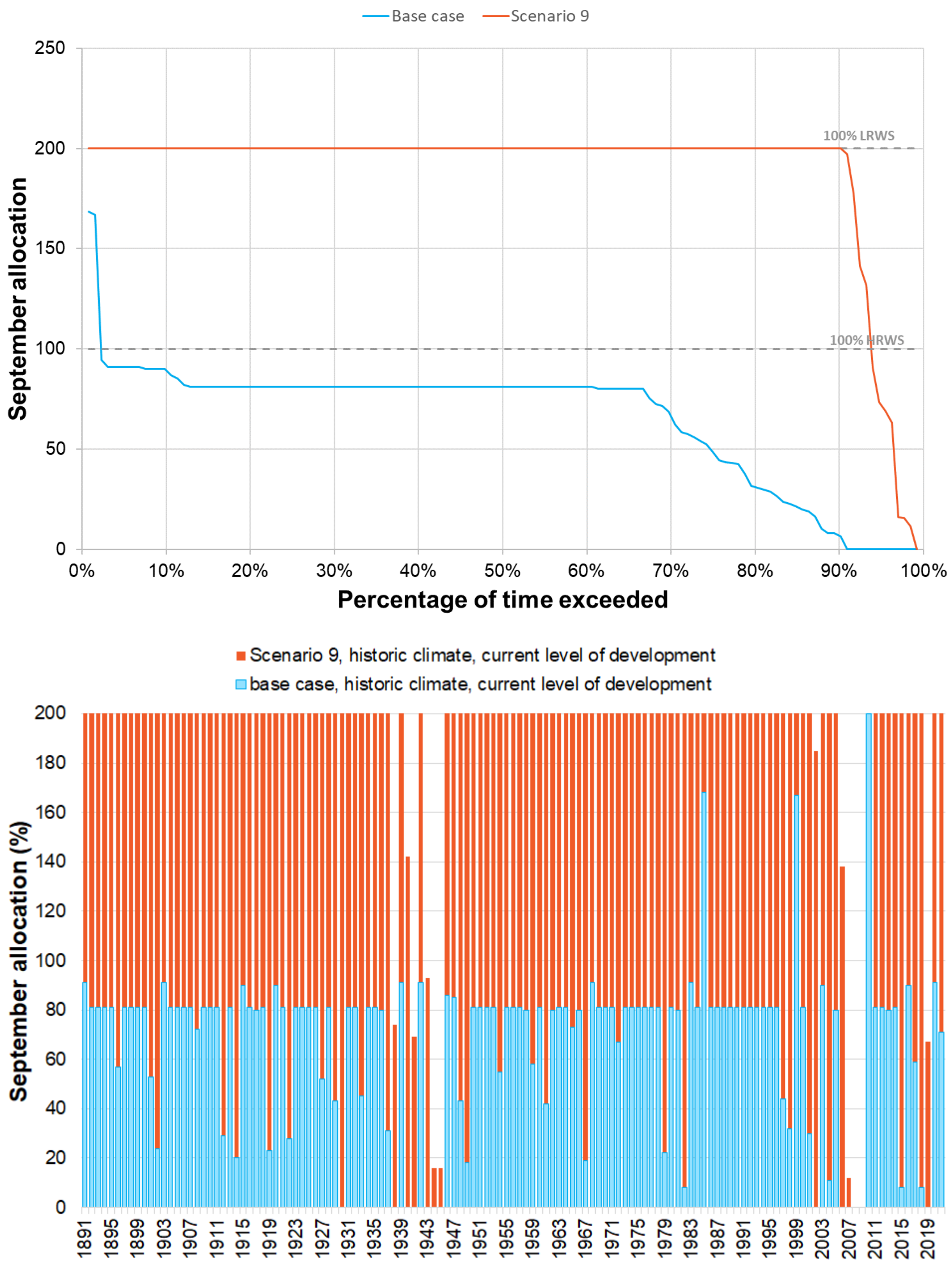


Figure 5-28: Scenario 9: September allocation (reliability) compared to the base case, historic climate

Results show that less irrigation and D&S demand exist in the system and hence less is supplied under this scenario. Again river flows are very similar to the base case because water that is now owned by the environment is still released down the river to satisfy environmental flow requirements. As a result Broken River losses are also are not significantly different but Broken Creek loss provision is now zero.

Table 5-30: Demand results, Scenario 8, historic climate, current demands

	Base case supplied	Scenario 8 supplied
Irrigation demands (ML/yr)	3,462	344
D&S demands (ML/yr)	677	398

Table 5-31: Mean annual flow at compliance points, Scenario 8, historic climate, current demands

	Base case Mean annual flow (ML/yr)	Scenario 8 Mean annual flow (ML/yr)
Broken R reach 1	69,367	69,485
Broken R reach 2	199,532	200,286
Broken R reach 3	225,757	230,022*
Broken Ck reach 1	5,015	3,979*

* Modelled flow results post processed as described in Section 5.1.5.

Table 5-32: Mean annual loss, Scenario 8, historic climate, current demands

Zone	Reach / location	Base case Mean annual loss (ML/yr)	Scenario 8 Mean annual loss (ML/yr)
Zone 1	Broken Weir	4,236	3,891
Zone 1	Hollands Creek	2,359	2,359
Zone 2	Stockyard Creek	292	292
	Total upstream of Caseys Weir	**6,887**	6,542
Zone 4	at Caseys Weir	8,340	8,314
Zone 4	supply loss between Caseys Weir and Gowangardie Weir	21	0
Zone 5	supply loss between Gowangardie Weir and Goulburn River	13	0
	Total downstream of Caseys Weir	**8,374**	8,314
Zone 3	Broken Creek loss provision	4,323	0

5.2 Comparison of results across scenarios

Table 5-33 and Figure 5-29 show that only small reliability gains are realised under Scenario 3, 4, 5 & 6. Gains are larger under Scenario 8, 9 and 2 because a greater redistribution of HRWS is assumed. When a D&S reserve is created under Scenario 7 reliability reduces slightly but results in very high reliability for D&S demands.

September allocations increase substantially for scenarios where the volume of consumptive HRWS is substantially reduced and/or when Broken Creek loss provision is not needed (Figure 5-30).

Table 5-33: Reliability comparison, historic climate and current demand

	base case	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
reliability	84%	90%	85%	85%	85%	87%	83%*	89%	93%
D&S reliability*							99.7%	99.0%	98.7%

* % of D&S demand supplied when a D&S reserve is in place

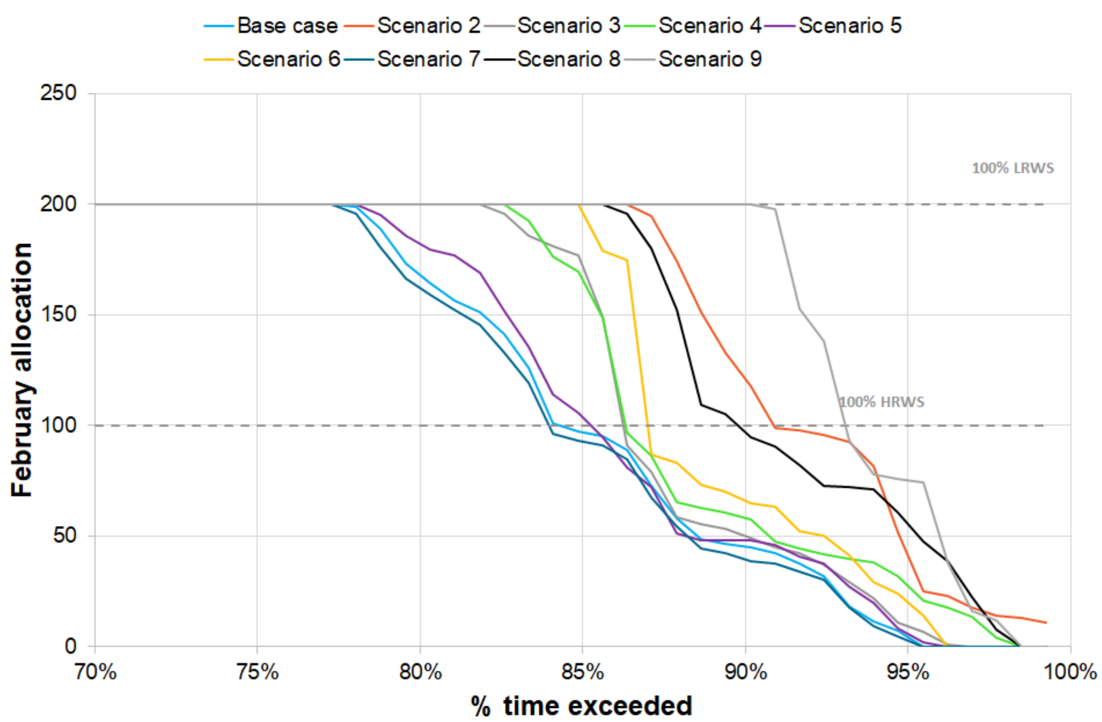


Figure 5-29: February allocation (reliability) comparison, historic climate current demand case

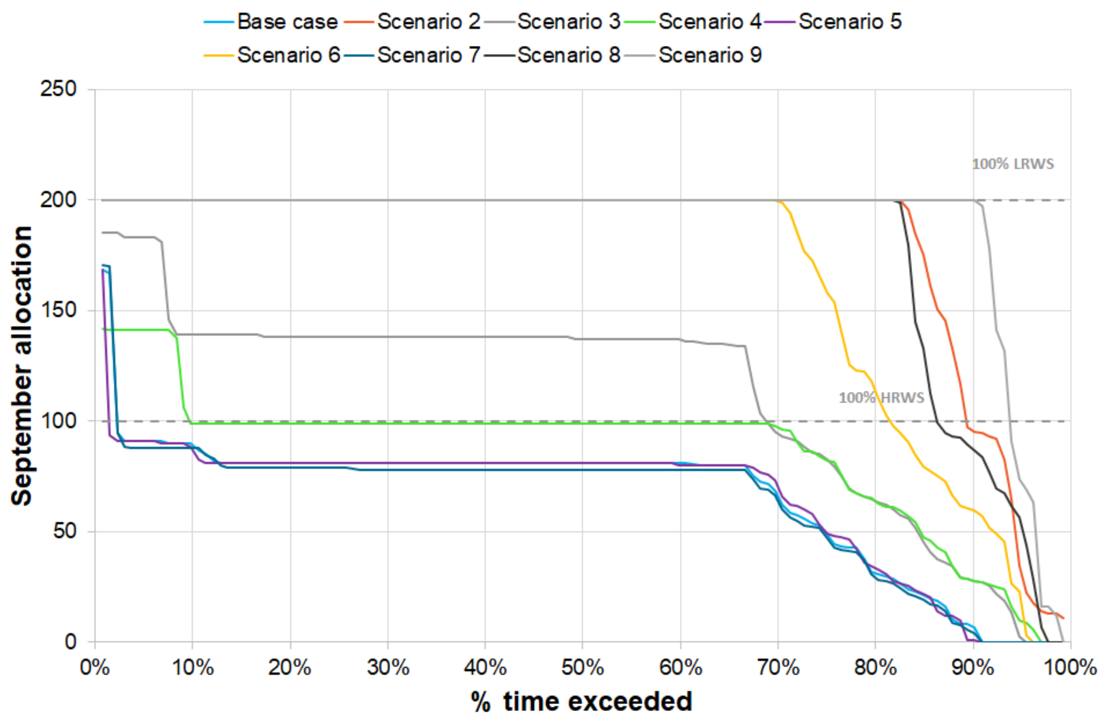


Figure 5-30: September allocation (reliability) comparison, historic climate current demand case

In terms of demand supplied there is not a big difference between the base case and the scenarios except for D&S supply in Scenario 2, 7, 8 and 9. For Scenario 2 this is due to the lack of irrigation demand and for Scenario 7, 8 & 9 this is due to the D&S reserve rule.

