



MINISTERIAL BRIEF

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Environment, Planning and Sustainable Development Directorate

To:	Minister for Water, Energy and Emissions Reduction	Tracking No.: 24/02688
Date:	5 February 2024	
From:	Executive Group Manager, Environment Heritage and Water	
Subject:	ACT Water Security Vulnerability Assessment	
Critical Date:	24 February 2024	
Critical Reason:	To provide you with the ACT Water Vulnerability Assessment in a timely manner, noting that the Assessment has been provided to the Cross-Directorate Advisory Committee for feedback	

- A/g DDG, Environment, Water and Emissions Reduction 14/ 2/ 2024

Recommendations

That you:

- Note** this update on the work to finalise the ACT Water Vulnerability Assessment (Vulnerability Assessment) and the proposed next steps.

Noted / Please Discuss

- Note** as discussed with you at the Environment, Planning and Sustainable Development Directorate (EPSDD) Executive Briefing 2 February 2024, the consultation copy (Attachment A) of the Vulnerability Assessment is being made available to you for early awareness.

Noted / Please Discuss

- Note** that resourcing to continue this critical body of work has been included in the Office of Water business case for 2024-25.

Noted / Please Discuss

Shane Rattenbury MLA  31/3/24

Minister's Office Feedback

Background

1. At the Environment, Planning and Sustainable Development Directorate (EPSDD) Executive Briefing with you on 2 February 2024, you were advised that the ACT Water Vulnerability Assessment (Vulnerability Assessment) had been circulated to the Cross-Directorate Advisory Committee (CDAC) inclusive of Icon Water for consultation purposes.
2. The security of the ACT's water supply has long been a priority focus area for ACT Government water policy:
 - a. A key action in the *ACT Water Strategy 2014-44* has been the development of a plan for long term water security. The first step is to develop an evidence base through a vulnerability assessment to support the planning.
 - b. On 27 November 2019, the Legislative Assembly resolved that 'water security has already been significantly influenced by climate change, rainfall patterns are shifting, and the severity of droughts has increased' and has agreed to 'ensure climate projections are considered in long-term planning and decision-making regarding water use and water restrictions' (ACT Legislative Assembly, Resolution on Water Security, 27 November 2019).
3. Following low water storage levels in 2019, Icon Water initiated a review of its planning assumptions within its water resource model and conducted contingency analysis for drought management planning. The review identified a projected decline in the availability of water, principally due to changes in rainfall-runoff. In response to the review outcomes, Icon Water has made operational changes to optimise the water supply system and brought forward their timeframe for progressing investigations into supplementary water sources to maintain service capability.
4. The Climate Change Risk Assessment that was considered by Cabinet in 2021 (22/174) identified the need in response to the increased frequency of drought for further modelling to provide a systematic approach to assessing climate risks and strategic adaptation planning that was centrally coordinated.
5. In responding to the need to adopt a strategic approach to the ACT's water security, the Office of Water has developed a Vulnerability Assessment model in that will support a systematic, detailed analysis of water security for evidence-based water policy and planning. The Vulnerability Assessment model:
 - a. provides a baseline assessment of water security and a repeatable tool to evaluate the effectiveness of policy proposals and implementation;
 - b. assesses impacts from climate, population growth and water resource development (internal and external to the ACT) on water quantity (supply), water quality, and aquatic and riparian ecosystems; and
 - c. encompasses indicators that support planning for ACT urban water supply (incorporating modelling data produced by Icon Water) and engagement on regional water management.
6. As part of Cabinet Submission (23/527) that you presented to Cabinet on 23 October 2023 about executing an agreement with the Australian Government about water recovery under the basin plan, Cabinet:

CABINET

- a. noted the preliminary findings from the Vulnerability Assessment (water supply) as supporting evidence for a Water Security Investment Package; and
- b. agreed that you bring forward further detail on the outcomes of modelling for ACT's water security and vulnerability to a changing climate.

Issues

7. The Vulnerability Assessment (Attachment A) is now with the CDAC inclusive of Icon Water for final comment and consideration of co-branding. For this report to progress in a successful manner, stakeholder endorsement will be critical.
8. The Vulnerability Assessment creates a picture of possible futures for ACT water security using a series of climate and population growth scenarios to 2050.
9. The scenarios assessed include two NSW and Australian Regional Climate Modelling (NARClIM) climate change projections. One is for moderate (RCP4.5 – mid-level global emissions) and one more severe (RCP8.5 – high-level global emissions). There is also a scenario for the repeat of climate conditions experienced in the Millennium drought, and two population growth projections (moderate and high growth rates).
10. The modelled values presented in the report are a result of assumptions built into the model based on peer reviewed data, government growth projections, scientific expert opinion and the application of current policy settings. The results provide a reference for comparison of the relative impacts from the drivers of water security and management intervention.
11. The results of the baseline Vulnerability Assessment (water supply theme) paints a concerning picture and identifies major vulnerabilities in the ACT's water supply modelled at year 2050, associated with potable and non-potable water supply, and environmental water. Results under a moderate climate scenario include:
 - a. the long-term mean annual flows in ACT waterways could decline by about 30%;
 - b. prolonged drought conditions could result in the total water storage dropping to 14%;
 - c. non-potable water supply is projected to become less reliable in most catchments, with water access reducing by 40%;
 - d. environmental water provisions, under the Environmental Flow Guidelines, would not be able to support priority environmental outcomes in the Murrumbidgee River and unregulated catchments with the projected reduced stream flows.
12. While modelling inherently contains some uncertainty, the findings of the Vulnerability Assessment are substantiated by independent water resource analysis conducted by Icon Water, empirical studies examining the recent historical trends in catchment hydrology (e.g. rainfall-runoff relationships), and published literature examining climate impacts within the Murray-Darling Basin. The independent evidence increases the level of confidence in the water security risk identified by the Vulnerability Assessment.
13. The vulnerability assessment findings for water quality and aquatic and riparian ecosystems will be finalised in early 2024.

Strengthening water security

14. The Vulnerability Assessment confirms our proposition that water security is impacted by climate change and population growth (e.g. increased water extraction). This proposition is reflected in the 2004 National Water Initiative, is emerging as a central tenet of a new national water agreement (subject to Water Ministerial Council in March 2024) and is being assessed by the Murray Darling Basin Authority for the Basin Plan review.
15. The Vulnerability Assessment provides detailed analysis that allows for planning and policy development that focuses on protecting critical values most susceptible to water insecurity and influencing the core drivers impacting the resource. The findings of the baseline assessment provide a case for investment in water security.
16. A detailed plan of action is required to maintain reliable access to adequate, high quality, affordable water into the future. The refresh of the ACT Water Strategy and a new national water agreement is expected to provide a renewed impetus for water security planning and action.
17. A new long-term water security plan for the ACT could:
 - a. provide detailed blueprint that sets out how the Government and Icon Water will work collaboratively to strengthen water security for the ACT's growing population under a drying climate; and
 - b. set out the Government's proposition for regional collaboration to address the shared risks of regional water security, noting the ACT's inter-dependency on upstream NSW water resource management.

Next steps

18. The Vulnerability Assessment confirms that the ACT Government must remain focused on the ACT's long term water security. The need for this focus is further reinforced by the fact that surrounding NSW Councils are all looking to the ACT to assist with their own water supply challenges, both current and future year. Strengthening collaboration with Icon Water to address these competing interests must be at the core of this work.
19. Permanent resourcing for the Office of Water has been included in the budget business case for 2024-25 and will be critical to maintain forward momentum on this critical issue.
20. Recognising the sensitive contents of the Vulnerability Assessment and the cross-portfolio interests, the following approach is proposed for consultation on the findings in bringing a submission to Cabinet, as agreed (23/527/CAB):
 - a. Through CDAC mechanisms, EPSDD is looking to settle consultation about the Vulnerability Assessment by the end of February. The final proposed Vulnerability Assessment will then be discussed with you with the view to EPSDD presenting it to a future Climate Action Sub Committee of Strategic Board to ensure that it is socialised across the government.
 - b. Subject to the outcomes of the briefing to the Climate Action Sub Committee of Strategic Board, your agreement will be sought to progress the Vulnerability Assessment to the Climate Action Sub-Committee of Cabinet, and then Cabinet. The Office of Water has commenced drafting the Cabinet Submissions in anticipation of the proposed steps above.

CABINET

21. Activities to respond to the Vulnerability Assessment, that may include a long-term water security plan, could be further developed and implementation prioritised through workplans for the water Cross-Directorate Advisory Committee and the ACT and Region Catchment Coordination Group (re. regional water security).

Financial Implications

22. Responding to the findings of the Vulnerability Assessment to strengthen ACT's water security will have long-term and significant financial implications. These will be further discussed as part of the proposed Climate Action Sub-Committee and Cabinet discussions.
23. A separate business case is being prepared for water efficiency measures to offset water being provided to the Commonwealth through the water recovery agreement (23/527/CAB). The water efficiency measures are one component of the Water Security Investment Package.
24. In 2023, the Independent Competition and Regulatory Commission (ICRC) was commissioned to conduct a review of the pricing methodology for the ACT water abstraction charge to align the fee with the principle of cost recovery (CMTEDD2023/4270). The cost of a Water Security Investment Package would be recovered through the water abstraction charge.
 - a. The Investment Package could be developed at a scale that would result in no material change to the charge on water users and no reduction to the revenue received by Government from the charge.
 - b. Advice on the new pricing methodology is expected to be received in February 2024 and the resultant revenue base incorporated into the 2024-25 budget.

Consultation

Internal

25. The Vulnerability Assessment was developed through a stakeholder workshop held in 2022 to scope indicators and scenarios for use in the Assessment.
26. Participants were included from business units across the EPSDD: Office of Water, Sustainability Policy, Infrastructure Planning and Projects, and Nature Conservation.

Cross Directorate

27. Policy and Cabinet Division (PCD) and Treasury in the Chief Minister, Treasury and Economic Development Directorate (CMTEDD) were consulted during the drafting of a Cabinet submission on the water security vulnerability and review of the technical report.
28. Targeted engagement on the findings of the Vulnerability Assessment has included the Office for the Commissioner for Sustainability and the Environment, and Office for Climate Action. Feedback has been supportive of the modelling tool for providing internal analytical capability. Nil issues were raised on the assessment findings.
29. The 2022 stakeholder workshop to scope the Vulnerability Assessment included Cross-Directorate participants from CMTEDD, Office for the Commissioner for Sustainability and the Environment, Environment Protection Authority, Office for Climate Action, Suburban Land Agency and Transport Canberra and City Services.
30. All members of the CDAC received a copy of the Vulnerability Assessment at its second

CABINET

meeting on 31 January 2024.

External

31. Icon Water were consulted in the development of the Vulnerability Assessment model, provided data for the potable water indicators and reviewed the technical report. The final report is currently with Icon Water for comment.
32. The 2022 stakeholder workshop to scope the Vulnerability Assessment included participants from National Capital Authority, NSW Department of Planning and Environment, community groups (Ginninderra Catchment Group, Southern ACT Catchment Group, Australian River Restoration Centre), water industry (Icon Water, eWater) and academic experts (Australian National University, University of Canberra, CSIRO).

Work Health and Safety

33. Nil identified.

Benefits/Sensitivities

34. The findings from the Vulnerability Assessment on the impact to the ACT water security are concerning.
35. The assessment provides greater detail on specific implications from climate change, population growth and other water management issues for the ACT. However, the assessment findings are not surprising as they are consistent with many studies examining the effect of climate change on water resources. Importantly, the Vulnerability Assessment provides the evidence base to target new policy initiatives.
36. Water security is becoming increasingly topical: demands for regional development in NSW regional towns, environmental concerns in the upper Murrumbidgee River, water quality of rivers and lakes, Icon Water's consultation on water supply augmentation, national water reforms, review of the ACT Water Strategy, and drying forecasts by the Bureau of Meteorology (BOM). A long term-water security plan could provide a policy response to issues arising.
37. An ACT Government led Water Security Plan would provide Icon Water with the policy direction and authorization to its investigations, set within a regional context, include opportunities for both potable and non-potable water supply, and seek to deliver broader benefits (social, cultural and environmental) that are not within the remit of the water utility.
38. Icon Water are well progressed with their investigations into options for water supply augmentation. Planning and stakeholder consultation is being conducted by Icon Water independently of Government. Some supply options that are being progressed to detailed analysis may not align with existing Government positions or has implications for inter-governmental relations; for example increasing diversion from the upper Murrumbidgee River.
39. The National Water Initiative (ACT) is currently being reviewed and will proceed to public consultation following the Water Ministerial Council meeting in March 2024. The Commonwealth are proposing to seek national agreement by the end of 2024. Water security and climate adaptation are emerging as priorities for national reform. Subject to

CABINET

ACT agreement, a long-term water security plan and broader water security investment could provide the foundations for the ACT's implementation plan for the new agreement.

40. CMTEDD is leading negotiations with NSW on cross-border water supply. The findings from the Vulnerability Assessment are part of the ACT's due diligence assessment and have supported the preferred option presented to NSW in the negotiation. Officials from CMTEDD PCD are seeking to distribute the Assessment findings to NSW and the relevant regional councils in early 2024 as part of on-going discussions. Cabinet consideration of the findings will be prudent before this occurs.

Communications, media and engagement implications

41. No media announcement on the outcome of the Vulnerability Assessment is proposed.
42. The technical report provided with this brief contains sensitive information that could be misinterpreted out-of-context of the model and report. The Office of Water is considering how the findings might best be represented for public use. Your agreement will be sought on any high-level public messaging on outcomes from the Vulnerability Assessment at the conclusion of the project.