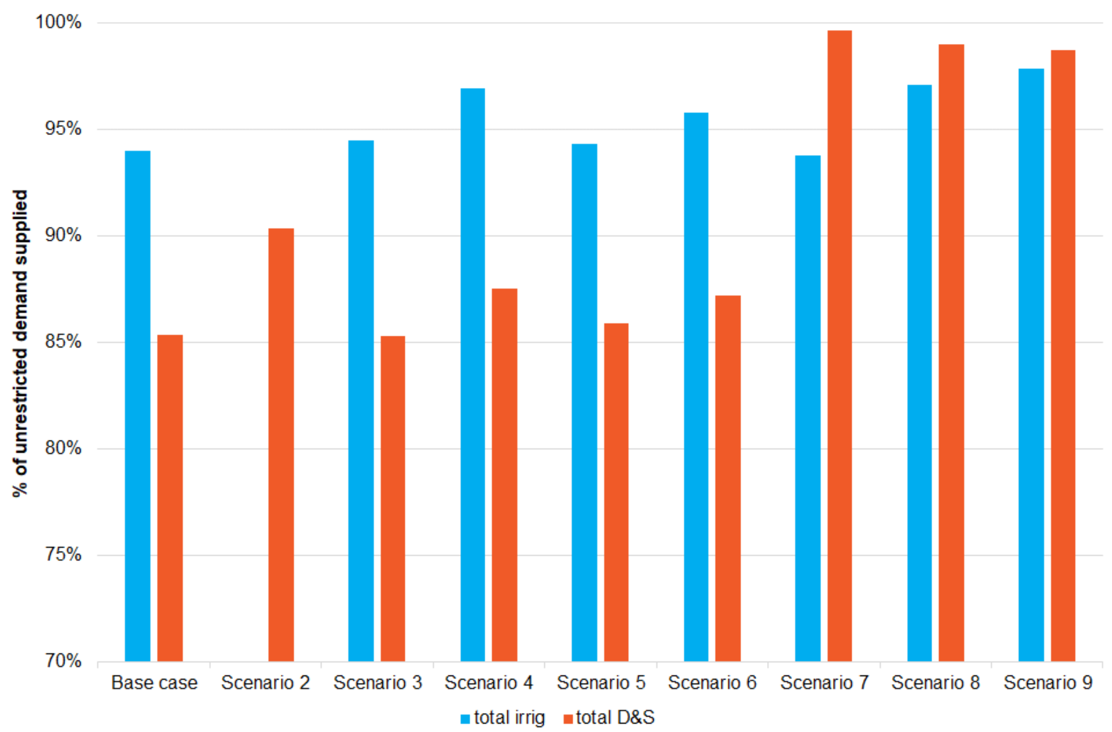


Figure 5-31: Percentage of unrestricted demand supplied, historic climate current demand case

Flows down Broken River vary little between scenarios as water redistributed to the environment is still released. This is some difference in flows down Broken Ck for scenarios where the Broken Ck loss provision is reduced or does not need to be provided. For the same reasons losses are also similar across scenarios except where Broken Ck loss provision is reduced or does not need to be provided (Figure 5-32).

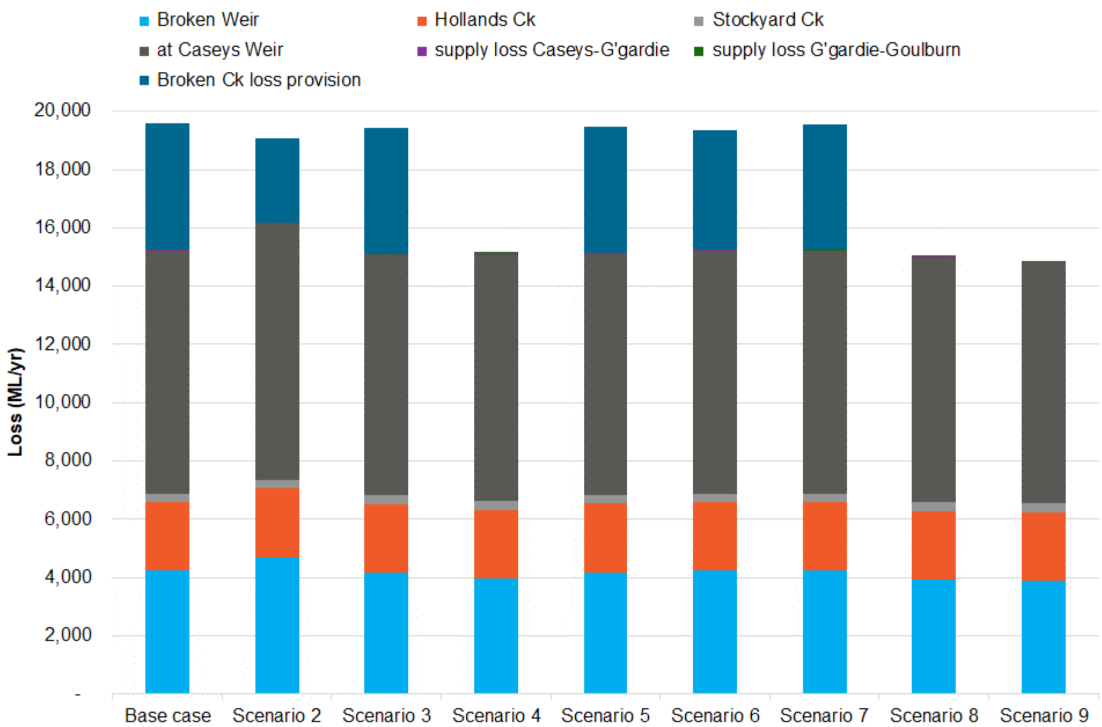


Figure 5-32: System loss comparison, historic climate current demand case

The degree to which environmental low flow requirements can be satisfied under each scenario was also examined. Results showed that this did not change substantially across scenarios except where there was a very large volume of stored water held by the environment (e.g. Scenario 2).

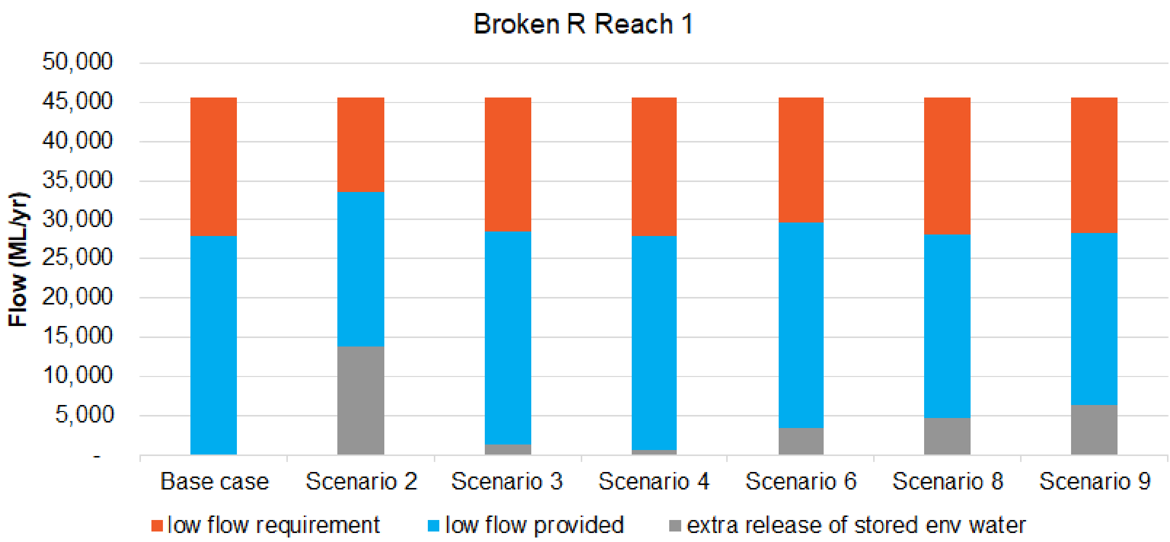


Figure 5-33: Environmental low flow comparison, Broken River, historic climate current demand case

Results for Broken Creek showed that low flow requirements are largely being satisfied by the Broken Creek loss provision. In scenarios where water is no longer being sent down Broken Creek (to satisfy demands Scenario 4, 8 & 9) mitigation water is provided as described in Section 5.1.5.

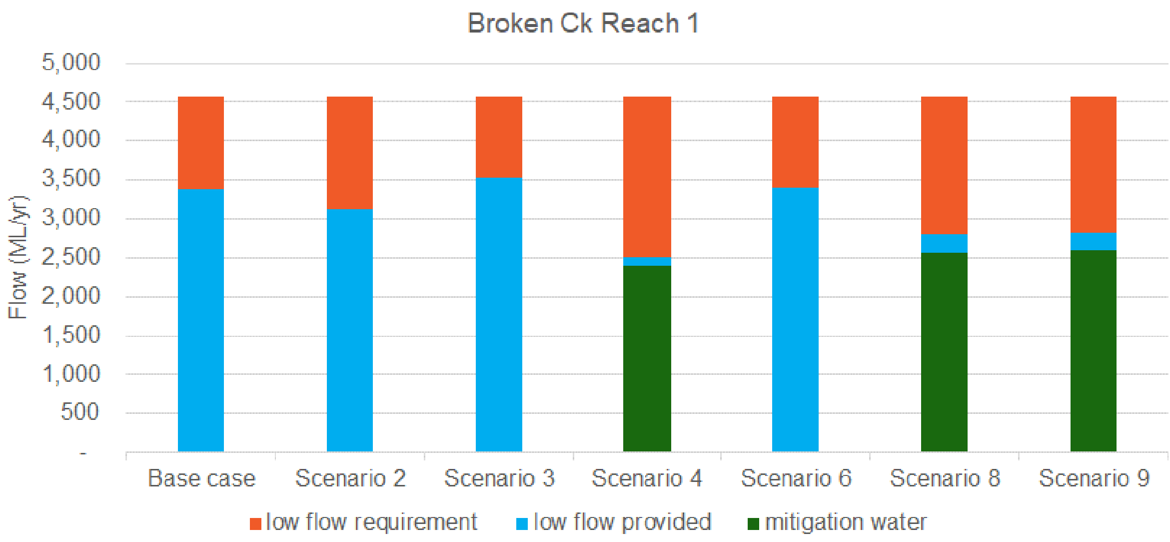


Figure 5-34: Environmental low flow comparison, Broken Creek, historic climate current demand case

5.3 Conclusions

A new base case model was established and a range of Broken Reconfiguration scenarios run under current and future climate conditions and current and future demand. Redistribution of HRWS was split between the environmental and reliability improvement. The performance of a D&S reserve was also tested. Results were compared with base case (do nothing) model results.

Base case modelling showed that current reliability is 84%. While most scenarios resulted in reliability gains, reliability is improved most under cases where a greater redistribution of HRWS is assumed or a D&S reserve is created (for D&S demands).

Early season (September) allocations are constrained by the volume of water that must be set aside for river and operational losses and Broken Creek loss provision. Therefore September allocations improved substantially for scenarios where consumptive demand magnitude and hence operational losses reduced, especially on Broken Creek.

The proportion of unrestricted demand supplied increased most for scenarios with a significant reduction in consumptive demand or where the D&S reserve was introduced.

Due to releases of stored environmental flows, flows and hence river losses vary little between scenarios except for cases where supply is significantly reduced or removed from Broken Creek. Provision of environmental summer-autumn and winter-spring low flow requirements only improved significantly in cases where there was a significant increase in the volume of stored environmental water.

Results showed that the impacts of climate change on system performance are similar for the base case and for reconfiguration scenarios due to there being a similar impact of climate on water availability. Where the model was run with historic climate and full demand, results showed that the impact of this demand increase on reliability is like the impact of post 1975 climate.

Table 5-34: Scenario performance comparison

	Base case	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
February reliability*	84%	90%	85%	85%	85%	87%	83%	89%	93%
D&S reliability with reserve							99.7%	99.0%	98.7%
September reliability^	2%	89%	69%	9%	1%	82%	2%	86%	94%
Unrestricted demand supplied	92%	90%	93%	95%	93%	95%	95%	98%	98%
Losses compared to base case	19,584	-523	-137	-4,432	-107	-228	-24	-4,565	-4,728
Provision of low flows compared to base case, ML/yr (scenarios with stored environmental water only)									
Broken River reach 1	27,983	+5,547	+462	-108	n/a	+1,558	n/a	+231	+326
Broken Creek reach 1	3,390	-265	+139	-887#	n/a	+10	n/a	-583#	-558#

*February reliability is calculated as the percentage of years over the whole model run when HRWS allocation is 100% or greater by February.

^September reliability is calculated as the percentage of years over the whole model run when HRWS allocation is 100% or greater by September.

Modelled flow results post processed as described in Section 5.1.5.

Attachment	Cost-Benefit Analysis Report
Attachment No.	4
Author	Natural Capital Economics

Broken System Reconfiguration

Cost-Benefit Analysis

July 2024

Natural Capital Economics

Natural Capital Economics, part of the Alluvium Group recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for country and the waterways within.

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Checked	Dr Amar Doshi
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FIGURES

1 Introduction

The Broken River system in north-eastern Victoria plays a crucial role in supporting the agricultural sector and local community. However, decreasing and unpredictable water inflows have created significant challenges for maintaining sustainable water use practices within the system.

In December 2019, the Victorian Minister for Water announced a review of the regulated Broken River system. The Broken system review 2020–22 (Victoria. Department of Environment, Land, Water and Planning, 2022) recognised that average annual inflows have declined, impacting all water users, and responded to the clear need to consider how to manage the system in a future, drying climate.

The seventh recommendation of the Broken River system review was to undertake a feasibility study of how the Broken system could be reconfigured—including the potential for a reduced irrigation footprint—so the local community can understand the long-term options for the future of the valley with reduced water availability. This prompted the initiation of the Broken System Feasibility Study (BRFS).

The intent of the BRFS is to develop and assess a list of reconfiguration scenarios, which can be combined (as required), and applied to different zones within the project area to achieve a reconfiguration of the Broken system. This includes assessment of zone-based option combinations (scenarios) against technical, environmental, social, cultural, and economic criteria to inform selection of a preferred scenario and associated recommendations.

NCEconomics has undertaken a Cost-Benefit Analysis of seven zone-based scenarios, compared to the *do-nothing* scenario (the base case). The CBA will complement the outcomes of the detailed environmental, social and cultural assessments described in the BRFS. It assessed the net public benefit of each scenario and the distribution of impacts amongst the different stakeholder groups. This report presents the approach and outcomes of the CBA.

Note that this report is an attachment to the BRFS report and therefore should not be read or interpreted in isolation without the context and information contained within the Feasibility Report.

1.1 Report structure

The subsequent sections of this report are structured as follows:

- *Chapter 2: Methodology*—provides an overview of the technical approach used for the Cost-Benefit Analysis
- *Chapter 3: Scenarios*—gives an overview of the scenarios being assessed
- *Chapter 4: Inputs and assumptions*—outlines the expected impacts from each scenario, and key inputs and assumptions used in the analysis
- *Chapter 5: Results*—presents the results of the Cost-Benefit Analysis—including the sensitivity analysis and distributional effects
- *Chapter 6: Conclusions* —summarises the findings.

2 Methodology

This chapter describes the methodology utilised for the Cost-Benefit Analysis. The methodology follows guidelines for Cost-Benefit Analysis published by the Victorian Department of Treasury and Finance (DTF) (Department of Treasury and Finance (Victoria), 2013).

2.1 Overview of Cost-Benefit Analysis approach

Cost-Benefit Analysis (CBA) is a holistic appraisal method that compares the base case (i.e., the 'do nothing differently' or status quo) with one or more alternatives. It aggregates all the costs and benefits associated with the various options across a 30-year assessment period to estimate the net impact on society, and to different stakeholder groups.

CBA includes both market impacts, such as investment and operating costs, but also impacts for which there are no market prices, such as changes to environmental values. The CBA approach is a useful tool to inform decision-making, providing valuable insights into the net impacts on community welfare from different initiatives.

The approach also underpins most business cases and government investment decisions. As such, guidelines for undertaking CBAs have been developed across and within jurisdictions and agencies. The prescribed approach typically involves as series of steps, as illustrated in Figure 1.

Key point

The CBA for this project did not assess the net benefits of a 'base case' per se; instead, the base case was a high-level context used to determine the incremental/additional benefits and costs for each scenario. The assumptions used to define the incremental benefits are outlined in chapter 4.

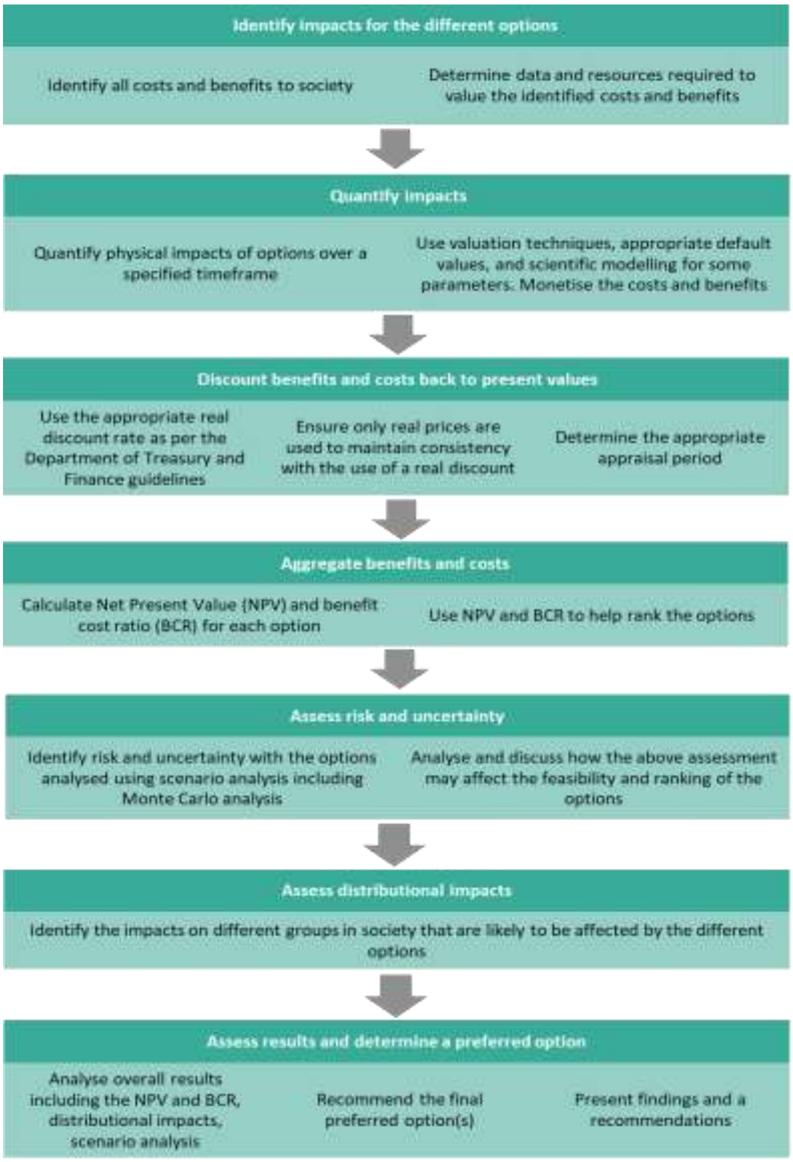

Figure 1. Overview of CBA

CBA has a significant advantage over other approaches as it enables comparisons of projects, options or in this case, scenarios, with different types of benefit streams and values. All costs and benefits are estimated over a specified timeframe and discounted to current, present value terms (2024 dollars).[1] The key metrics and decision rules for the assessment and comparison of options are:

- the present value of costs (PVC)—the total value of all quantified costs discounted to present value terms.
- the present value of benefits (PVB)—the total value of all quantified benefits discounted to present value terms.
- the net present value (NPV)—the net benefit, calculated as PVB less PVC. Where the NPV > 0, the quantified value of benefits exceeds the costs.

[1] Discounting is necessary because a dollar of benefit in the future is worth less than a dollar of benefit today. The discount rate represents the social opportunity cost of capital used in the project: what benefits to society the funds would return if left in the private sector (Australian Transport Assessment and Planning (ATAP) Steering Committee, 2022).