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Attachments

Attachment A ACT Water Vulnerability Assessment (Consultation Copy)



ACT
Government

ACT Water Security Vulnerability Assessment – Water Supply Technical Report

Baihua Fu, Danswell Starrs, Ryan Breen, Sayani Dey

Office of Water, November 2023

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Version History

Version	Revision Date	Author	Key Changes made
V2.2	21 September 2023	Baihua Fu	Full draft sent for Office of Water internal review
V3.1	16 October 2023	Baihua Fu	Addressed comments after Office of Water internal review, and draft sent to Icon Water for review
V4.0	15 November 2023	Baihua Fu	Addressed comments from Icon Water's initial review
V4.1	17 November 2023	Baihua Fu	Addressed additional minor comments from Icon Water, and draft sent to CMTEDD for pre-exposure review
V5	29 November 2023	Baihua Fu	Addressed additional minor comments from CMTEDD during pre-exposure consultation.
V5.1	3 December 2023	R. Breen	Cleared version for submission.

Acknowledgement

We would like to thank Icon Water who provided the modelling and output data for the potable water supply indicators and the environmental flow release indicator, as well as technical review of the report.

Citation

Baihua Fu, Danswell Starrs, Ryan Breen, Sayani Dey, 2023. ACT Water Security Vulnerability Assessment – Water Supply Technical Report. Office of Water, Environment, Planning and Sustainable Development Directorate (EPSDD), ACT Government.

Table of Contents

1	Introduction.....	5
2	Scenarios.....	5
3	Indicators.....	7
3.1	Potable water supply.....	7
3.2	Non-potable water supply.....	8
3.3	Environmental water.....	9
4	Modelling and analysis.....	10
5	Findings.....	11
5.1	Annual stream flows.....	11
5.2	Potable water supply.....	13
5.3	Non-potable water supply.....	17
5.4	Environmental water.....	21
5.4.1	Drinking water catchments.....	21
5.4.2	Non-drinking water catchments.....	21
6	Caveats.....	27
6.1	Representation of climate change.....	27
6.2	Assumptions in water resource operations.....	28
6.3	Vulnerability indices represent relative change.....	28
6.4	Confidence in water modelling.....	29
6.4.1	Potable water supply indicators.....	29
6.4.2	Non-potable water and environmental water indicators.....	30
6.4.3	Effects of growth underestimated.....	31
6.4.4	Indicator values sensitive to analysis period.....	32
6.4.5	Future work on Source modelling.....	32
7	Conclusion.....	32
	References.....	33
	Appendix 1: VA sites (in red squares) and corresponding catchments (polygons).....	34
	Appendix 2: Major differences between the Current and future scenarios.....	35
	Appendix 3: Summary of ACT Environmental Flow Guidelines for non-drinking water catchments.	36
	Appendix 4: Process of generating supply vulnerability indices.....	38
	Appendix 5: Process of standardisation and aggregation to convert indicator to Index.....	38

Executive Summary

The ACT Water Security Vulnerability Assessment Project was initiated to assess current and future vulnerabilities of ACT's water security to major risk drivers such as climate change, population growth and water resource development. The current phase of the assessment (VA 1.0) focuses on the vulnerabilities of three themes: water supply, water quality and aquatic and riparian ecosystems. This report examines vulnerabilities to the first theme, water supply, which includes supply of potable water, non-potable water and environmental water.

A series of climate change and water resource development scenarios are created as at 2050, using two climate change projections (aimed at reflecting a moderate and a more extreme climate change), and two population growth projections (moderate growth and high rate of growth). An additional drought scenario reflecting the Millennium drought climate is also included. These scenarios collectively provide a holistic overview of potential vulnerability in ACT water security.

The assessment identified significant risks to ACT's water security as at 2050. Key findings include:

- On average, the ACT region is projected to experience 30% reduction in flows under the moderate climate change and population growth compared to the Current Scenario, and 45% reduction under the more extreme climate change and high population growth.
- Based on the current water supply network (infrastructure and operating rules) and per capita water demand, ACT's potable water supply storages are projected to run critically low (14% or zero depending on scenarios), with the costs of temporary water restrictions reaching approximately AUD\$100 million per year under the moderate climate change and growth scenario, and approximately AUD\$300 million per year under the more extreme climate change and growth scenario.
- In most sub-catchments, non-potable water supply is projected to be less reliable under the future scenarios, with available water projected to reduce by around 40% under the moderate impact scenario, and 60 – 80% under the more extreme scenarios.
- Existing environmental water provisions are unlikely to support priority environmental outcomes within the Murrumbidgee River and unregulated catchments (e.g. Paddys River, Gudgenby River), as defined by the *ACT Environmental Flow Guidelines*.

This assessment highlights the need for identifying and implementing policy, management and infrastructure options, and adapting to the new norms of diminishing water resources in the ACT and region. For this purpose, future planning should:

- take a holistic approach to water security that balances the needs of water users and environment;
- consider climate resilient solutions, in addition to climate dependent options;
- support adaptive responses to existing and emerging risks.

The assessment tools will continue to evolve and be used for conducting future assessments, with alternative scenarios and indicators in response to management queries. The next phase of the vulnerability assessment (VA 2.0) will focus on supporting the creation and assessment of adaptation options and pathways through stakeholder participation. These activities will be a central part of endeavours to safeguard ACT's water security.

1 Introduction

The water resources of the ACT are being impacted by climate change, population growth, and water and land management, both within the ACT and in the surrounding upper Murrumbidgee River sub-catchments. These impacts are being observed as changes in river flow and water storage levels, decline in health of key ecological assets, such as fish populations and declining water quality that poses a risk to human health. The long-term water security for the ACT is likewise under threat. A detailed understanding of how and to what extent these future risks may affect the water resources and environment is required to support water policy and planning to implement effective treatment of risk.

The ACT Water Security Vulnerability Assessment (VA) Project, initiated by the Office of Water, aims to:

- generate new information on potential future risks to the ACT's water security;
- develop new analytical tools that can be applied in the future to evaluate the effectiveness of water policy and planning with regard to water security.

The project assesses the vulnerabilities of water supply, water quality, and aquatic and riparian ecosystem indicators to major risk drivers such as climate change, population growth and water resource development. Best available science and modelling were used to evaluate these indicators under current and 2050 scenarios. Assessment locations include the ACT Water Management Areas and major upstream catchments outside the ACT (Appendix 1).

Insights generated from the assessment provide new quantitative evidence to support ACT Government policy development and evaluation, including but not limited to the Murray-Darling Basin Plan evaluation and review, water reforms under the National Water Initiative, ACT Water Strategy refresh and the development of a long-term environmental watering plan.

This report examines vulnerabilities to the first theme, water supply, which includes supply of potable water, non-potable water and environmental water. It describes the development of climate and water resource use scenarios, the development of vulnerability indicators for water supply, the modelling approach used, and the findings associated with these indicators.

This phase of the assessment (VA 1.0) primarily focuses on establishing a baseline of vulnerability given climate change and water resource use, by assuming no change to water use behaviour, operating rules, water policy, regulations or infrastructure augmentation. The findings from this baseline assessment will support the development of adaption options in future assessments.

2 Scenarios

Scenarios in this report refer to assumptions on the driving factors of water security, these being climate change, population growth, land use changes and water resources development. Six scenarios were assessed for this VA project including a Current Scenario, a Predevelopment Scenario, and four 2050 scenarios reflecting the levels of climate change and population growth in 2050. These scenarios were identified based on modelling capability, stakeholder input and

consultation with Icon Water. The scenarios account for a range of climate change (from historical climate to climate change driven by high emissions) and projected growth in 2050 (from pre-development to high growth) (Figure 1). These scenarios are summarised below, and their major differences are listed in Appendix 2.

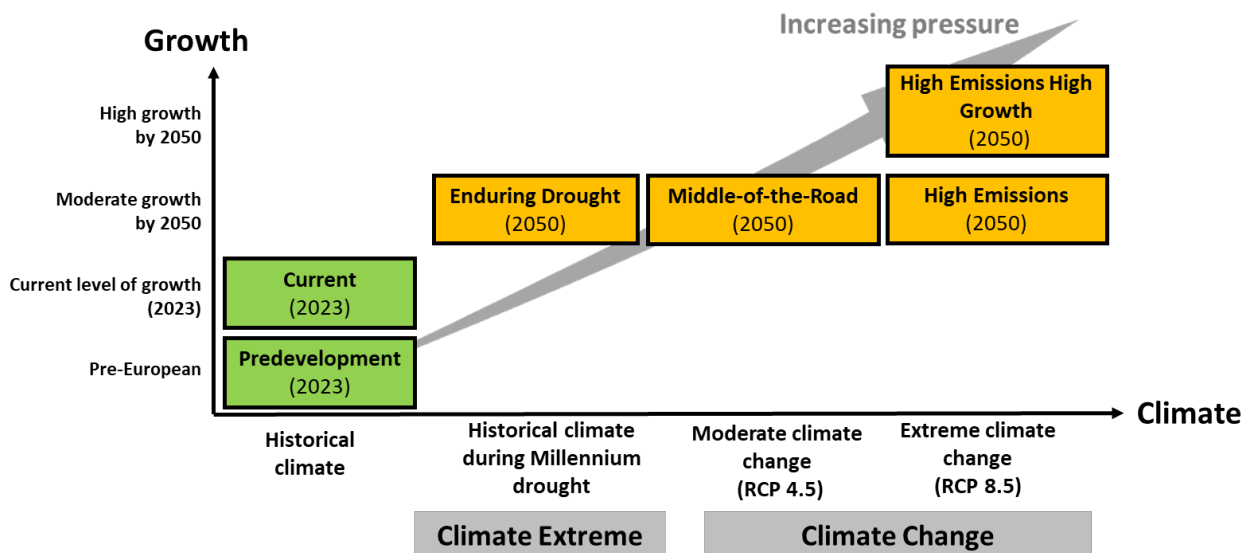
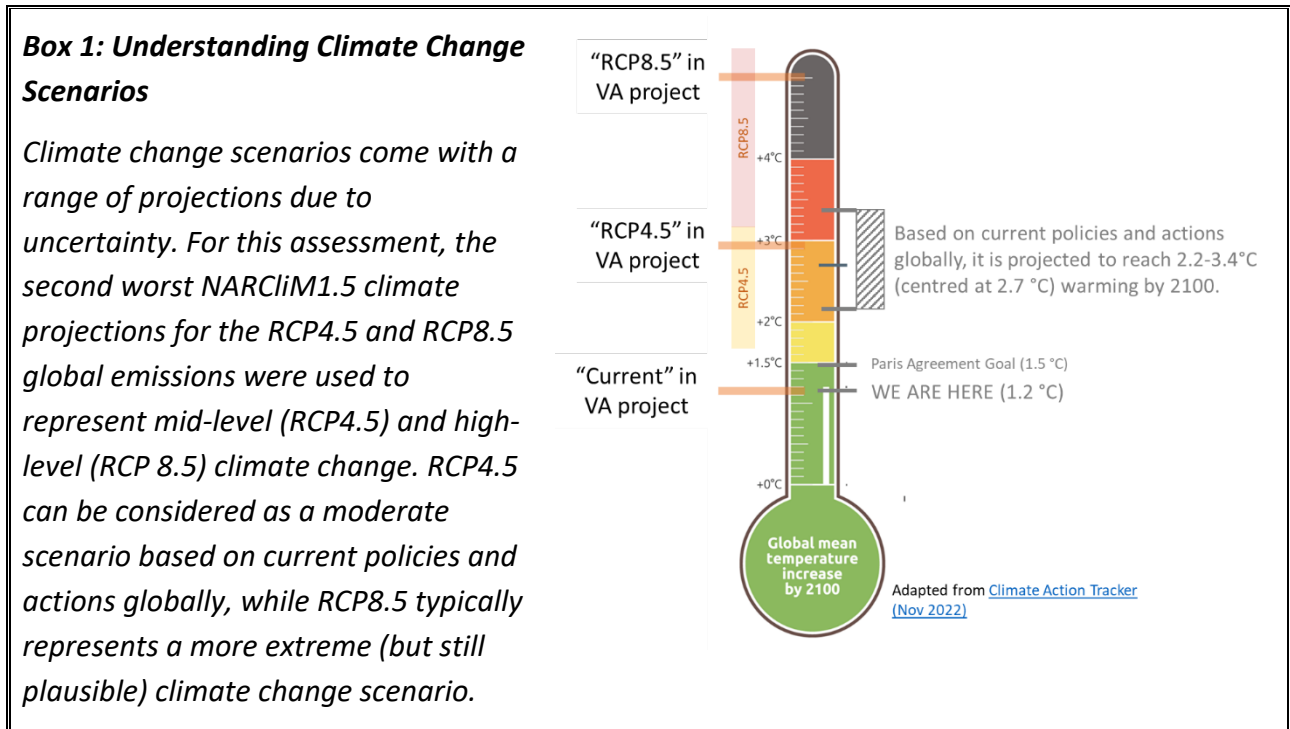


Figure 1: The six scenarios used in the VA project, and their positions across the range of climate and growth levels.

- **Current Scenario:** this scenario provides a main reference point for other scenarios. It is based on recent historical climate (1980 – 2016), current population, land use and level of water resource development as of 2023.
- **Predevelopment Scenario:** this scenario assumes no dam/reservoir (e.g. no Tantangara Dam or Cotter Dam), no urban development (e.g. no ACT, no regional towns), and no water extraction. This scenario was mainly used as a reference point for “natural” condition, such as to test the impact of Tantangara Dam and urban development. Note that this scenario was not used for potable water vulnerability indicators (which was provided by Icon Water). The recent historical climate (1980 – 2016) was used for this scenario.
- **Enduring Drought:** this scenario tests what could happen if the millennium drought climate is repeated with a moderate level of population growth to 2050. It uses historical climate inputs from the millennium drought (1999 - 2009) and does not consider any additional climate change. This scenario can be interpreted as “like the millennium drought, but slightly worse because of higher population and growth”. As such, this scenario does not contain wet years while other scenarios do.
- **Middle-of-the-Road:** this scenario represents a future with moderate climate change. It assumes RCP4.5 climate projection (about 3 degrees warming by 2100), moderate population growth, land uses and water resource development as at 2050 that reflects current trends.