- benefit-cost ratio (BCR)—a ratio of PVB divided by PVC. Where the BCR > 1, the quantified value of benefits exceeds the costs.

While both NPV and BCR provide a similar picture of the net benefits to society and are hence reported, only the NPV can be used to compare and rank options when they are not independent of each other (i.e., it is not feasible to choose more than one reconfiguration scenario). As such, the NPVs were used to compare the scenarios in this assessment.

2.2 Estimation of economic values

The reconfiguration scenarios were expected to provide a range of market and non-market benefits. Typically, these benefits would be quantified for a CBA using a range of economic valuation techniques (Table 1). However, given the time and data restrictions associated with this assessment, only a subset of these approaches was utilised, specifically productivity-based values and benefit transfer of stated preference values.

Table 1. Examples of economic valuation techniques

Method	Based on …	Useful for …
Market-based techniques		
Market values	Actual market transactions	Where there are established markets (e.g., costs for new pipelines)
Productivity-based	Inputs to production of commercial goods	Changes in costs of service provision
Replacement cost	Costs of replacing a service	Reduced future costs of emergency repairs
Avoided cost	Avoiding costs to business or government service delivery	Valuing external impacts (e.g., avoided commercial losses attributable to service disruptions)
Non-market based techniques		
Hedonic pricing	Values of goods bundled with market traded goods (e.g., aesthetic amenity/view which is accessed through buying a house in a particular neighbourhood)	The recreational value of improvements in water quality and recreational uses of receiving environments (e.g., primary, secondary, tertiary use)
Travel cost	Costs incurred in visiting a site	Valuing tourism, recreation, or cultural use of a site
Stated preference techniques	Surveys and community willingness to pay to protect an asset	The value of the existence of biodiversity and ecosystem functions
Benefit transfer	Studies undertaken in similar locations. The original studies could have involved any of the techniques outlined in this table.	Situations where budgets are constrained and primary research into non-market values are not possible

It should be noted that there were several benefits/costs pertaining to the relevant scenarios that were not quantified in this assessment, such as effects on opportunities for recreation or community wellbeing. Social and environmental impacts have been described in detail in the multi-criteria analysis attached to the Feasibility Report.

2.3 Analysis of uncertainty

It is common to have to make assumptions for a CBA where data is missing or of poor quality. Furthermore, there is often a range of values that could be used for specific benefits or costs. To account for this uncertainty and variability in data inputs, it was important to perform sensitivity analysis to understand the potential range of possible outcomes and the extent to which individual assumptions effect the overall results.

Monte Carlo simulation is a sophisticated approach to capturing the uncertainty with parameters within a CBA. In scoping the associated costs and benefits of a project, ranges for each parameter can be established to reflect any risk and uncertainty. These values then interact with each other in multiple iterations (e.g., 20,000 iterations) of the model to determine the impact of the aggregate uncertainty. Monte Carlo simulations are conducted using specific applications or spreadsheet plug-ins, which require expert practitioners.

The simulations allow the practitioner to generate metrics (such as confidence intervals) and insightful charts that effectively illustrate the uncertainty associated with the CBA results. One example is a probability distribution, which demonstrates the likelihood of outcomes within the ranges and confidence intervals (**Error! Reference source not found.**). The range and distribution of results provide clear illustration of the uncertainty associated with individual projects and thus, enables a more informed comparison between the projects and allows decision-makers/investors to pursue projects which are reflective of their risk appetite.

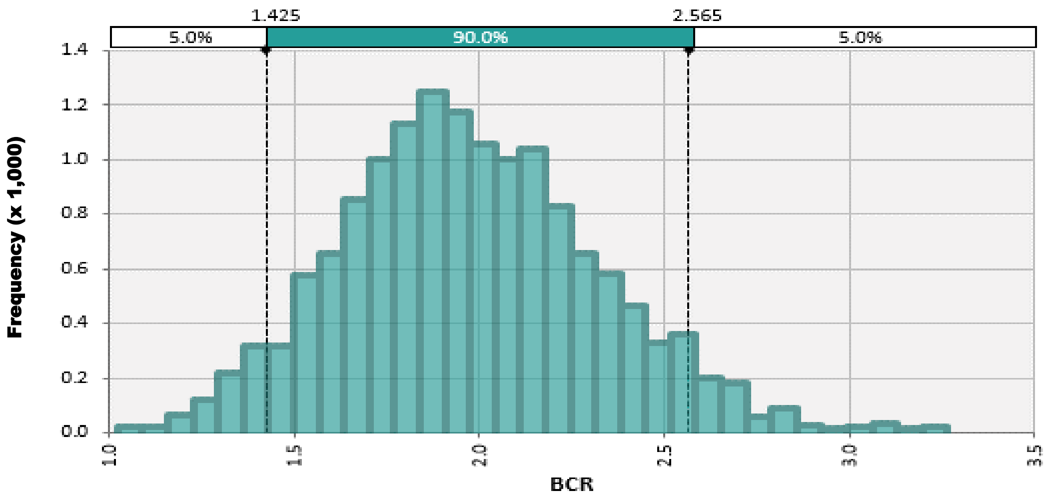

Figure 2. Example of confidence intervals from Monte Carlo simulations

Monte Carlo simulations also enable the identification of how much variability in estimates is attributable to individual input parameter or assumptions (Figure 5) and provides a better reflection of the relative impact of each parameter on the final estimate. This provides useful insight to future research, project design and ongoing targeting for monitoring and evaluation of project outcomes.

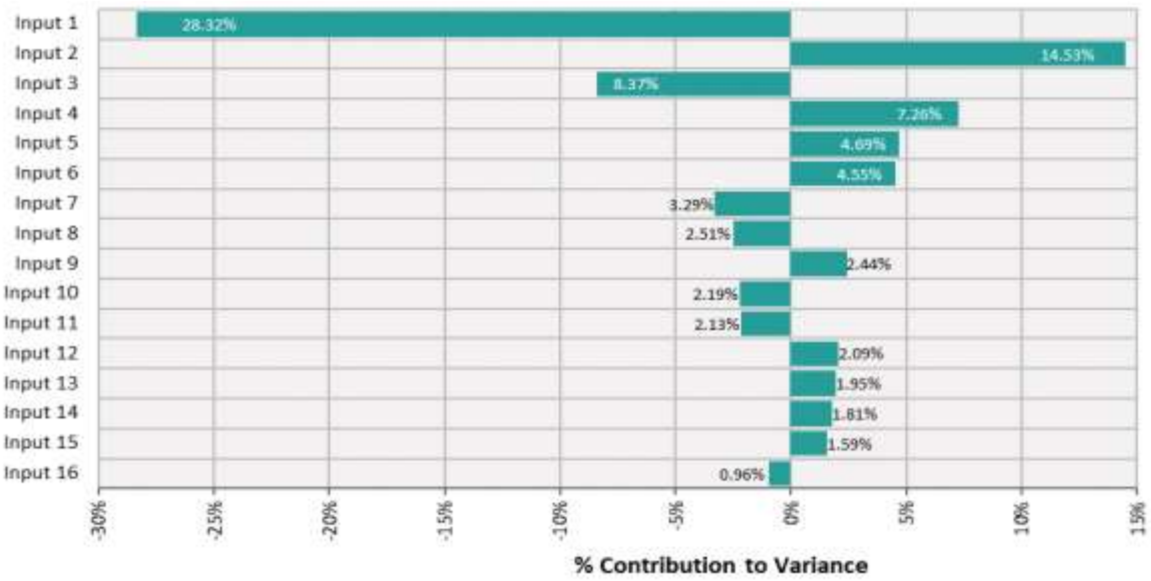

Figure 3. Example of source of variance chart from Monte Carlo simulations

3 Scenarios

The aim of the study was to consider changes to the Broken River system's configuration to better meet the region's long-term needs. A zone-based approach was utilised as this recognised the different geological characteristics, usage pattens, and physical limitations that influence the effectiveness of options. The five zones assigned within the project area were as follows:

Zone 1. Broken River from Lake Nillahcootie to Lake Benalla.

Zone 2. Broken River from Lake Benalla to Casey's Weir, including entitlement holders connected to the Mokan Pipeline system.

Zone 3. Broken Creek from Casey's Weir to Waggarandal Weir

Zone 4. Broken River from Casey's Weir to Gowangardie Weir

Zone 5. Broken River from Gowangardie Weir to the confluence with the Goulburn River.

A map of these five zones is shown in Figure 4 below.

Figure 4. Broken System Reconfiguration Zones.

Source*:* Broken Reconfiguration Feasibility Study report, figure 17, p. 44.

Through a process of shortlisting options, the BRFS identified nine individual zone-based scenarios. These scenarios were assessed in a multi-criteria analysis. Through the multi-criteria analysis and considerations from the stakeholder engagement, one scenario was not considered necessary to proceed with in a CBA (ZBS 5 Lake Mokoan pipeline channel savings). The list of scenarios assessed in the CBA is given in Table 2.

A complete overview and details of each scenario is provided in the BRFS. ZBS 8 and ZBS 9 were combination options. The former was a combination of Scenario 3, Scenario 4, Scenario 6 and Scenario 7. The latter included the scenarios of Scenario 8, in addition to Scenario 5[2] and removing or reconnecting all services in zone 4. Note that Scenario 9 included a fish passage enhanced at Gowangardie Weir through decommissioning or other works. This fish passage was not considered for any of the other scenarios analysed in the CBA.

Table 2. Overview of zone-based scenarios

Scenarios	Description
Scenario 1 (Base Case)	**Do nothing.** Scenario 1 was the base case used to compare current conditions to subsequent reconfiguration scenarios
Scenario 2	**Transition out of irrigation (whole district).** Scenario 2 entailed a complete transition away from irrigated supply in the Broken system. It was assessed for the purpose of understanding the extent of loss reduction possible noting that it is not the intended or likely outcome.
Scenario 3	**Remove or Reconnect Zone 5.** The aim of this scenario was to resupply or remove all services for Zone 5 to reduce operational losses downstream of Gowangardie Weir.
Scenario 4	**Remove or Reconnect Zone 3.** This scenario aimed to resupply or remove all services in Zone 3 (Broken Creek)
Scenario 6	**Systemwide initiatives.** Voluntary purchase of water entitlements supported by an adjustment program which would include advisory support to plan for a transition to dry land farming and whole farm planning incentives.
Scenario 7	**Secure access to D&S water.** This scenario looked at establishing a new type of entitlement (or system rules) that would enable D&S to be prioritised ahead of HRWS and LRWS for seasonal determinations.
Scenario 8	**Combination option.** Scenario 8 was a combination of Scenario 3, Scenario 4, Scenario 6 and Scenario 7.
Scenario 9	**Extended Combination option.** Scenario 9 was a combination of Scenario 3, Scenario 4, Scenario 5, Scenario 6 and Scenario 7. In addition, it included removing or reconnecting all services in zone 4.

[2] ZBS 5 is described in the Feasibility Report and involves the construction of a pumped pipeline from Caseys Weir to the existing Mokoan Pumping Station, to supply the pumping station directly from the Broken River. ZBS 5 has not been modelled explicitly in the CBA, but forms part of ZBS 9.

4 Inputs and assumptions

This chapter gives an overview of the key assumptions used in the estimation of costs, benefits, and dis-benefits, for the following categories:

- capital costs
- operating and maintenance costs
- agricultural productivity
- environmental outcomes from changes in streamflow.

It should be noted that these scenarios will also result in social impacts. However, these were not assessed within the CBA. Further information of the social (and other) outcomes can be found in the multi-criteria analysis.

Key point

The inputs and assumptions outlined here were used to determine the incremental/additional costs and benefits of the scenarios, against the contextual base case.

4.1 Capital costs

The capital costs that were included in the CBA encompass the following categories:

- infrastructure costs
- entitlement purchases
- farm reconfiguration costs

Business case development costs and project delivery management costs[3] were not considered in the CBA as they were not available at the time of this analysis being developed. It should be noted that preliminary estimates have since been estimated by Sequana and are provided in the BRFS report. Future iterations of this CBA should consider these cost inputs as they vary across scenarios.

Entitlement purchases were for purpose of the CBA considered a transfer from one party to another and therefore did not have a net impact on the results.

Infrastructure costs

Four scenarios included pipeline construction: Scenario 3, Scenario 4, Scenario 8 and Scenario 9. Note that Scenario 8 was a combination scenario including the infrastructure costs associated with Scenario 3 and Scenario 4. Scenario 9 included the same scenarios as Scenario 8, in addition to the construction of a pumped pipeline from Caseys Weir to the existing Mokoan Pumping Station (Scenario 5), and removal or reconnection of all services in zone 4.

[3] These costs are the expenditures involved in the planning, development and management of the project after it has received Commonwealth funding approval based on the detailed business case. The costs encompass various non-construction activities and resources required to plan, develop and manage the delivery the project to completion.

All capital costs were assumed to be incurred in year 0 of the analysis period and therefore, did not require discounting.

In Scenario 3, all Zone 5 properties would be resupplied from outside zone 5. This would involve the construction of a pipeline from the Shepparton Irrigation Area to Gowangardie Weir, as well as on-farm reconnection works to connect some D&S properties to the Tungamah Pipeline District. These costs are listed in Table 3.

Table 3. Infrastructure cost assumptions Scenario 3

Category		Value ($)
Gowangardie Weir pipeline	Construction cost	$16,955,250
	Planning and design costs	$1,271,644
On-farm reconnection works (Irrigation and D&S)		$1,420,000
Total		**$19,646,894**

Source: Assumptions prepared by Advance Survey Design on request from Sequana

In Scenario 4, all Zone 3 properties would be resupplied from outside of Zone 3, with a new Irrigation and D&S pipeline at the southern end (Casey's Weir) supplied from Zone 4 and the northern end supplied with D&S only via an extension to the Tungamah Pipeline. The associated costs are presented in Table 4.

Table 4. Infrastructure cost assumptions Scenario 4

Category		Value ($)
Casey's Weir pipeline	Construction cost	$7,820,203
	Planning and design costs	$782,020
Tungamah extension	Construction cost	$1,165,493
	Planning and design costs	$116,549
On-farm reconnection works (Irrigation and D&S)		$685,000
Total		**$10,569,266**

Source: Assumptions prepared by Advance Survey Design on request from Sequana

As previously mentioned, Scenario 8 included the infrastructure costs of Scenario 3 and Scenario 4. For Scenario 9, there were additional costs associated with the construction of a pumped pipeline from Caseys Weir to the existing Mokoan Pumping Station, as well as the extension of pipelines into zone 4 (from zone 5 and zone 3). The total infrastructure costs associated with Scenario 9 are given in Table 5.

Table 5. Infrastructure cost assumptions Scenario 9

Category		Value ($)
Broken Creek pipeline extension to Zone 4	Construction cost	$12,038,000
	Planning and design costs	$1,203,800
Tungamah extension	Construction cost	$1,165,493
	Planning and design costs	$116,549
Gowangardie Weir pipeline Extension to Zone 4	Construction cost	$25,860,250
	Planning and design costs	$1,939,519
Mokoan Pipeline extension	Construction cost	$4,277,629

Category	Value ($)
Design and planning	$427,763
Decommissioning of Gowangardie Weir	$4,882,268
On-farm reconnection works (Irrigation and D&S)	$2,450,000
Total	**$54,361,271**

Source: Assumptions prepared by Advance Survey Design on request from Sequana

It was assumed that the life span of the infrastructure investments would be 50 years. Since the appraisal period for this CBA is 30 years, a residual value of the assets was included at the end of the period, assuming this value would be a simple proportion of useful life remaining of the total capital value (i.e., 40% or 20/50 fraction of total capital investment).

Operating and maintenance costs associated with the above-mentioned investments are described in section 4.2.

Entitlement purchases

The assumed prices for voluntary entitlement purchases of HRWS and LRWS in the Broken River system are presented in Table 6. The prices were based on market data from recent sales, multiplied by a market price multiplier to reflect the higher price that could be expected to be offered by the Government. This was based on the assumption that current market prices are based on low volumes of sales and drawing significant volumes of water into the market for purchase would require a price premium. The suggested rate for this multiplier for the purpose of estimating at a feasibility stage was 1.3.

Table 6. Price assumptions—Voluntary entitlement purchase

Assumption	Unit value ($/ML)
HRWS purchase price	$3,510
LRWS purchase price	$325

Source: Assumptions prepared by Sequana

In addition to the purchase price, the cost of entitlement purchases included legal fees associated with the transfer of water entitlements.

Properties resupplied from the Goulburn system would need to acquire Goulburn shares. This was relevant for Scenario 3 and Scenario 4. The value of Goulburn shares is not equal to Broken Shares, and a rate of conversion is likely to be applied. Based on recent sales prices, the market purchase price for Goulburn system HRWS was assumed to be $4,100 per ML.

For Scenario 7, it was assumed that entitlement held by GMW through completion of the Cosgrove Project would form part of a reserve set aside each season to support D&S allocation. This was assumed to involve a financial contribution from landholders (properties that only hold 2 ML) to reflect the value of access to additional water to create the high reliability D&S service. Two key elements were considered in the estimation of capital costs for this scenario: 1) water entitlement changeover and 2) administration of entitlement changes. The assumptions for these costs are given in Table 7.

Table 7. Capital cost assumptions for Scenario 7

Assumption	Cost ($)	Description
Water entitlement changeover	$702,000	Assumed 200 properties hold only 2 ML and to access Cosgrove savings. Cost per ML is assumed $3510. This represented the current market value, multiplied by an upscaling factor of 1.3
Administration and implementation	$250,000	Additional costs for administration and implementation of the water entitlement changeover.

Source: Assumptions prepared by Sequana

For the CBA, the entitlement purchases were considered a transfer from one party to another and therefore should not have a net impact on the results. However, legal fees and additional costs for administration and implementation associated with entitlements purchases were included as capital costs (not transfers).

Farm reconfiguration

Most of the scenarios included some level of farm business planning, which would involve professional specialist advice and support for farmers to develop a strategic business plan for their entire farming enterprise. Farm business planning costs for each scenario are given in Table 8.

Table 8. Farm business planning costs

Zone based scenario	Cost ($)
Scenario 2	$1,053,000
Scenario 3	$144,000
Scenario 4	$90,000
Scenario 6	$368,550
Scenario 7	$0
Scenario 8	$434,706
Scenario 9	$533,706

Source: Assumptions prepared by Sequana

Table 9 shows the estimated costs of farm reconfiguration works associated with Scenario 6 and the assumed percentage split between government and private contributions. These costs were also included in Scenario 8 and Scenario 9. The detailed assumptions underlying these cost estimations are provided in the BRFS report.

Table 9. Farm reconfiguration costs for Scenario 6

Category	Cost ($)	Assumed share of government and private contribution	
		Government	Private
Whole farm planning	$607,140	45%	55%
Transition to dryland agriculture	$463,800	100%	0%
Transition to efficient irrigation	$4,401,950	20%	80%
Increased on-farm storage - investigation and design	$240,000	100%	0%
Increased on-farm storage - installation/construction	$5,893,500	20%	80%
Supported market correction	$119,486	100%	0%
Total	**$11,725,876**		

Note: The farm reconfiguration costs are also included in Scenario 8.
Source: Assumptions prepared by Sequana.

4.2 Operating and maintenance costs

Annual operating and maintenance costs associated with the pipeline construction in Scenario 3 and Scenario 4 are summarised in Table 10 and Table 11. These costs were assumed to remain consistent across the 30-year assessment period.

Table 10. Annual operating and maintenance costs Scenario 3

Category		Value ($/year)
Gowangardie Weir pipeline	Operating cost	$7,209
	Maintenance cost	$63,561
	Total	**$70,770**

Source: Assumptions prepared by Advance Survey Design on request from Sequana

Table 11. Operating and maintenance costs Scenario 4

Category		Value ($/year)
Casey's Weir pipeline	Operating cost	$3,458
	Maintenance cost	$82,688
Tungamah extension	Operating cost	$1,839
	Maintenance cost	$14,713
	Total	**$102,698**

Source: Assumptions prepared by Advance Survey Design on request from Sequana

For Scenario 3, it was assumed that there would be a reduction in on-farm pumping/energy costs for customers who would be receiving water on site for use via the Gowangardie Weir pipeline, instead of pumping from the river.

Operating and maintenance costs for Scenario 8 were the combination of the costs listed for Scenario 3 and Scenario 4. The operating and maintenance costs associated with Scenario 9 are given in Table 12.

Table 12. Operating and maintenance costs Scenario 9

Category		Value ($/year)
Broken Creek pipeline extension to Zone 4	Operating cost	$8,092
	Maintenance cost	$120,206
Tungamah extension	Operating cost	$1,839
	Maintenance cost	$14,713
Gowangardie Weir pipeline Extension to Zone 4	Operating cost	$13,977
	Maintenance cost	$101,447
Mokoan Pipeline extension	Operating cost	$47,082
	Maintenance cost	$39,578
	Total	**$346,936**

Source: Assumptions prepared by Advance Survey Design on request from Sequana

4.3 Agricultural productivity

A range of agricultural practices are utilised within the Broken system, with livestock, cropping and dairy enterprises accounting for the majority of water use. The reconfiguration scenarios could affect agricultural production in the area, through changes to the reliability of water supply.

As identified in the Broken System Review 2020–2022 (Victoria. Department of Environment, Land, Water and Planning, 2022), climate change is intensifying the impacts to this annual system, increasing variability between years, and decreasing volumes of inflows in the catchment. System users have reported low confidence to invest in irrigation infrastructure due to annual variability, uncertainty, and timing of allocations.