CABINET

- **High Emissions:** this scenario tests what could happen if the greenhouse gas emissions continue to grow at a high rate. It assumes RCP8.5 climate projection (about 5 degrees warming by 2100), but the level of development is the same as the Middle-of-the-Road Scenario.
- **High Emissions High Growth:** this scenario is a variation of the High Emissions Scenario. It uses the same climate inputs as the High Emissions Scenario but assumes greater population growth in the ACT and surrounding NSW towns (supplied from the ACT water supply), and a higher level of urban land uses and farm dam water interception.



3 Indicators

Vulnerability does not exist as something we can observe and measure. Therefore, we use indicators as proxy measures of “vulnerability”. Three classes of water were evaluated to assess the vulnerability in water supply: potable water, non-potable water and environmental water. These indicators are described below. In this report, potable water supply refers to water sources that are used to provide drinking water supplied by Icon Water, while non-potable water refers to surface water taken from ACT’s water management areas in its untreated form for irrigation and other non-drinking purposes. Environmental water refers to environmental flows specified in the *ACT Environmental Flow Guidelines* (2019) which apply to all water bodies in the ACT, and are provided through releases or spills from dams or by restricting water abstraction from water management areas.

3.1 Potable water supply

The potable water vulnerability index considers five indicators:

CABINET

- 1) “**Minimum storage**” indicator reports the minimum percentage of active storage¹ in the ACT potable water supply reservoirs (Corin, Bendora, Cotter and Googong dams). The lower the percentage value, the higher the vulnerability.
- 2) “**Supply shortfall**” indicator reports the percentage of time each scenario experiences shortfalls in potable water supply, i.e. when there is not enough water available to meet restricted demands.
- 3) “**Inflow shortfall**” indicator reports the percentage of time when inflow to the dams is less than water demand. The greater the percentage value, the higher the vulnerability.
- 4) “**Water restriction**” indicator reports the percentage of time any stage of temporary water restrictions² will be imposed for each scenario. The higher the percentage value, the higher the vulnerability (more time in restrictions).
- 5) “**Restriction cost**” indicator reports the costs of temporary water restrictions to the community. This indicator factors both the amount of time each stage of temporary water restriction might occur, and the cost for each stage of water restriction.

Data on these indicators was generated from Icon Water modelling for each scenario. Note that these indicators do not vary spatially. For all indicators, the index values were generated by rescaling the indicator values to 0 to 1 across scenarios and assessment sites, with 1 being the most vulnerable. The final potable water index was the average of the five indicators.

3.2 Non-potable water supply

The *ACT Environmental Flow Guidelines* define the conditions for which abstraction (pumping) can occur or must cease. Pumping is allowed when flow is higher than a given threshold, and only 10% of water above that threshold can be pumped (Appendix 3). The *Murray-Darling Basin Plan (2012)* identifies that no net reduction in planned environmental water is to occur. As such, to represent the current operational constraints on non-potable water supply, and vulnerability to this water under the future scenarios, thresholds for non-potable water supply were derived by applying the current *ACT Environmental Flow Guidelines* definitions (e.g. flow percentiles) to the flows generated from the Current Scenario. These thresholds were then applied to all scenarios. This differs to recalculating the percentiles for each scenario, which would result in a net reduction in planned environmental water under drier conditions. No other changes (e.g. demand management, changes to operating rules) were incorporated. Two indicators for non-potable water vulnerability were assessed:

- 1) “**Non-potable supply**” indicator is associated with the volume of available non-potable water in the ACT for abstraction, based on the conditions specified in the *ACT Environmental Flow Guidelines*.

¹ Active storage does not account for dead storage, which is the body of water in the dams that cannot be extracted for consumptive use.

² Four stages of temporary water restrictions have been approved by the Legislative Assembly. Icon Water modelling uses six stages of temporary water restrictions as an internally planned response to a severe drought. Thus, six stages of water restrictions were included in this assessment.

CABINET

- 2) “**Non-potable accessibility**” indicator is associated with the number of days non-potable water can be pumped from the rivers. That is, “how many times a year the flows are above the threshold when pumping is allowed”? This indicator represents the accessibility of non-potable water; longer periods of low flows will result in less accessible non-potable water due to restrictions on water extractions.

Data on these indicators was generated from Office of Water (OoW) Source modelling for each scenario. For each indicator, the index value was generated to represent the change in indicators between a future scenario and current. Each index was rescaled to between 0 and 1, with 1 being the most vulnerable. The final non-potable water index was the average of the non-potable supply and non-potable accessibility indicators.

3.3 Environmental water

The *ACT Environmental Flow Guidelines* specify environmental flow requirements for four different types of systems (drinking water catchments, modified streams, urban streams and natural systems) (Appendix 3). These environmental flow requirements have been applied to all VA sites (Appendix 1), including those outside of the ACT.

For the drinking water catchments, only one indicator was assessed:

- 1) “**Environmental flow releases**” indicator reports the percentage of time environmental release from the dams (Bendora, Corin, Cotter and Googong) is not met. This indicator was generated based on Icon Water modelling.

For the non-drinking water supply catchments, the following five indicators were generated based on OoW Source modelling.

- 2) “**Baseflow days**” indicator reports how many days per year the baseflow requirement is not met.
- 3) “**Baseflow volume**” indicator represents how much water per year is provided through the baseflow requirement.
- 4) “**Riffle flow days**” indicator reports how many days per year the riffle maintenance flow requirement is not met.
- 5) “**Riffle flow volume**” indicator represents how much water per year is provided through riffle maintenance flows.
- 6) “**Channel flow frequency**” indicator reports how frequent channel maintenance flow may be occurring under different scenarios.

Like the non-potable water indicators, the thresholds for the last five environmental water indicators were derived by applying the rules specified in the *ACT Environmental Flow Guidelines* (e.g. flow percentiles) to the flows generated from the Current Scenario. These thresholds were then applied to all scenarios, to be consistent with the no net reduction in planned environmental water principle specified in the *Murray-Darling Basin Plan* (2012). In unregulated catchments, meeting the environmental flow requirements (or not) may be largely driven by changes in runoff. The index value was generated to represent change between a future scenario and current. Each

index was rescaled to between 0 and 1, with 1 being the most vulnerable. The final environmental water index for non-drinking water catchments was generated as the average of the five indices.

4 Modelling and analysis

To explore the effects of climate change and water resource use on water supply vulnerability, two water models were used: the Icon Water model and the OoW Source model. The scenarios determined key assumptions around climate and growth (e.g. population, ACT and NSW water resource development). These assumptions informed key inputs for the water models. The models also incorporated a range of other assumptions regarding operating rules, infrastructure, water use behaviour and other constraints. These models predicted flows, and together with the environmental flow guidelines, generated indicator values (Appendix 4). These indicator values were then standardised and aggregated to vulnerability indices (Appendix 5).

The potable water supply network was modelled by Icon Water. The Icon Water model estimates changes to inflows due to climate change, and the supply of water to Canberra and Queanbeyan. This model incorporates the current infrastructure within the ACT water supply and demand network and the current Icon Water operating rules. No change to existing infrastructure, operating rules, water sources or water use efficiency was made to the model for this assessment. The results from the period 1980 – 2016 water years³ were used for the analysis.

The OoW Source model was used to examine the impacts of climate change, land use change and water resource use for the indicators associated with the non-potable water and environmental water indicators. The OoW Source model depicts all the sub-catchments of the ACT and region, including those upstream of the ACT. The model was run over a period of 36 years (1980 – 2016) and results from the period 1980 – 2016 water years were used for the analysis. Potable water take is not explicitly represented in this model (rather the Icon Water model is used for this analysis), however returns of potable water to rivers via the two sewage treatment plants (Queanbeyan STP and LMWQCC) are explicitly represented in the OoW Source model. The volumes of returned flows vary with climate and population size.

In the OoW Source model, non-potable water take is conceptualised as surface water take (other than by Icon Water) from seven water management areas of the ACT (Appendix 1). Examples of this form of take include for agricultural use and irrigation of public open space. Groundwater take has not been explicitly considered in the modelling. Changes in sources of non-potable water or change in patterns of non-potable water use have not been considered in this modelling.

The modelled vulnerability indicators were analysed based on the averages of the modelled period (1980 – 2016 water years), as well as averages of the indicators in dry years. Dry years were defined as the years with an observed annual flow below the 25th percentile of annual flow at Gauge 410761 (Murrumbidgee River at Lobbs Hole) and were used for all scenarios for statistical analysis.

³ A water year starts on 1 July and ends on 30 June.

5 Findings

5.1 Annual stream flows

On average, the ACT region is projected to experience 30% reduction in flows under the moderate climate change and population growth compared to the Current Scenario, and 45% reduction under the more extreme climate change and high population growth.

Significant reductions in annual flows are projected across the ACT. The long-term average annual stream flow is projected to reduce by about 30% under the Middle-of-the-Road Scenario, and about 45% under the Enduring Drought and two high emissions scenarios, which is comparable to the historical Millennium drought during 2000 – 2009 (Figure 2). A drier future similar to the historical millennium drought may become a new norm. The historical drought in 2017 – 2019 saw a reduction of 65% in annual flows, which currently only occurs during a severe drought. However, under the Middle-of-the-Road Scenario an average drought (occurring 25% of the time) is projected to reach this level of reduction.

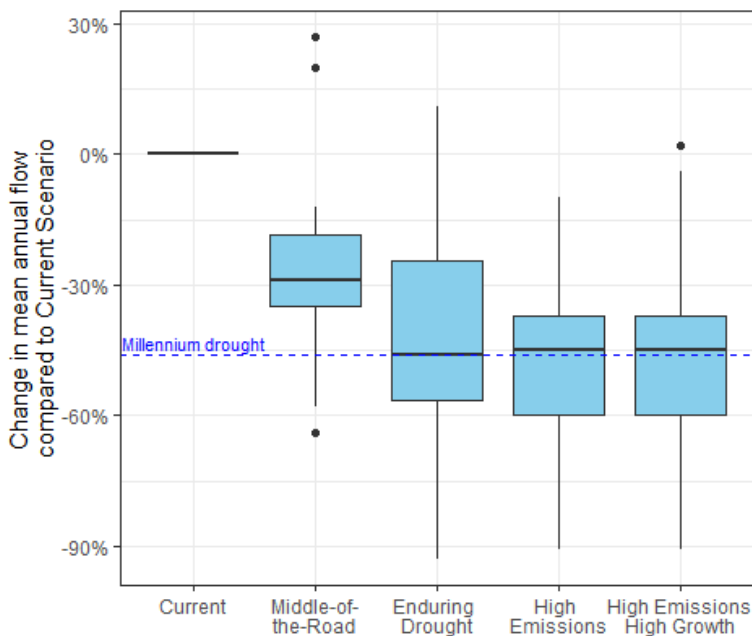


Figure 2: Percentage change in mean annual flow compared to the Current Scenario (historical climate with 2023 population and growth). The boxplot presents the spatial variability across the ACT as represented by the VA sites. The blue dashed line indicates the level of change during the historical Millennium drought.

The scenarios assume that by 2050 the ACT region is likely to experience longer droughts with fewer wet periods to recover. For the drier conditions that currently occur 25% of the time⁴, the occurrence is projected to increase to 45% of the time under the Middle-of-the-Road Scenario, over

⁴ Defined based on annual flows that currently occur 25% of the time.

55% of the time under the Enduring Drought Scenario, and 65 – 70% of the time under the two high emissions scenarios (Figure 3). Conversely, the wetter conditions are projected to decrease considerably. For the wetter conditions that currently occur 25% of the time, the frequency will decrease to only 10% of the time under the Middle-of-the-Road Scenario and just over 5% of the time under the two high emissions scenarios.

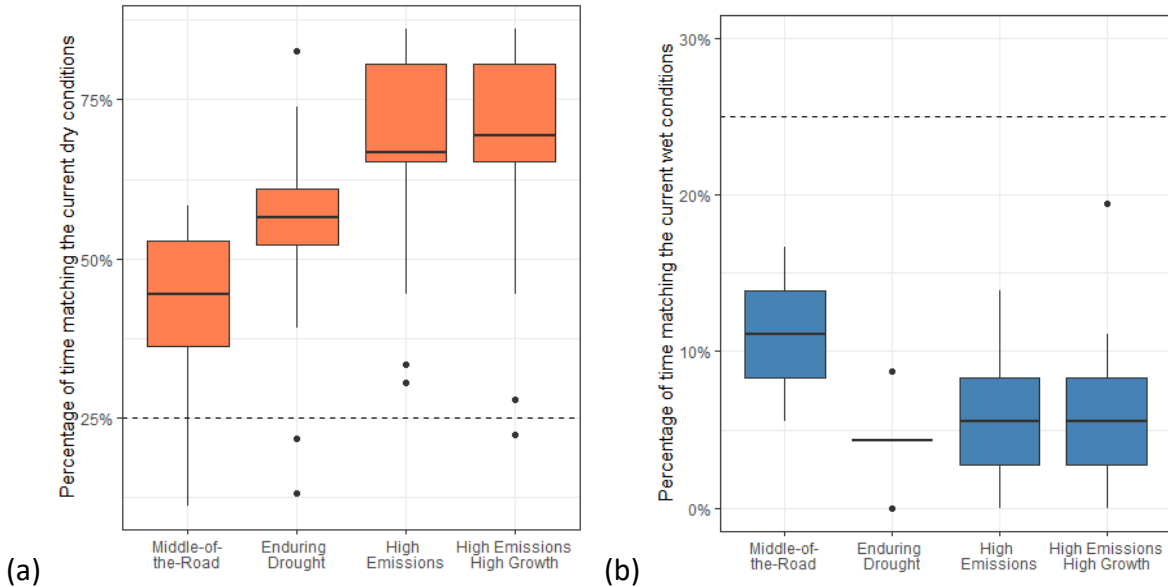


Figure 3: Percentage of time similar to the current dry (a) and wet (b) conditions under the four future scenarios. The boxplots present the spatial variability across the ACT as represented by the VA sites.

The analysis shows the scenarios impact the region with spatial variability. Significant decreases in stream flow are found at sites entering the ACT from the Murrumbidgee, Molonglo and Queanbeyan rivers (Figure 4). Under the Middle-of-the-Road Scenario, these decreases become less severe as the rivers pass the ACT, indicating that run-off from the ACT urban areas offset some reduction in annual flow in these rivers. This results in less reduction in stream flow leaving the ACT. This finding highlights the need for a regional approach to water security, with management focus to include the catchments upstream of the ACT border.

Within the ACT Water Management Areas, greater percentages of reduction in mean annual flow are found for the drinking water catchments (Cotter and Queanbeyan River catchments) and the Upper and Central Molonglo catchments. Urban catchments are found to be less affected by flow reductions.

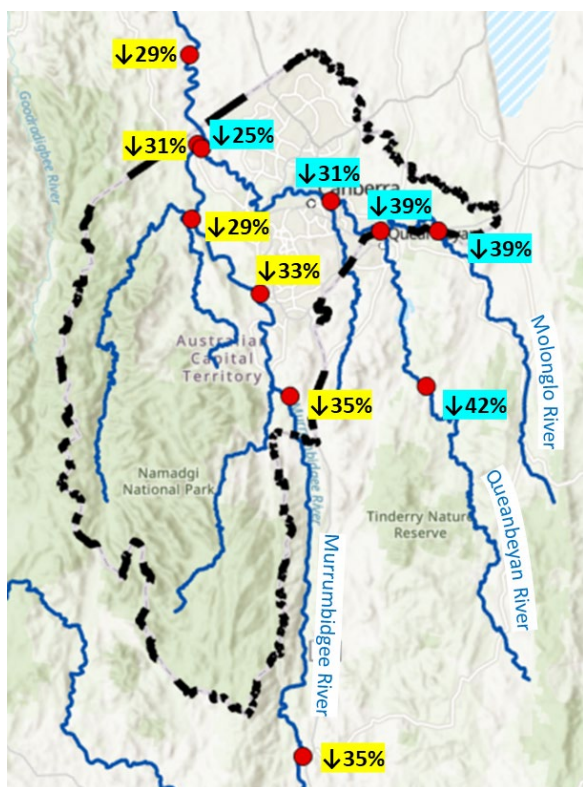


Figure 4: Percentage change in mean annual flows along the Murrumbidgee River (yellow highlights), Molonglo and Queanbeyan Rivers (blue highlights), under the Middle-of-the-Road Scenario. These rivers flow north-west from NSW into the ACT, then out of the ACT at the north-west border.

5.2 Potable water supply

Based on the current water supply network (infrastructure and operating rules) and per capita water demand, ACT's potable water supply storages are projected to run critically low as at 2050 (14% or zero depending on scenarios), with the costs of temporary water restrictions reaching about AUD\$100 million per year under the moderate climate change and growth scenario, and AUD\$300 million per year under the more extreme climate change and growth scenario.

The amount of potable water available in the dams depends on a range of factors such as rainfall, the amount of water can be stored in the dams, and the amount of water taken by the consumers. When water in the dams becomes low, temporary water restriction measures will come into effect to reduce water demand and ensure security of supply. These restrictions create an opportunity cost to the ACT community due to restrictions on opportunities to recreate and loss of economic activity from irrigation dependent events (e.g. Floriade). The findings reported here assume temporary water restrictions in place, but with no additional water efficiency measures or supply augmentation.

The assessment found that under the Current Scenario the minimum active dam storage volume remains above 60%, resulting in no triggering of temporary water restrictions. Under the Enduring Drought Scenario, the minimum active dam storage could drop to just below 40%. However, when factoring climate change, the minimum active dam storage is projected to drop to about 14% under the Middle-of-the-Road Scenario, and to zero percent under the two high emissions scenarios

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(Figure 5). As a context, the current level of service target is to maintain no temporary water restriction 95% of the time. Temporary water restriction is triggered when dam storage drops below 50% (about 139 GL based on current total storage of 277.84 GL). A 14% of minimum dam storage is about 39 GL (based on current total storage), which is significantly lower than the level for entering temporary water restrictions (based on the current trigger thresholds). The projected minimum dam storage under future scenarios typically drops below 50% during droughts, indicating significant vulnerability of potable water supply security in these conditions. The results above reflect the modelled current operation of storages and do not consider the effect of measures such as water use efficiency that may occur in response to actual conditions.

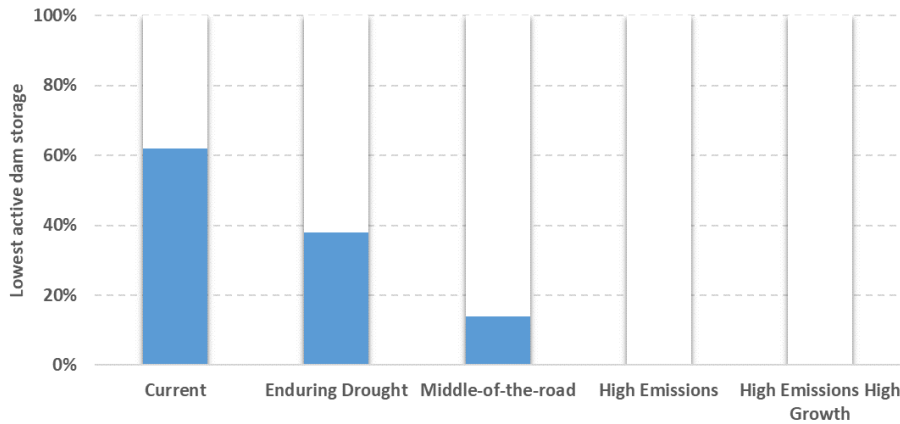


Figure 5: The minimum active dam storages over the modelled period (from 1980-81 to 2021-22 water years).

Water restrictions are projected to be triggered under all future scenarios (Figure 6). On average over the modelled period, the occurrence of temporary water restrictions being applied increases to about 25% of the time under the Enduring Drought and Middle-of-the-Road scenarios, and over 65% of the time under the two high emissions scenarios. In dry years (25% occurrence), the restrictions are projected to be more frequent, with over 60% of the time under the Middle-of-the-Road Scenario, and about 90% of the time under the two high emissions scenarios. The temporary water restrictions are also projected to be more severe, with Stages 3 and 4 restrictions commencing under the Middle-of-the-Road Scenario, and Stages 5 and 6 restrictions commencing under the two high emissions scenarios. No temporary restriction occur under the Current Scenario.

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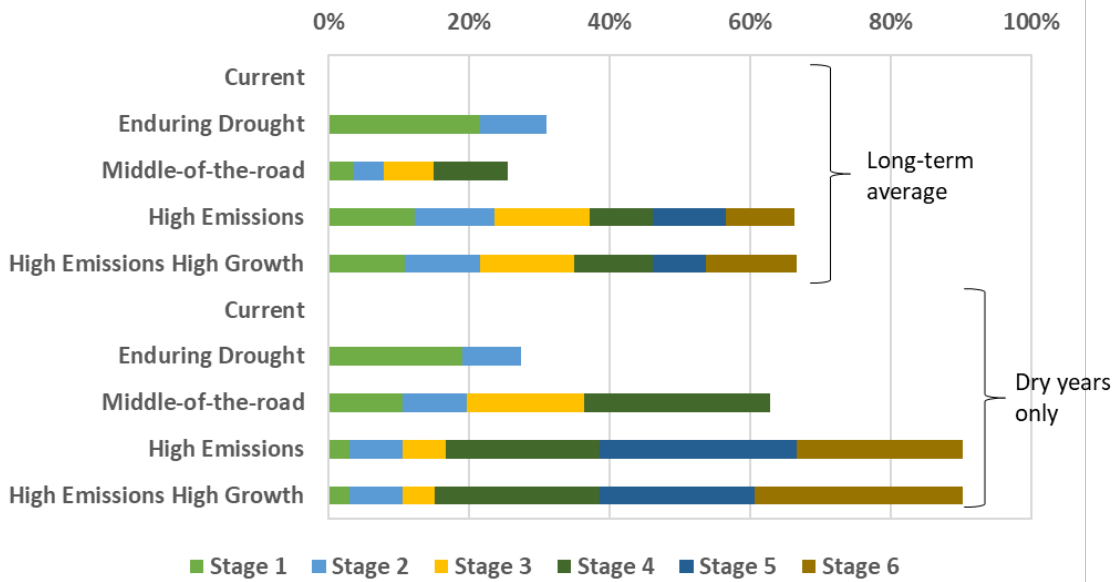


Figure 6: Percentage of time with temporary water restrictions, on average during the modelled period (from 1980-81 to 2021-22 water years) and in dry years only.

The triggering of water restrictions results in social costs to the community, such as costs due to less water for gardening, swimming pools and maintaining public open space, restoration of sports fields, replacement of street trees, loss of profits from events (e.g. Floriade) and business activities relying on water (e.g. plant nurseries). The higher the stages of restrictions, the higher the costs⁵.

The analysis indicates that the average social costs to the community from the projected water restrictions would be over AUD\$100 million/year under the Middle-of-the-Road Scenario, and over AUD \$300 million/year for the two high emissions scenarios (Figure 7). Greater restrictions could be expected to be imposed in drier years; during drier years the costs of water restrictions are projected to more than double compared to the long-term averages over the modelled period.

⁵ The data on social costs for each stage of temporary water restrictions was provided by Icon Water. These costs were estimated through an economic study conducted by the Centre for International Economics (CIE, 2017). As with other economic studies on social costs, the uncertainty is relatively high. However, this is the best available estimates in the ACT on the social cost of temporary water restrictions.

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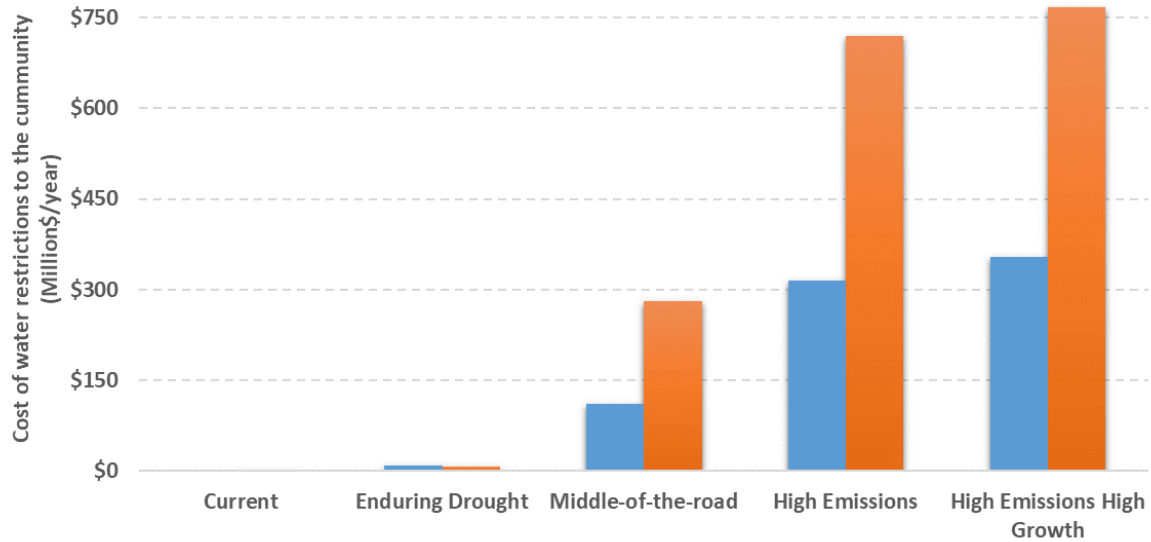


Figure 7: Average annual costs of water restrictions to the community (in million AUD\$/year), on average over the modelled period (from 1980-81 to 2021-22 water years) (blue), and in dry years only (orange).

The changes in individual water supply indicators vary by scenarios (Figure 8). Under the Enduring Drought Scenario, the change in inflow shortfall indicator is the highest among the five indicators. With the Middle-of-the-Road Scenario, both the changes in inflow shortfall and minimum active dam storage volume indicators are significant. With the two high emissions scenarios, the changes in almost all indicators are high, resulting in very high overall potable water supply vulnerability score. From management perspective, the inflow shortfall and minimum storage indicators can be used as the early signposts for detecting potable water supply vulnerability.

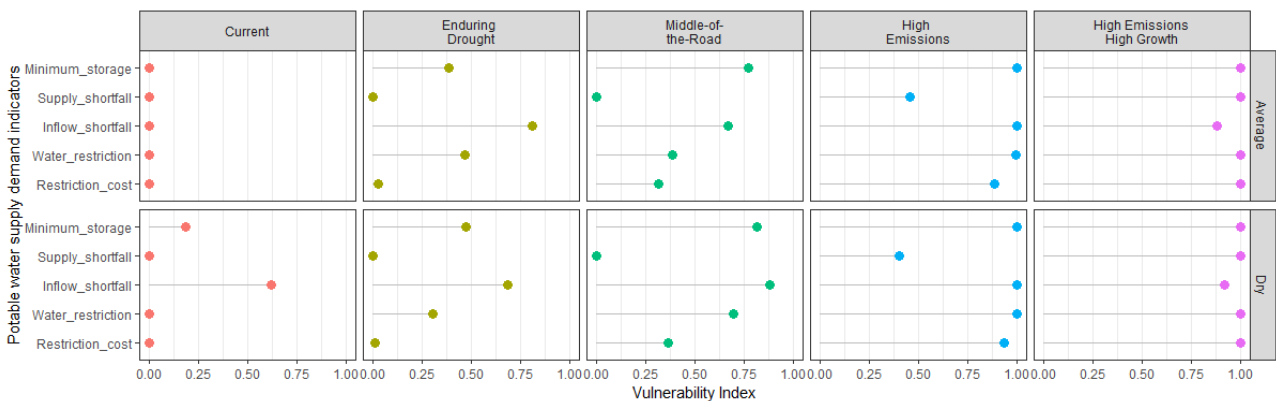


Figure 8: Standardised potable water supply indices, showing the relative contribution of individual indicators on average over the modelled period (from 1980-81 to 2021-22 water years) and in dry years only. Indicators were standardised to between 0 and 1 based on the minimum and maximum range assessed for each indicator. An index of 1 indicates the most vulnerable.