It was assumed that irrigators under the base case would be unable to maintain the current level of production into the future, while the reconfiguration scenarios would increase the reliability of the system and thereby contributing to avoid this reduction in production.

A key component of the calculation of impacts on agricultural productivity included the **avoided loss of production** from higher reliability (measured by the change in gross margins), described in more detail below.

Avoided loss of production

In the base case, it was assumed that enterprises would use more of their land for dryland cropping rather than irrigated land use due to the lower water availability. Under the reconfiguration scenarios, some of that conversion to lower value dryland use was assumed to be avoided due to higher reliability of water supply.

First, the value of agricultural production under the **base case** was calculated using the following method:

- Customer data on water use was collated for each land use type (horticulture, cropping, cattle, dairy, sheep and D&S) for each zone. The water use for the base case was calculated as the average annual use over the past 5 years, from 2018/19 to 2022/23.
- For each commodity type, water volumes were converted to a total irrigated area using the water consumption rates (ML/ha) given in Table 13. For example, if the current water use for cropping in a certain zone is 300 ML per year and using the water consumption rate for cropping of 2 ML per hectare, the irrigated area (ha) of cropping would be estimated to 150 ha.

- Gross margins for the respective commodities (Table 14) were then applied to the estimated total irrigated areas to determine the estimated total gross margin for each commodity in each zone, as an approximation of the current value of agricultural production under the base case.

Table 13. Water consumption rates by commodity type

Commodity	Stocking rate (head/ha)	Water consumption (ML/head)	Water consumption (ML/ha)	Source
Horticulture	N/A	N/A	7.6	University of Adelaide, 2022
Cropping (wheat)	N/A	N/A	2	Carr & Rogers, 2022
D&S	N/A	N/A	0.029	Agriculture Victoria, 2022
Cattle	1.54	0.024	0.037	Agriculture Victoria, 2022
Sheep	11.20	0.003	0.029	Agriculture Victoria, 2022
Dairy (irrigated pasture based)	1.54	0.042	2.80*	Agriculture Victoria, 2022, ABS, 2022

* Note: Dairy water consumption (ML/ha) includes allowance for irrigating pastures.

Table 14. Gross margin by commodity type

Commodity	Gross margin ($/ha)	Source
Horticulture	$6,766	University of Adelaide, 2022
Cropping (wheat)	$980	Carr & Roger, 2022
D&S	$609	Agriculture Victoria, 2022
Cattle	$949	Agriculture Victoria, 2022
Sheep	$609	Agriculture Victoria, 2022
Dairy	$2,270	Nelson, Waterman, Harman, Farm Business Economists, & Argriculture Victoria, 2023

Note: Gross margins have been adjusted for inflation.

The incremental increase in total gross margins for **each scenario,** resulting from avoided loss in irrigated area, was estimated as follows:

- The relative *increase in reliability* for each scenario, compared to the base case, was used to estimate an associated avoided loss in water use, irrigated area, and gross margin.
- The *productivity change* was calculated as the difference between the estimated total gross margin in the base case and each scenario.

System reliability was expressed as the probability that users can expect to receive 100% allocation against their High Reliability Water Shares (HRWS) in each water season. The reliability estimates for HRWS and LRWS from modelling and estimations performed by HARC and Alluvium Consulting are shown in Table 15. These estimates are based on HARC modelling assuming 50% of water is recovered for the environment and 50% for improving reliability. The reliability of Goulburn system HRWS was used for scenarios 3 and 4, where some customers were assumed to be connected to the Goulburn system.

Table 15. Estimated reliability

Scenario	Reliability (%)		Increase in reliability (%) relative to base case	
	HRWS	LRWS	HRWS	LRWS
Scenario 1 (Base Case)	84.0	77.9	NA	NA
Scenario 2	90.1	87.0	6.1	9.2
Scenario 3	85.5	82.4	1.5	4.6
Scenario 4	85.5	82.4	1.5	4.6
Scenario 6	85.5	82.4	1.5	4.6
Scenario 7	83.2	77.9	-0.8	0.0
Scenario 8	89.3	86.3	5.3	8.4
Scenario 9	93.1	90.8	9.1	12.9
Goulburn system HRWS	93.0		9.0	

Source: HARC modelling and calculations by Alluvium Consulting (for Scenarios 1–9); Reliability estimate for Goulburn system HRWS is based on advice from Sequana.

Where the base case identified that irrigated agriculture was likely to decline due to the decrease in reliability, it was assumed that landholders would switch to dryland cropping to mitigate financial losses. Figure 5 illustrates this concept, where the orange line (no conversion to dryland) represents the potential decline in the economic value of agricultural production due to lowered reliability, and the dotted green line (conversion to dryland) illustrates the potential relative increase in economic value with conversion to dryland cropping. The expected incremental benefits from a reconfiguration scenario would be the difference between the productivity with sustained reliability from irrigated cropping (reconfiguration scenarios) and conversion to dryland cropping.[4]

[4] This is given that dryland cropping would result in higher economic value of productivity than 'doing nothing' with the decline in irrigated cropping.

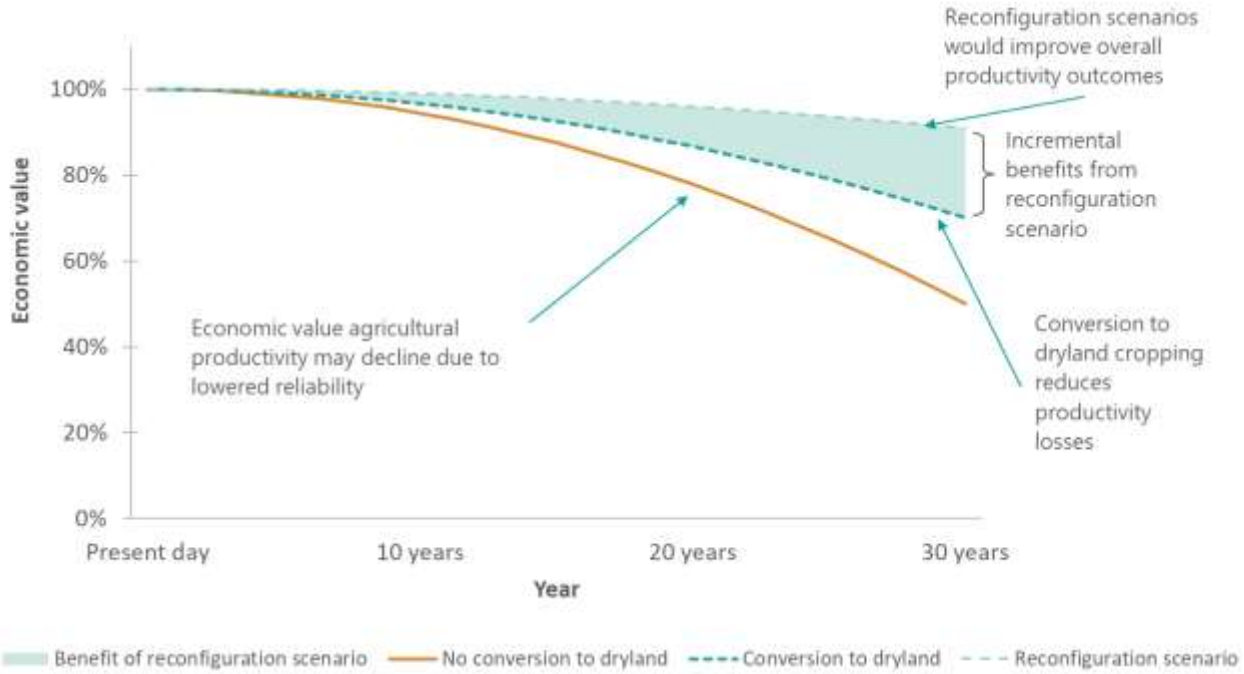

Figure 5. Conceptual illustration of the incremental economic benefit where dryland cropping was assumed

D&S landholders are not 'commercial' in nature and idle land was assumed not to be converted to dryland cropping for these users.

Note that the overall estimation of productivity impacts also accounted for any losses of productivity from agricultural enterprises transitioning out of irrigation (through entitlement purchases).

Opportunity costs

The opportunity cost represents the value of the next best outcome that is foregone when a scenario is selected. This is an important aspect of a CBA as it demonstrates the true incremental economic benefit of an option. For this CBA, the opportunity cost was estimated for reconnection to the Goulburn system (Scenario 3 and 4), relinquishment of shares (Scenario 6) and a decrease in HRWS reliability for non-D&S customers (Scenario 7).

In scenarios Scenario 3 and Scenario 4, some irrigators were assumed to be reconnected to the Goulburn system. This entailed the purchase of Goulburn HRWS entitlements. It was assumed that those selling entitlements from the Goulburn system currently use water for low value cropping, and this was used to represent the opportunity cost of the sale of those water shares.

In Scenario 6, a number of shares were assumed to be relinquished through voluntary purchase (6,693 HRWS and 3,313 LRWS), enabled through an adjustment program of farm reconfiguration works. The value foregone of irrigators no longer having the option to use these shares was calculated based on the assumption that those shares could have been used for cropping.

Specifically, this opportunity cost was calculated as follows:

- The volume of shares relinquished was multiplied by the average utilisation rate of the Broken River system.

- The water volumes were converted to a total irrigated area using the water consumption rate for cropping (ML/ha) (see Table 13).
- Finally, the gross margin for cropping per hectare (shown in Table 9) was applied to the estimated total irrigated area to determine the estimated total gross margin. The costs of setting up the infrastructure required to use the water was subtracted from this value.

Scenario 7 involved the assumption that entitlement held by GMW, through completion of the Cosgrove Project, would form part of a reserve set aside each season to support D&S allocation, rather than supporting existing HRWS allocation. For this option, opportunity costs reflect the reduced productivity resulting from the decrease to HRWS reliability for non-D&S customers.

Key point

Several assumptions were required to estimate the net benefits from agricultural productivity, reflective of the level of detail and quality of data available. However, it should be noted that given this analysis was being used to compare scenarios and these assumptions were applied consistently across scenarios, any uncertainty caused by the assumptions would not materially impact the relative performance of scenarios against each other.

4.4 Environmental impacts

The reconfiguration scenarios were expected to result in different environmental outcomes compared to the base case. Detailed descriptions of expected environmental outcomes can be found in the multi-criteria analysis.

To incorporate environmental outcomes into the CBA, the following key data inputs were used:

- The difference in streamflow resulting from changes to irrigation water deliveries and environmental water use between the base case and reconfiguration scenarios, measured as the difference in annual average GL (Table 16).
- An estimate of the non-market value for an additional GL of environmental water.