Overall, potable water supply within the ACT is most vulnerable (i.e. highest deviation from current) under the two high emissions scenarios, due to significant impacts from climate change (Figure 9).

The Middle-of-the-Road and Enduring Drought scenarios exhibit characteristics that are comparable to, and experienced during the Millennium drought in 2000-2009. These results highlight significant risks associated with climate change for potable water supply in 2050.

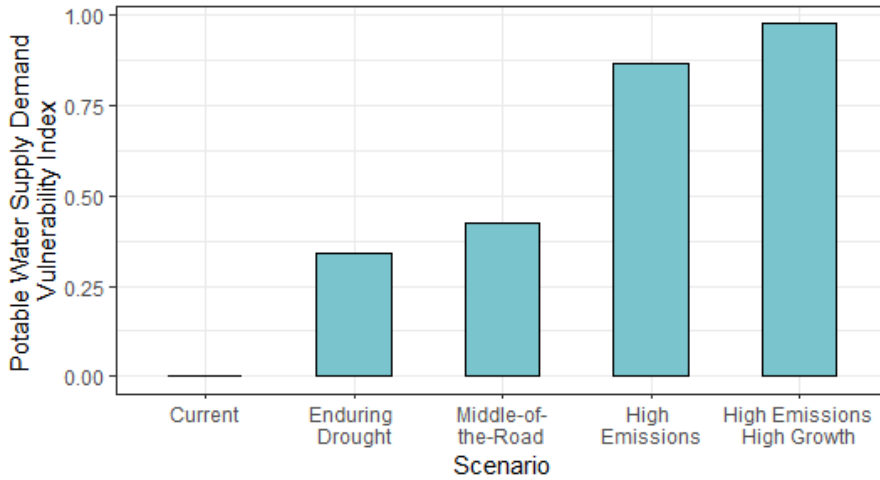


Figure 9: Overall relative vulnerability for potable water supply across scenarios. An index of 1 indicates the most vulnerable.

5.3 Non-potable water supply

Non-potable water supply is projected to be less reliable under the future scenarios, with available water projected to reduce by around 40% under the Middle-of-the-Road Scenario, and 60 – 80% under other future scenarios.

The abstraction of water from surface water sources (e.g. rivers) in non-drinking water catchments is subject to rules within the *ACT Environmental Flow Guidelines*. These rules define the conditions for which abstraction (pumping) can occur or must cease, and how much water can be abstracted. The findings reported here reflect the accessibility and volume of non-potable water under future scenarios, assuming no change in the current abstraction thresholds, as defined by the current *ACT Environmental Flow Guidelines*.

Subject to the abstraction conditions, the assessment found that under the Current Scenario, the average volumes of available non-potable water range from about 1 GL/year in urban streams, to 2 GL/year in natural reaches; 4GL/year in modified reaches, and 21 GL/year in the Murrumbidgee River.

Non-potable water abstraction is projected to become less reliable under the future scenarios, both in terms of supply and accessibility. These volumes are projected to reduce by about 40% under the Middle-of-the-Road Scenario, and by 60 – 80% in other future scenarios (Figure 10).

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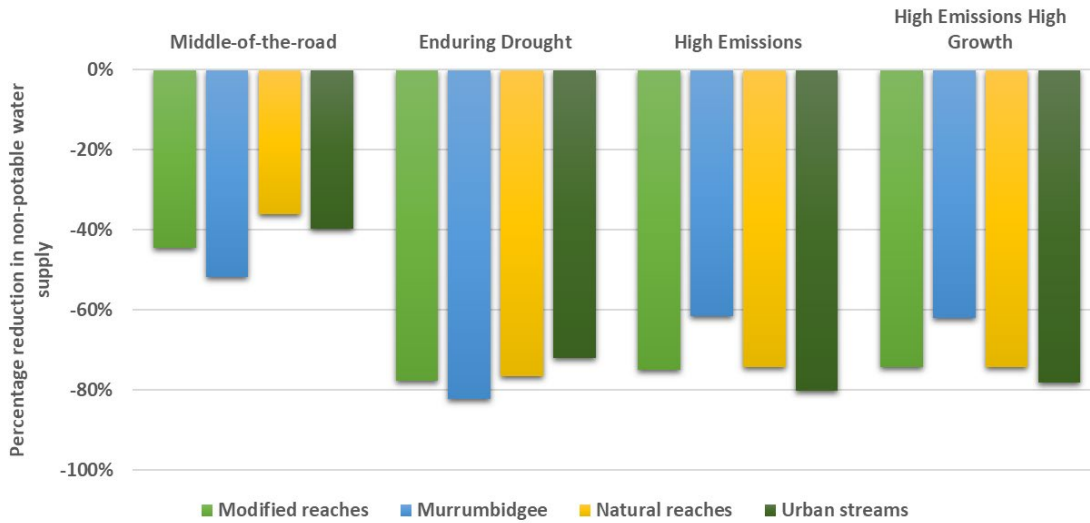


Figure 10: Average percentage reduction in non-potable water supply indicator over the modelled period.

Under the Current Scenario, on average about two months per year the non-potable water is not accessible (due to the pumping thresholds defined in the *Environmental Flow Guidelines*). However, the number of days that water abstraction is not accessible is projected to increase to 2 to 3 months under the Middle-of-the-Road and Enduring Drought scenarios, and 3-4 months under the two high emissions scenarios (Figure 11).

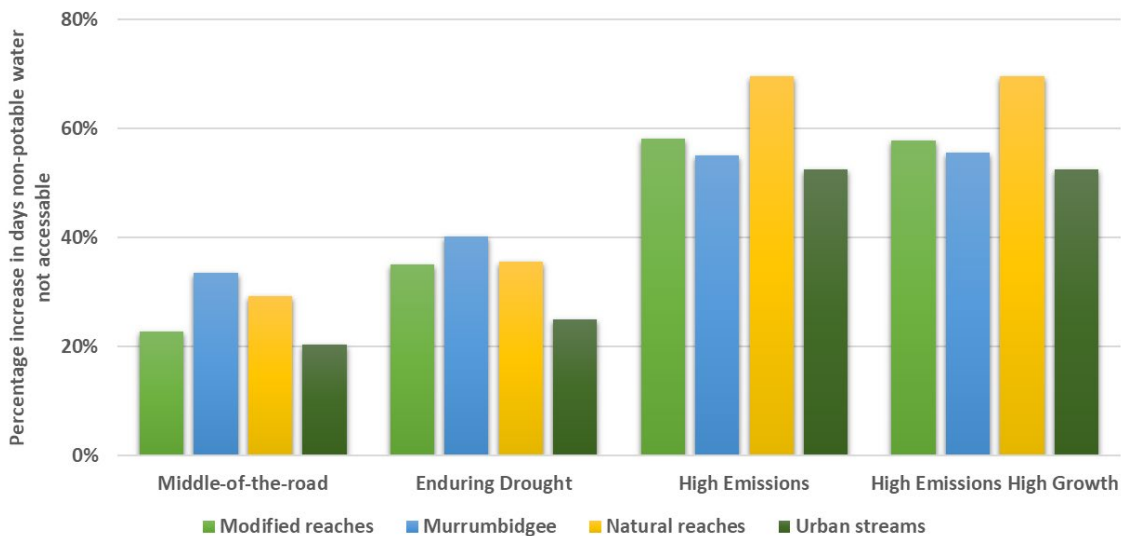


Figure 11: Average percentage increases in the number of days non-potable water not accessible.

Spatially, under the Middle-of-the-Road Scenario, the Murrumbidgee, Paddys and Gudgenby catchments are more vulnerable to reduced water access (i.e. deviate more from Current) than other catchments such as the Molonglo River and urban catchments (Figure 12). Under the two high emissions scenarios, the Paddys and Gudgenby River catchments are highly vulnerable (i.e. more deviation from Current) to reduced access to non-potable water. A few urban sites are also highly

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vulnerable, such as the lower Ginninderra, Sullivans, and Tuggeranong creek catchments. The Murrumbidgee River is projected to be moderately vulnerable compared to other sub-catchments.

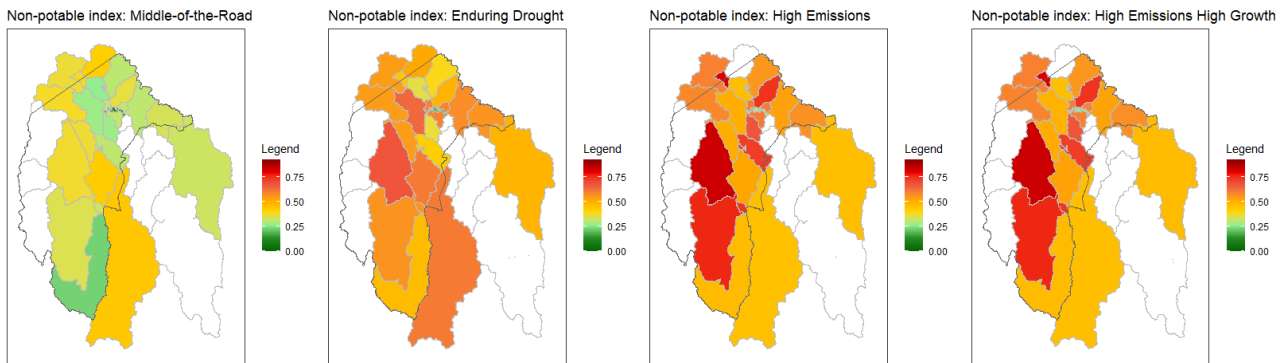


Figure 12: Overall relative vulnerability (i.e. deviation from Current) of non-potable water supply across scenarios, showing variations between sub-catchments. An index of 1 indicates the most deviation and is interpreted here as the most vulnerable. Drinking water catchments are not subjected to the abstraction rule tested here, therefore no data is provided for these catchments (white).

Figure 13 shows the non-potable water relative vulnerability in wet and dry years for each future scenario. The assessment suggests a decline in the non-potable water supply indicators at most sites under future climate change scenarios compared to the current long-term averages, even in wet years. The situations are significantly worse in dry years, with all assessed sites projected to be highly vulnerable for all scenarios, even for the Current Scenario. This highlights the vulnerability of activities and business sectors that rely on non-potable water in the ACT region, which will likely have higher demand for water during dry periods.

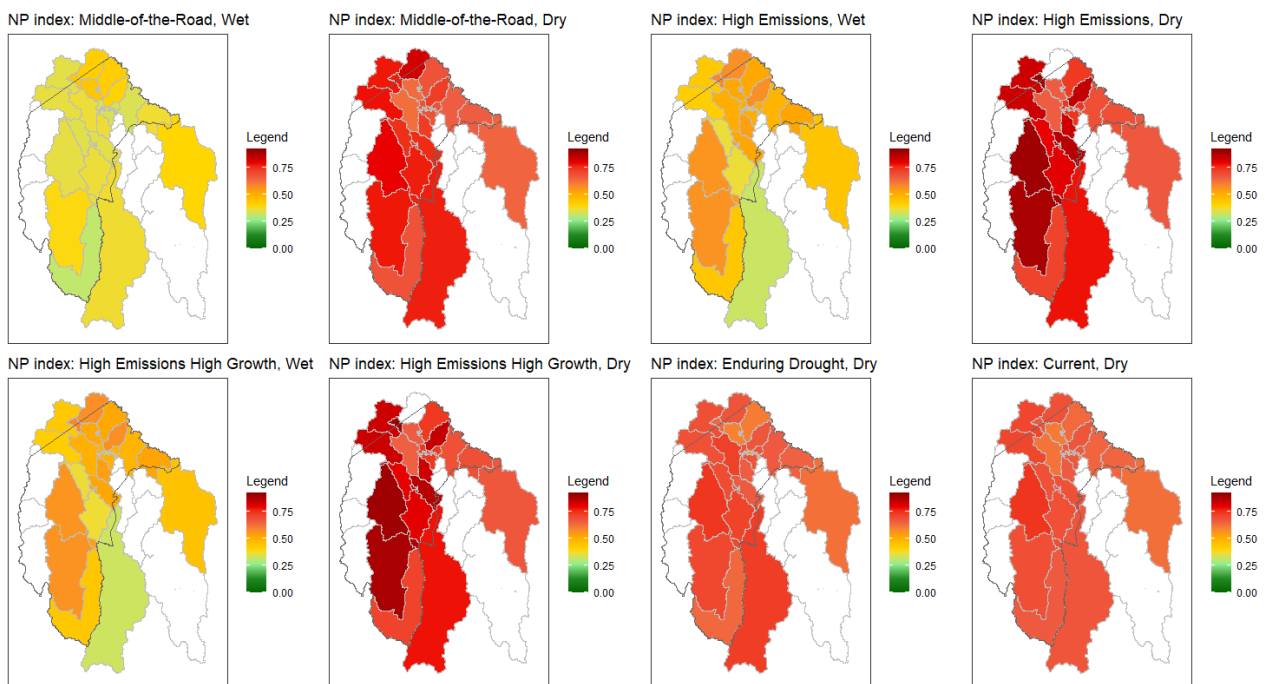


Figure 13: Overall relative vulnerability (i.e. deviation from Current) of non-potable water supply across the scenarios, showing variations between wet and dry years (note there is no wet year under the Enduring Drought Scenario). An index of 1 indicates the most vulnerable.

The non-potable water vulnerability index was largely due to greater changes in non-potable water supply indicator (Figure 14). This is the case regardless of scenarios or wet dry conditions. As a result, policy options addressing the non-potable water supply (volume) may be more effective than those targeting accessibility.