The average annual change in streamflow was calculated by Alluvium Consulting, based on modelling outputs from HARC. This did not directly measure ecological outcomes, such as impacts on native fish or platypus populations, but it was a quantitative proxy for the assumed associated impacts from changes in water flow.

Table 16: Difference in streamflow relative to base case

Scenario	Difference in streamflow (average annual GL)
Scenario 2: Transition out of irrigation (whole district)	1.07
Scenario 3: Remove or Reconnect Zone 5	0.61
Scenario 4: Remove or Reconnect Zone 3	0.24
Scenario 6: Systemwide initiatives	0.75
Scenario 7: Secure access to D&S water	-0.05
Scenario 8: Combination option	-0.28
Scenario 9: Extended Combination option	-0.61

Source: HARC modelling and calculations by Alluvium Consulting

A benefit transfer approach (as mentioned in Table 1) was applied to estimate the non-market value for additional GL of environmental water. This approach involved using an estimate from a previous primary study that was considered 'transferrable' in terms of relevance and scope of the source study to the Broken River system.

The value estimate was derived from Cooper, Crase, and Burton (2023), who estimated the willingness to pay (WTP) of 700 households in Greater Melbourne for obtaining enhanced environmental outcomes from additional environmental flows in the Yarra, Tarago, and Werribee catchments, during dry years.

The study used two stated preference techniques (choice modelling and best-worst scaling) to estimate the value of environmental water and the motivations for households paying for an increase in environmental water reserves. The respondents were presented with different scenarios of improved ecological outcomes and asked how much they would be willing to pay for such changes, through increased water charges, for one year. The ecological outcomes associated with the additional amount of water allocated to the environment were in the survey described in terms of native fish, frog and platypus populations, and changes to water quality.

To 'transfer' the WTP value to the context of this CBA, the following assumptions were made:

- The reference study applied the estimated WTP values for the target population of households in the Melbourne Water (MW) service catchment. Thus, the benefit transfer for this CBA applied the WTP to households in the Goulburn-Murray Water (GMW) service catchment. While it is possible that households outside the GMW catchment may also exhibit a value to the changes in environmental flows; this value is expected to decrease with distance from the catchment, but this actual 'distance-decay' is unknown and thus not included in the analysis.
- The survey undertaken by Cooper and colleagues (2023) would have a higher degree of urban households than the GMW catchment. The potential implication of this for the transfer of WTP value is unknown and has not been explored for this CBA.
- The WTP estimate was indexed to 2024-dollars and adjusted for differences in income levels between the MW and GMW catchment areas. That resulted in a WTP per household in GMW catchment area of $0.90 per household (compared to $1.13 per household in the source study).

Based on the change in GL of environmental water from the reconfiguration scenarios, the economic value to a household from the shift in level of environmental water, was calculated as the WTP per household ($/GL) multiplied by the amount of GL. Finally, this value was multiplied by the number of households in the GMW catchment.

Table 17: Input values for estimation of environmental outcomes

Input	Value	Description
WTP per household in GMW catchment area	$0.90/household	Value derived using benefit transfer approach. The WTP estimate was adjusted for inflation and differences in income levels*, compared to the source study.
Number of households in GMW catchment area	180,202	The number of households was derived by aggregating the household composition of 2016 data from ABS.

* The difference in income levels was estimated based on the average of the median weekly household income for the suburbs of the two areas.
Sources: Australian Bureau of Statistics, 2016 data of All person QuickStats for Local Government Areas. Suburbs within GWM and MW catchments were sourced from GMW and MW websites.

The difference in streamflow resulting from changes to irrigation water deliveries and environmental water use were positive for some scenarios and negative for others (Table 16). This difference in streamflow was a result of changes to which reaches the water may be regulated into, including the timing of such deliveries and/or the ownership of the water (i.e. whether it is put towards consumptive use, losses, or environmental use).

A limitation of the calculation used in this CBA is that the value of environmental water is based on the *willingness-to-pay* (WTP) for improvements, not the *willingness-to-accept* (WTA) degradation or loss of ecological values. The literature generally suggests that WTA is generally higher than the WTP because of the concept of loss aversion, with the pain of losing something being more significant than the pleasure of gaining something.

Key point

By applying WTP values to scenarios with net reductions in streamflow, the negative values of such losses were most likely underestimated. Furthermore, in applying average annual volumes of streamflow for the system, the calculation did not consider seasonal fluctuations or differences between zones.

Note that Scenario 9 included a fish passage enhanced at Gowangardie Weir through decommissioning or other works, which could result in environmental benefits. These have not been assessed in the CBA because of the limited prevailing assessments on the benefits. The potential environmental impacts of removing Gowangardie Weir have been described in the multi-criteria analysis attached to the Feasibility Report. Future assessments for this scenario may consider approaches to include the benefits/costs of increased fish passage and this will require:

- understanding key species and value (commercial, recreational, non-use or Cultural)
- investigating the biophysical and consequential economic improvements
- estimating relevant economic values, including primary research where relevant.

4.5 Summary of benefit and cost estimates

A summary of the present values of costs or benefits for each of the impact categories mentioned above is shown in Table 18.

Table 18: Present value of net costs and benefits by category, $million (FY2024 dollars)

Scenario	Capital costs	Operating and maintenance costs	Productivity gain/loss	Environmental impacts
Scenario 2: Transition out of irrigation (whole district)	-$4.64	$0.00	-$217.60	$0.16
Scenario 3: Remove or Reconnect Zone 5	-$19.49	-$0.70	$12.38	$0.09
Scenario 4: Remove or Reconnect Zone 3	-$10.33	-$1.27	$6.16	$0.04
Scenario 6: Systemwide initiatives	-$13.14	$0.00	$3.57	$0.11
Scenario 7: Secure access to D&S water	-$0.25	$0.00	$6.76	-$0.01
Scenario 8: Combination option	-$43.85	-$2.15	$23.78	-$0.04
Scenario 9: Extended Combination option	-$67.38	-$4.31	$32.29	-$0.09

Source: NCEconomics estimates

Note: Productivity impacts and environmental impacts included benefits or dis-benefits. That means that the net impacts on productivity or the environment were aggregated as net benefits. This resulted in the negative value of net benefits for Scenario 2 i.e., the dis-benefits outweighed the benefits.

5 Results

This chapter presents the results of the CBA, including the NPVs and BCRs of each scenario and sensitivity ranges to illustrate the uncertainty associated with the data inputs. A simple distributional analysis was undertaken to illustrate the differences in costs and benefits between stakeholder groups.

5.1 General assumptions

The general assumptions applied in the CBA were:

- The assessment period was assumed to be 30 years, consistent with the DTF's (2013) guidelines.
- The discount rate used was 7% (with a range of 4–9% for sensitivity analysis), consistent with the DTF's (2013) guidelines.
- Although climate change is expected to increase the variability of water availability between years and decrease volumes of inflows in the catchment, it was assumed that the net impact from this variability would be consistent across the base case and reconfiguration scenarios.

5.2 CBA results

The NPVs and BCRs were calculated for the net benefit of each zone-based scenario relative to the base case. This was done taking the outcomes for each scenario minus the outcomes from the base case. The NPVs and BCRs for each scenario are shown in Table 19.

While both NPV and BCR provide a similar picture of economic viability, only the NPV should be used to compare and rank scenarios when they are not all independent of each other.

Table 19: CBA results

Scenario	PV Costs ($M)	PV Benefits ($M)	NPV ($M)	BCR
Scenario 2: Transition out of irrigation (whole district)	$59.11	-$145.95	-$205.05	-2.47
Scenario 3: Remove or Reconnect Zone 5	$32.79	$24.69	-$8.10	0.75
Scenario 4: Remove or Reconnect Zone 3	$13.27	$7.47	-$5.80	0.56
Scenario 6: Systemwide initiatives	$37.71	$28.01	-$9.69	0.74
Scenario 7: Secure access to D&S water	$0.95	$7.58	$6.63	7.96
Scenario 8: Combination option	$78.54	$55.16	-$23.38	0.70
Scenario 9: Extended Combination option	$114.81	$73.45	-$41.36	0.64

Source: NCEconomics estimates
Note 1: NPVs are in FY2024 dollars.

Note 2: Productivity impacts and environmental impacts included benefits or dis-benefits. That means that the net impacts on productivity or the environment were aggregated as net benefits. This resulted in the negative value of net benefits for Scenario 2 i.e., the dis-benefits outweighed the benefits.

Scenario 2 stood out as the scenario with the lowest NPV of -$222 million (a net loss to society). The costs of this scenario were largely driven by the loss of agricultural productivity as a result of a full transition out of irrigation for the whole district.

The remaining scenarios (Scenario 3 to Scenario 9) have much more comparable NPVs that range from -$41.4 million to $6.6 million. For Scenario 3, Scenario 4, Scenario 6, Scenario 8 and Scenario 9, the costs were driven by implementation costs and ongoing costs, and benefits were largely driven by productivity gains as a result of increased reliability of water supply.

Scenario 7 was generally a low-cost option, with productivity gains for D&S users driving the positive NPV for this scenario.

Key point

The results illustrated that Scenario 2 was not economically viable with an NPV significantly below zero and BCRs significantly less than one. With negative NPVs (ranging between -$41.4 million and -$5.8 million), Scenario 3, Scenario 4, Scenario 6, Scenario 8 and Scenario 9 may not be economically viable. However, it should be noted that:

- This analysis only considered a subset of possible benefits and costs—consideration of broader outcomes, including any other ecological or social impacts, could improve (or worsen) the viability of some options. Future refinements of the CBA should consider extension of the scope of benefits/dis-benefits and costs.
- These results were subject to uncertainty from data inputs and assumptions, which was investigated through sensitivity analysis outlined in the next section. Further research could be undertaken on these data inputs and assumptions to enhance the accuracy of the sensitivity analysis.
- This analysis was done at a feasibility stage and thus, more information could be considered in future iterations of the CBA, which may include mitigation measures for costs and disbenefits.

Scenario 7 is likely economically viable within the scope of this CBA, with NPV greater than zero and BCR greater than one.

5.3 Sensitivity analysis

Monte Carlo simulations with 20,000 iterations were used for sensitivity analysis of the CBA. Table 20 presents P10, P50 and P90 Monte Carlo simulation estimates for the NPV.[5]

A triangular distribution was assumed for all parameters. Unless other information was available, a 20% decrease in the more likely value was used for the low value, and a 20% increase for the high value.

The results from the sensitivity analysis indicated that there was no probability for Scenario 2, Scenario 6, Scenario 9 to be economically viable (i.e. having NPVs greater than zero). On the other hand, under all 20,000 iterations (100% of iterations) of the Monte Carlo simulation, Scenario 7 displayed economic viability.

[5] P-values are probabilistically estimated values based on the sensitivity analysis. A P10 value is the value that 10% of the simulations were less than and P90 value is the value that 10% of the simulations were more than. See section 2.3 for an illustration.

Table 20: Sensitivity analysis—NPV

Scenario	P10	P50	P90	Probability of NPV > 0
Scenario 2: Transition out of irrigation (whole district)	-$298.70	-$208.05	-$147.76	0%
Scenario 3: Remove or Reconnect Zone 5	-$11.07	-$6.87	-$0.92	8%
Scenario 4: Remove or Reconnect Zone 3	-$7.16	-$5.21	-$2.72	1%
Scenario 6: Systemwide initiatives	-$10.96	-$9.10	-$7.01	0%
Scenario 7: Secure access to D&S water	$4.95	$7.44	$11.32	100%
Scenario 8: Combination option	-$28.07	-$21.09	-$11.53	1%
Scenario 9: Extended Combination option	-$48.55	-$39.46	-$26.39	0%

Source: NCEconomics estimates

The input parameters that had the greatest impact on the uncertainty on the NPV were analysed through the simulation for Scenario 3, Scenario, 4, and Scenario 8—which had NPV ranges that went across the feasibility threshold of being greater or equal to zero. The findings from this analysis suggested that the input parameters with the greatest source of overall uncertainty were consistent across these four scenarios. These parameters were the gross margins, water consumption, and stocking rates of the various livestock types (cattle, dairy, and sheep), except for Scenario 3 where the construction costs of the Zone 5 Shepparton Irrigation Area to Gowangardie Weir pipeline was one of the key parameters of uncertainty (Figure 6).

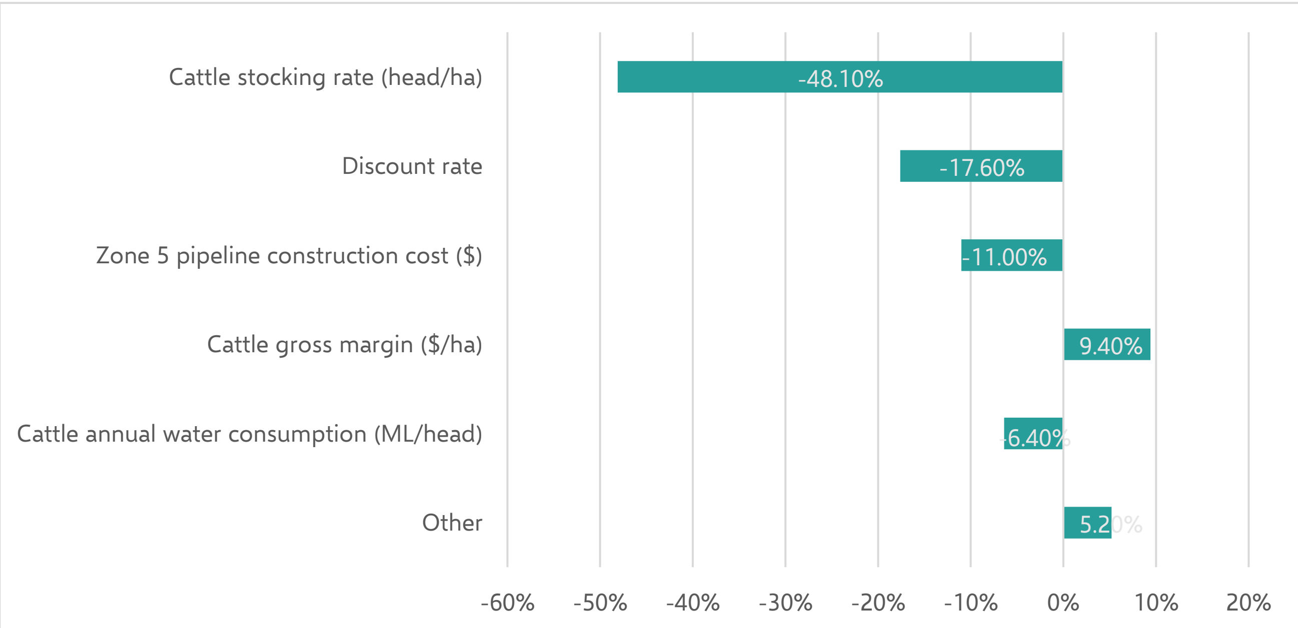

Figure 6. Contribution of input variance to uncertainty of NPV for Scenario 3

The uncertainty associated with these key parameters (livestock gross margins, water consumption, and stocking rates) could be addressed through further studies that focus on sense-checking these assumptions with landholders. However, this is still not expected to have a material outcome for the recommendations in this CBA when comparing scenarios.

5.4 Distributional analysis

A distributional analysis was also conducted to identify how the economic values from outcomes would be attributed to different key stakeholder groups, with the aim of demonstrating who benefits/loses the most with each scenario. This would provide valuable information on co-funding and compensation packages.

Table 21 outlines the two stakeholder groups that were identified and how the values would be attributed to these groups.

Table 21: Assumptions for distributional analysis

Stakeholder group	How values were attributed
Landholders	Landholders would benefit (or lose) from any productivity gains (or losses). This stakeholder group was defined as landholders both within and outside the Broken River system (i.e. it included landholders in the Goulburn system).
General community	The impacts on the general community were in this CBA measured by the value households within the Goulburn Murray Water catchment might assign to ecological outcomes from changes to average annual streamflow.

Table 22 shows the present value of net benefits for each of the above-mentioned stakeholder groups, specifically the present value of net productivity and environmental impacts. In general, environmental impacts (and the associated value to the general community) were marginal compared to the productivity outcomes of the different reconfiguration scenarios.

For Scenario 2, the large cost to landholders was due to productivity losses from transitioning the whole district out of irrigation. The other reconfiguration scenarios were expected to result in net productivity gains. As illustrated in Table 22, the majority of the outcomes from Scenario 3 to Scenario 9 were expected to benefit landholders, as a result of improved agricultural productivity. Note that this distributional analysis did not illustrate differences between zones or areas within the Broken River system.

Table 22: Present value of net benefits by stakeholder group, $million (FY2024 dollars)

Scenario	Landholders	General community
Scenario 2: Transition out of irrigation (whole district)	-$200.57	$0.16
Scenario 3: Remove or Reconnect Zone 5	$11.99	$0.09
Scenario 4: Remove or Reconnect Zone 3	$5.77	$0.04
Scenario 6: Systemwide initiatives	$3.33	$0.11
Scenario 7: Secure access to D&S water	$6.88	-$0.01
Scenario 8: Combination option	$22.67	-$0.04
Scenario 9: Extended Combination option	$30.43	-$0.09

Source: NCEconomics estimates

Capital costs (infrastructure investments, entitlement transfers and farm reconfiguration costs) and operating and maintenance costs associated with the reconfiguration scenarios were not included in the values in Table

22. As previously noted, entitlement purchases were treated as a transfer of wealth in the CBA. Income from entitlement sales would benefit landholders and be incurred as a cost to the government.

Key point

Within the limited scope of this CBA, the distributional analysis demonstrated that agricultural landholders would experience most of the impacts across the reconfiguration scenarios, with most scenarios projecting an improvement except for Scenario 2. Where funding of initial capital or ongoing costs are being sought, consideration should be given to how public funding is allocated based on these outcomes.

6 Conclusions

A Cost-Benefit Analysis (CBA) was undertaken with the aim to estimate the net impact on society from the reconfiguration scenarios shortlisted in the BRFS report. This analysis included:

- determining the net benefits of each reconfiguration scenario compared to a scenario of *doing nothing* (the base case)
- analysing the sensitivity of results to sources of uncertainty from inputs and assumptions to demonstrate the uncertainty in actual outcomes
- determining how impacts would be distributed amongst different stakeholder groups.

The CBA complements the outcomes of the detailed environmental, social and cultural assessments outlined in the BRFS report.

The following seven scenarios were assessed against the base case:

- Scenario 2: Transition out of irrigation (whole district)
- Scenario 3: Reconfigure zone 5
- Scenario 4: Reconfigure zone 3
- Scenario 6: Systemwide initiatives
- Scenario 7: Secure access to D&S water
- Scenario 8: Combination scenario with Scenario 3, Scenario 4, Scenario 6 and Scenario 7
- Scenario 9: Extended combination scenario with Scenario 3, Scenario 4, Scenario 5, Scenario 6 and Scenario 7, in addition to removing or reconnecting all services in zone 4.

The available data allowed the following values to be estimated for the CBA:

- initial capital costs
- ongoing operating and maintenance costs
- outcomes to agricultural productivity
- environmental outcomes from changes in streamflow.

Based on the scope of the CBA as summarised above, Scenario 2 was found to result in a large net negative impact on society. This negative outcome was driven by losses in agricultural productivity from transitioning the whole district out of irrigation. The results from the sensitivity analysis indicated that there was no probability for Scenario 2 being economically viable.

The results indicated that Scenario 7 would be economically viable, with an NPV greater than zero. Scenario 7 represents a low cost-option, with comparably significant expected productivity benefits for D&S users as a result of higher reliability. This was the only scenario found to be viable under 100% of simulations of the sensitivity analysis.

For Scenario 3, Scenario 4, Scenario 6, Scenario 8 and Scenario 9 the sensitivity analysis showed ranges of NPVs that were mostly below the feasibility threshold of zero. Despite this, it is important to note this assessment has been conducted at the feasibility stage and there is still opportunity to mitigate costs and disbenefits and enhance the economic viability of these scenarios. The results were most sensitive to changes in the inputs used for estimations of impacts on agricultural productivity. The differences in estimated NPVs across scenarios may not be significant enough to clearly identify a preference based on the uncertainty of inputs.

Considerations for further analysis

There were limitations with this project that should be considered where further analysis is required:

- **Limited scope of valued outcomes**: While environmental outcomes from changes in average annual streamflow were assessed in this CBA, further work to value environmental (and social) outcomes may provide a more comprehensive picture of the net impacts of the reconfiguration scenarios.
- **Reducing uncertainty of input values**: The sensitivity analysis identified that the results were most sensitive to changes in the input parameters used in the estimation of productivity impacts (gross margins, water consumption, and stocking rates of the various livestock types), as well as construction costs of the Zone 5 Shepparton Irrigation Area to Gowangardie Weir pipeline. Further work could be done to increase the accuracy of these parameters such as collecting or ground-truthing inputs with landholders in the catchment through engagement.
- **Detailed demand assessment**: Water demand has been assumed constant over time. This was a simplified assumption, and more detailed demand modelling could create a more nuanced picture of expected future demand in the *do-nothing* scenario and reconfiguration scenarios. This includes understanding feasible actions based on reliability (e.g., switching to dryland cropping) and factoring in impacts from climate change (e.g., greater water requirements for irrigated cropping).
- **Optimised options**: An assessment of optimised options was not undertaken in this CBA. This includes prioritising works based on most appropriate implementation timing and thresholds for reconfiguration. This may improve relative performance of scenarios and may be considered for a further shortlist of scenarios.

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