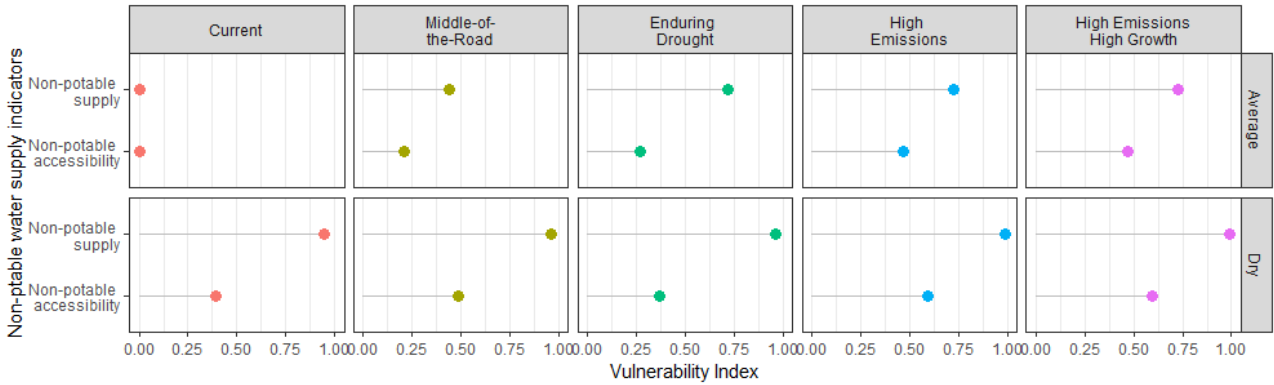


Figure 14: Standardised non-potable water vulnerability indices (i.e. deviation from Current), showing the relative contribution of indicators for each scenario, on average for the modelled period and in dry years only. Indicators were standardised to between 0 and 1 based on the minimum and maximum range assessed for each indicator. An index of 1 indicates the most vulnerable.

Overall, the two high emissions scenarios are the most vulnerable scenarios, with a relative vulnerability index value of 0.6 (Figure 15). The Middle-of-the-Road Scenario is about half the level of vulnerability score compared to the scenarios under RCP8.5. The vulnerability index for the Enduring Drought Scenario sits between the Middle-of-the-Road Scenario and the High Emissions Scenario.

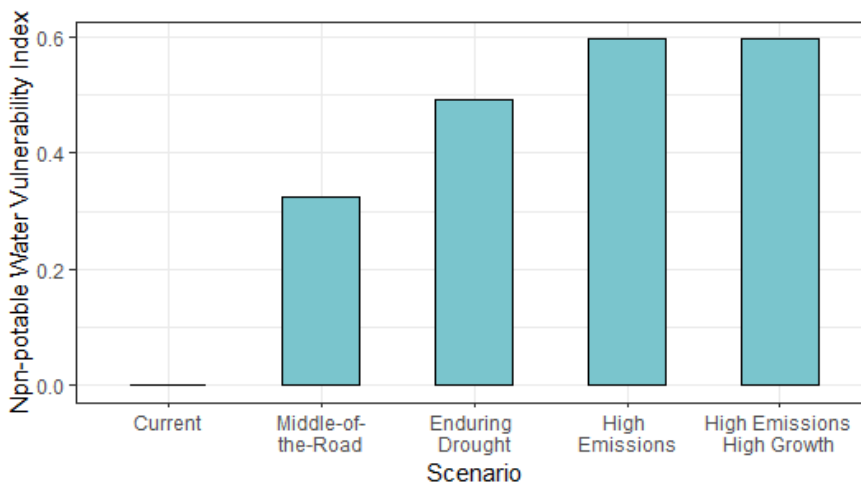


Figure 15: Overall relative vulnerability (i.e. deviation from Current) of non-potable water supply across scenarios. An index of 1 indicates the most vulnerable.

5.4 Environmental water

Existing environmental water provisions are unlikely to support priority environmental outcomes within the Murrumbidgee River and unregulated catchments (e.g. Paddys River, Gudgenby River), as defined by the ACT Environmental Flow Guidelines, which is a legislative instrument under the ACT Water Resources Act 2007.

Aquatic species such as fish and waterbirds need stream flow to maintain population and health. The *ACT Environmental Flow Guidelines* determine the water needed by a stream or river to stay healthy and fulfil important ecological functions. The *Guidelines* target different parts of the flow. For example, baseflow is essential to sustain habitats whereas riffles are critical for fish spawning.

In the ACT, the environmental flows in the regulated, potable water catchments are maintained by Icon Water through environmental flow releases from the dams, as specified in the *ACT Environmental Flow Guidelines*. In the unregulated, non-potable water catchments, the only direct measure to manage environmental flows is through Tantangara dam releases to the Murrumbidgee River, which is managed by Snowy Hydro under a NSW water licence. The findings reported here reflect how well the environmental flow requirements will be met under future scenarios, assuming no change in current operation rules relating to environmental flow releases (by Icon Water or Snowy Hydro).

5.4.1 Drinking water catchments

Modelling analysis supplied by Icon Water suggests that in the regulated, potable water supply catchments, the environmental flow release requirements will generally be met. Only 1-2% of the time the environmental water releases are projected to not be met under the two high emissions scenarios, corresponding to the periods when the dams are projected to be at critically low storage levels (Table 1).

Table 1: Percentage of time when environmental flow requirements are not met under different scenarios.

	Current	Enduring Drought	Middle-of-the-road	High Emissions	High Emissions High Growth
Environmental flow releases	0%	0%	0%	1%	2%

5.4.2 Non-drinking water catchments

Under the *ACT Environmental Flow Guidelines*, non-drinking water catchments are characterised under four stream types: modified reaches, Murrumbidgee River, unregulated, natural waterways and urban waterways. Of these, three types of flow regimes (baseflow, riffle maintenance flow and channel maintenance flow) were required (by the *ACT Environmental Flow Guidelines*) and thus assessed for the Murrumbidgee River, whereas only two (baseflow and channel maintenance flows) were required and thus assessed for the other three types of streams (Appendix 3).

The assessment found that under the Current Scenario, the average annual volumes of baseflows delivered under the environmental flow guidelines for the urban streams, natural reaches, modified reaches and Murrumbidgee River are about 0.9GL/year, 3.7GL/year, 3.4GL/year and 22.9GL/year,

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respectively (averaged across the relevant VA sites). These volumes are projected to decrease by up to 4% under the Middle-of-the-Road and Enduring Drought scenarios, and up to 9% under the high emissions scenarios (Figure 16a). These percentage decreases in the environmental flows rise to 15-25% in dry years (when baseflows become more critical) for most systems in most scenarios (Figure 16b).

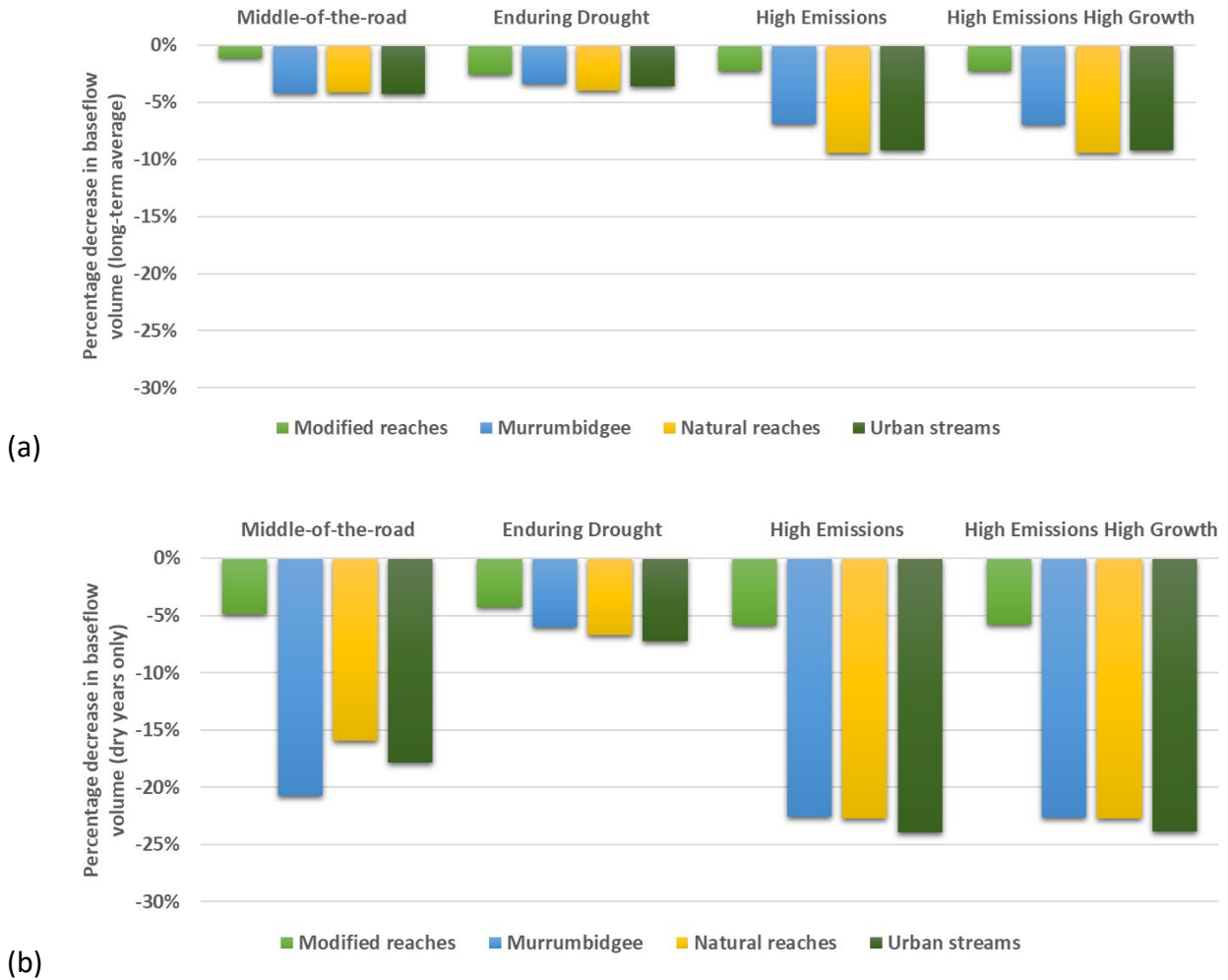


Figure 16: Percentage reduction in environmental baseflow volume indicator over the modelled period (a) and in dry years only (b).

Greater changes are projected for the number of days that baseflow requirements are not met. Currently, days baseflows are not met range from an average of 2 months per year in the Murrumbidgee River to 3 months per year in the urban streams; these increase to about 3.5 to 4.5 months in dry years. Under the Middle-of-the-Road and Enduring Drought scenarios, the days are projected to increase to 2.5 to 4 months on average over the model period (Figure 17a), and 3.5 to 5 months in dry years (Figure 17a). Under the high emissions scenarios, they are projected to increase to 3 to 4.5 months on average, and 5-6 months in dry years. The Murrumbidgee River is especially vulnerable to the changes in number of days that baseflow requirements are met, with the numbers of days baseflow not met projected to nearly triple in dry years under the future scenarios, compared to average currently.

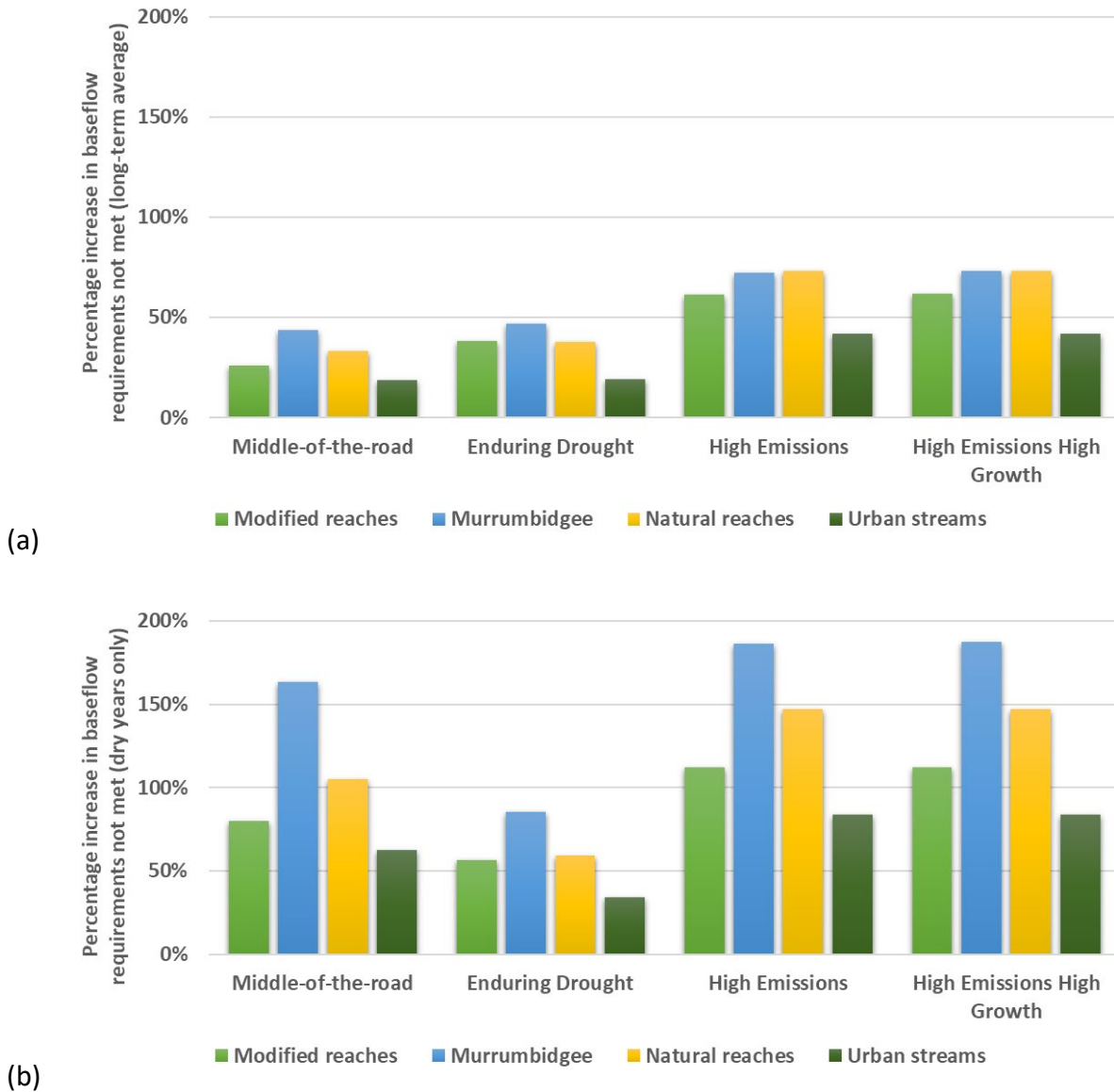


Figure 17: Percentage increase in days baseflow requirements not met over the modelled period (a), and in dry years only (b).

Riffle maintenance flow requirements only apply to the Murrumbidgee River, requiring “a minimum of 195 ML/d natural flow for a period of 1 day, once every 30 days”. When an event occurs more than 30 days from the previous event, the additional days above the 30 days threshold were counted towards the days riffle maintenance flows are not met. Currently, on average about 7 days a year the riffle maintenance flow requirement is not met; the volume of water delivered under the riffle maintenance flows is about 380 GL/year. In dry years, the number of days that riffle maintenance flows are not met double, with volumes reduced by 50%. Under future scenarios, the number of days riffle maintenance flows are not met triple (except Enduring Drought which is slightly less), and the volumes are projected to reduce by 66% of what is currently achieved on average (Figure 18).

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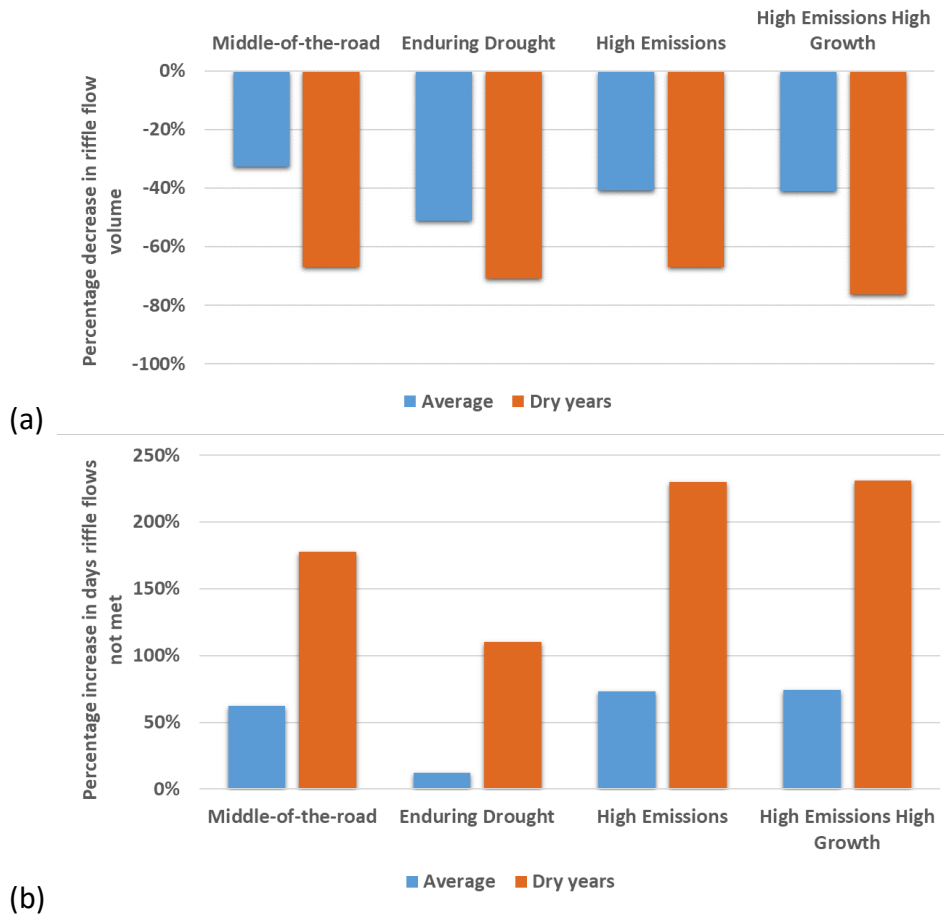


Figure 18: Percentage decrease in riffle maintenance flow volume (a) and number of days riffle maintenance flow requirement not met (b) over the modelled period (i.e. long-term average) and in dry years only.

In terms of channel maintenance flows, currently the recurrence intervals for all sites are about once every two years (as specified in the Environmental Flow Guidelines). This is projected to increase to once every 6.5 years for the modified reaches, 4.5 years for the Murrumbidgee River, and around 2.5 years for the unregulated waterways and urban waterways, under the Middle-of-the-Road Scenario (Figure 19). The recurrence intervals of channel maintenance flows for the modified reaches are projected to increase further under the two high emissions scenarios, to once every 8.5-9.5 years. Channel maintenance flows are projected to be not achievable under the Enduring Drought Scenario or in dry years because channel maintenance flow can only occur in wet years which does not exist in the Enduring Drought Scenario.

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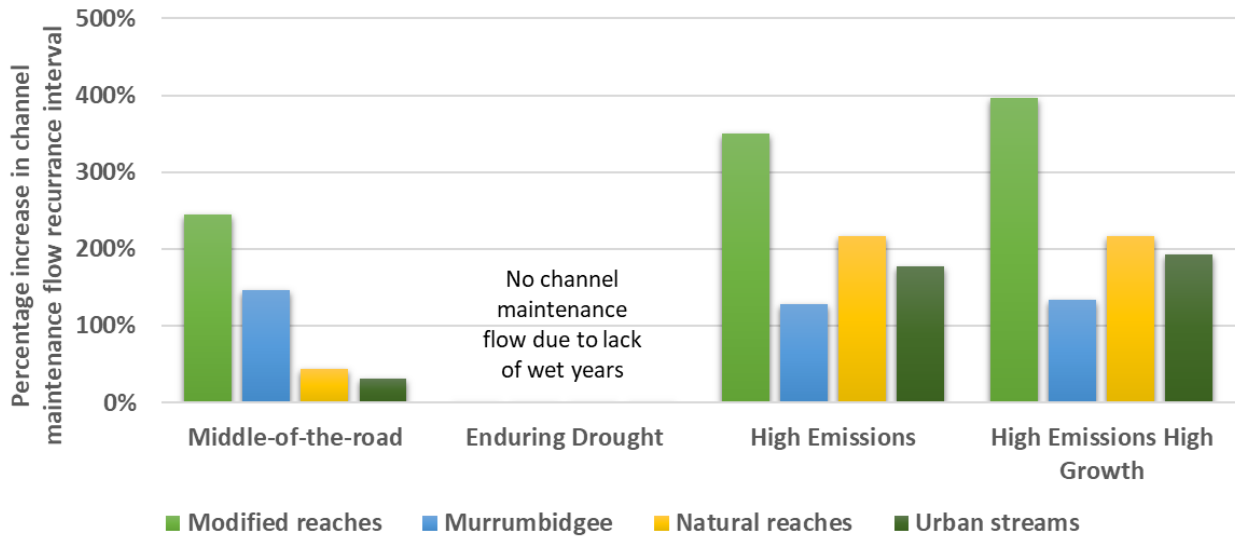


Figure 19: Percentage increase in channel maintenance flow recurrence interval over the modelled period.

Spatially, the Murrumbidgee River is found to be especially vulnerable (i.e. greater deviation from Current), with significant increase in overall environmental water vulnerability index even under the Middle-of-the-Road Scenario (Figure 20). Under the two high emissions scenarios, catchments such as the Paddys and Gudgenby also are projected to be vulnerable. The Enduring Drought Scenario is projected to bring the most significant changes overall because this scenario only contains dry years when the pressure on environmental water supply is the highest, whereas other scenarios contain wet years when the environmental water supply can be recovered. This situation is further described below.

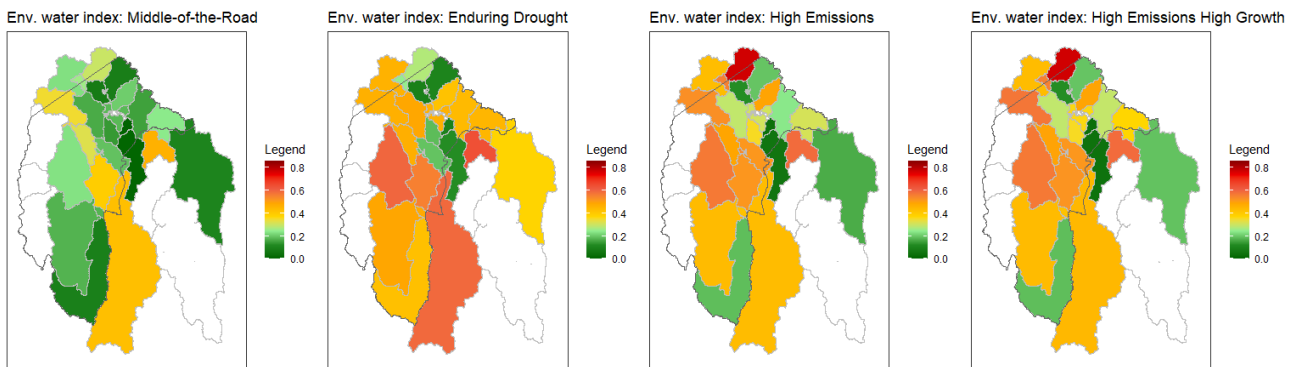


Figure 20: Overall relative vulnerability (i.e. deviation from Current) of environmental water supply across scenarios, showing variations between sub-catchments. An index of 1 indicates the most vulnerable.

Comparison of the environmental flow indices in wet and dry years highlights the significant impact of droughts on achieving environmental flow requirements. As shown in Figure 21, the wet years (occurring 25% of the time) across the future scenarios are projected to have limited deviation from the current long-term average. However, the vulnerability increases substantially in dry years (occurring 25% of the time) across all scenarios, including the Current Scenario (bottom right in Figure 21).

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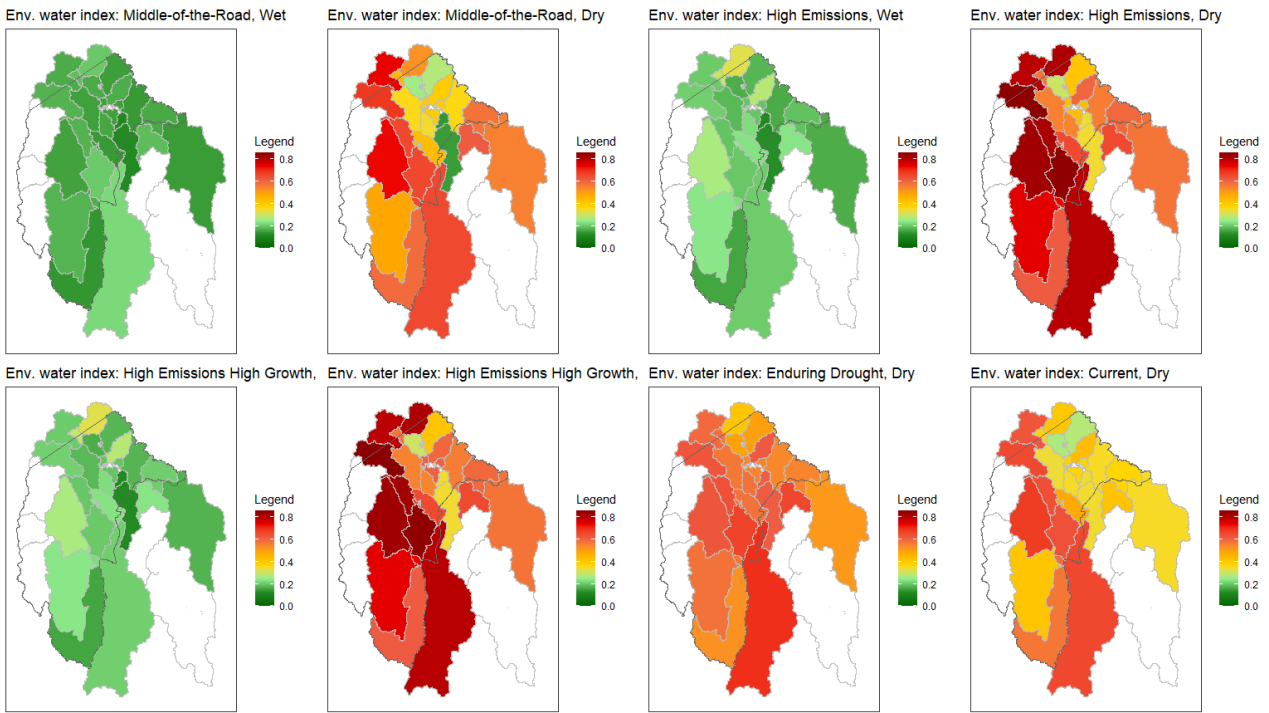


Figure 21: Overall relative vulnerability (i.e. deviation from Current) of environmental water supply across four scenarios, showing variations between wet and dry years. An index of 1 indicates the most vulnerable.

The environmental water vulnerability index is mostly affected by reductions in riffle maintenance flows (Figure 22). This is the case regardless of scenarios or wet/dry conditions. Changes in baseflows and channel maintenance flows are found to become more prominent in dry years, for all scenarios.

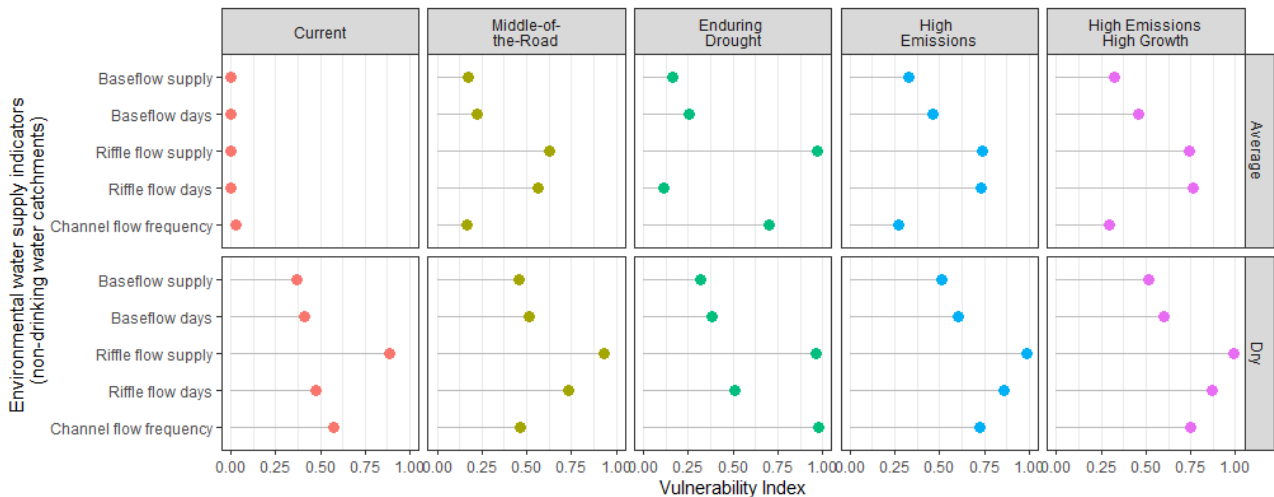


Figure 22: Standardised environmental water supply indices, showing the relative contribution of individual indicators for each scenario, on average for the modelled period and in dry years only. Indicators were standardised to between 0 and 1 based on the minimum and maximum range assessed for each indicator. An index of 1 indicates the most vulnerable.

Overall, the Enduring Drought and two high emissions scenarios are projected to be similar, with environmental vulnerability index values close to 0.4 (Figure 22). The Middle-of-the-Road Scenario is about half the level of vulnerability compared to the other future scenarios.

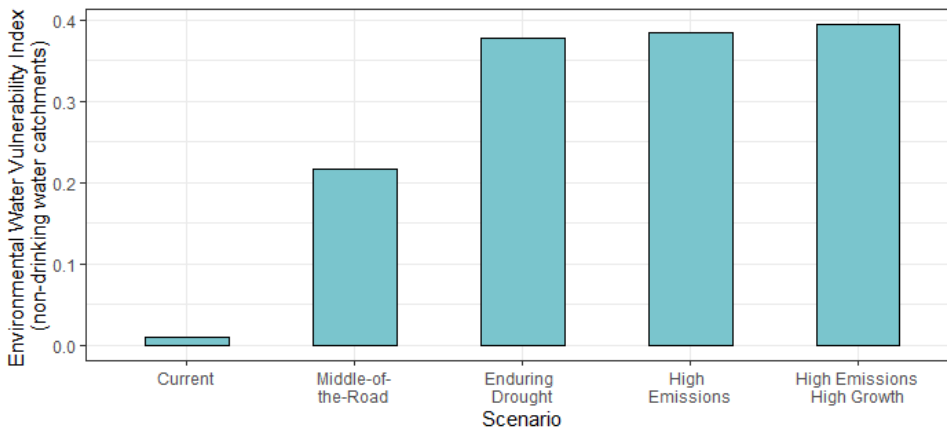


Figure 23: Overall relative vulnerability (i.e. deviation from Current) of environmental water supply across scenarios. An index of 1 indicates the most vulnerable.

6 Caveats

6.1 Representation of climate change

The assessment assumes NARClIM 1.5 climate projections are representative of future climate change for the ACT region, and that water security is especially vulnerable to drier futures. As such, three out of four future scenarios (i.e. Middle-of-the-Road, High Emissions, and High Emissions High Growth scenarios) were based on NARClIM 1.5 climate projections. The second driest of the six NARClIM 1.5 climate projections for moderate (RCP4.5) or high (RCP8.5) emission projections was selected for this vulnerability assessment (see Box 1 in Section 2).

The use of NARClIM 1.5 climate projections is justifiable because it is the best available climate change data at this time. The more recent climate models (CMIP6) are being incorporated in a new version of NARClIM (NARClIM 2.0), which is yet to be released. Nevertheless, Grose et al. (2020) reported that the global climate models for CMIP5 and CMIP6 are broadly comparable in terms of projections of Australian temperature and rainfall by 2050. Additionally, the approach of using the second driest climate projection is similar to Icon Water’s method when evaluating climate change impacts on potable water supply. Ensemble approach (e.g. taking an average of the six climate projections) was not used because some NARClIM 1.5 projections point to notable increase in rainfall but were considered less likely in the southern Australia in the updated climate models (Grose et al. 2020).

However, it is acknowledged that there are large uncertainties in climate modelling, including for the ACT region. This assessment has a strong focus on drier futures; scenarios with increased climate variability, such as periods of prolonged and/or more intense rainfall, have not been tested. The results reported in this assessment should be interpreted as a stress test of drier outlooks of the

system given moderate (Middle-of-the-Road) and more extreme (High Emissions and High Emissions High Growth) levels of climate change.

Updating the modelling and assessment of indicators based on new NARClIM 2.0 climate projections is recommended for the next phase of vulnerability assessment. Analysis of climate projections between NARClIM 1.5 and NARClIM 2.0 and analysis of the variations within the NARClIM 2.0 climate projections will help inform the selection of the new climate projections.

6.2 Assumptions in water resource operations

The assessment assumes that the current water resource operations in the ACT and region are largely business-as-usual. These include operations conducted by Icon Water who manage the Corin, Bendora, Cotter and Googong dams, and operations by Snowy Hydro who manages the Tantangara Dam.

This assumption is valid because the primary objective of this assessment is to establish a baseline of vulnerability given climate change and water resource use. The information generated from this baseline assessment can be used as a benchmark to support the development and evaluation of climate adaption options in future investigations.

With climate change, the operations are likely to change. For example, Icon Water may implement additional supply augmentation and/or water efficiency measures. Additional sources of water may be developed to ensure that the water security level of service target⁶ is continued to be met. With changes in snow falls in the alpine region and change in storages under the new Snowy Hydro 2.0, the operation rules for Tantangara dam release may be affected.

For future work, additional scenarios incorporating potential changes in water resource operations can be considered. A range of supply augmentation options are being explored by Icon Water. Source model is currently being upgraded; ability to incorporate Tantangara dam releases is a priority (subjected to support from Snowy Hydro). These works will pave the way for incorporating water resource operation options in the assessment to support policy and planning.

6.3 Vulnerability indices represent relative change

The assessment assumes a higher deviation (towards worsening conditions) from the current long-term average condition indicates greater vulnerability. The vulnerability indices (e.g. as those shown in maps, not the actual indicator values) were estimated based on relative change between a future scenario and the current scenario for a given site. Then, to compare the vulnerability indices across sites and scenarios, these changes were rescaled to 0 to 1 across scenarios and locations. Thus, a vulnerability index of 1 means the highest deviation (towards worsening conditions) from the Current Scenario among the sites and scenarios, while a vulnerability index of 0 means the least deviation from the Current Scenario.

⁶ Current level of service target is that the probability of entering temporary water restrictions is 5%.

This approach was used because the information in management targets for most indicators is lacking. For example, does 2 months a year of not meeting environmental baseflow requirements make the system vulnerable or severely vulnerable? Without this information, generating vulnerability scores based on targets of some significance is not possible. As such, the next best option is to assume the worst modelled result as the most vulnerable, and the best modelled result as the least vulnerable, as applied in this assessment.

In this report, the finding in vulnerability indices is accompanied by the reporting of states of indicators (e.g., percentage increase in days baseflow not met). The combined reporting of states and relative changes collectively inform the vulnerability of the system. However, only indices can be aggregated to create an overall vulnerability score.

The assessment also assumes the indicators are equally important in assigning the overall vulnerability score. It is possible that some indicators are considered more important than the others, thus could be given more weights when aggregating the indicators. However, reaching a consensus on weights is challenging, because the consideration of relative importance of indicators reflects social values that are inherently diverse. Thus this assessment does not use weights in aggregation.

Future work could include a sensitivity analysis to test the robustness of vulnerability indices when different aggregation (including weighting) and standardisation approaches are used. Future research and discussion on management targets will help generate vulnerability indices based on targets that have some significance (e.g., keeping days baseflow requirements not met below X% of a year). The findings from this assessment (e.g. baseflow requirements not met range from 2 to 5 months) provide boundaries where future investigation on management targets can focus on.

6.4 Confidence in water modelling

6.4.1 Potable water supply indicators

The assessment for indicators associated with regulated, potable water catchments (potable water supply and environmental water releases) was based on Icon Water modelling. These models have been developed, reviewed and improved over the last decade, and have proven to provide high confident outputs. As such, the confidence associated with the minimum storage, supply shortfall, inflow shortfall, water restrictions and environmental flow releases indicators in this assessment is high.

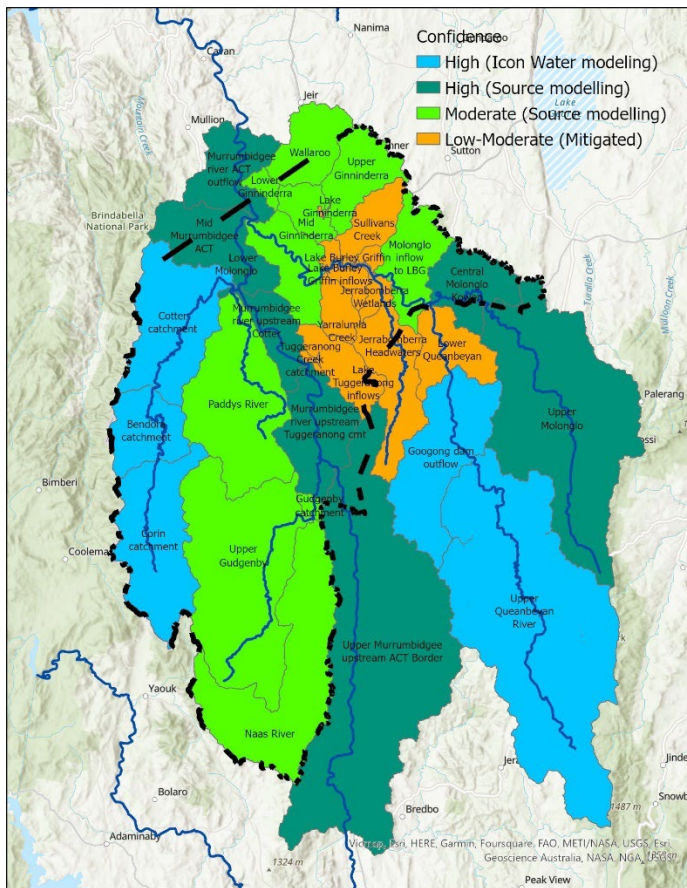
The restriction cost indicator is based on the frequency and social cost of each stage of temporary water restrictions. The estimates on social cost carry considerable uncertainty, as with all other similar economic studies. However, it is the best available estimates for the ACT. As such, the confidence associated with the restriction cost indicator is moderate. Future work to increase confidence in this indicator by reviewing and updating the social cost of temporary water restrictions can be beneficial.

6.4.2 Non-potable water and environmental water indicators

The OoW Source model was used to predict flows under different scenarios, providing critical inputs to the assessment of non-potable water and environmental water supply indicators. The Source model was calibrated based on daily flow observations (1980 – 2016) in the ACT region.

Confidence in Source modelling results is spatially represented in Figure 24. The confidence is defined based on comparing the modelled and observed daily flows – the closer the match, the higher the confidence. The most widely used model evaluation guidelines in Moriasi et al (2007) was used to classify the confidence⁷.

We have high confidence in the results for the Murrumbidgee River and areas in the upper Molonglo system (Figure 24). Moderate confidence is placed in results associated with sites at the natural reaches and mid Molonglo (upstream and downstream of the Lake Burley Griffin). Lower confidence is placed for results in most urban catchments. However, the vulnerability assessment reported annual or mean annual results, which to some extent mitigated the lower confidence associated with modelled daily flows for the urban areas.



⁷ High confidence is given to sites with Moriasi rating of “very good”; Moderate confidence is given to Moriasi rating of “good” or “satisfactory”; low to moderate confidence is given to sites with Moriasi rating of “unsatisfactory”, but with mitigation due to the use of mean annual information rather than daily information the Moriasi rating is based on.

Figure 24: Mapping the confidence in modelling. Note the supply indicators associated with drinking water catchments were generated from Icon Water modelling.

6.4.3 Effects of growth underestimated

Minimal differences are found between the High Emissions (moderate growth) and High Emissions High Growth scenarios. However, this should not be interpreted as growth have negligible impacts on water resources. This is because the effects of growth are underestimated in this assessment for the non-potable and environmental water indicators, due to limitations in modelling and data.

Growth can increase and decrease flows. For example, higher growth may increase STP outflows (due to increase in population) and urban runoffs (due to increase in surface imperviousness associated with urban development); these effects were accounted for in this assessment.

Higher growth will also decrease flows through more water extractions and interceptions, which are underestimated in this assessment. This is because the current version of Source model cannot adequately simulate changes in potable water and non-potable water demands upstream of (and more broadly external to) the ACT, and non-potable water demand within the ACT under future climate scenarios (Table 2). The effects of water resource development in NSW are likely to be underestimated. More specifically,

- NSW irrigation demand was not included because data on irrigation demand under future scenarios is not available;
- NSW town water demand (e.g. Cooma) was not included due to projected minimal impacts from decline in Cooma’s population;
- Water interception from farm dams is probably underestimated due to assumption of no future increase in farm dam density.

Table 2: Effects of higher growth, and how they are represented in this assessment

Effect of growth	Represented in VA1.0	
Increase flows	<ul style="list-style-type: none"> • Increased STP outflows • Increased urban runoff due to urban development 	
	Represented in VA1.0	Not represented in VA1.0
Decrease flows	<ul style="list-style-type: none"> • Increased Icon diversion – assumed a rate of about 12ML/day based on Icon Water model. • Farm dam interception – assumed up to 3% reduction in flows for future climate at selected sites. • Non-potable demand – assumed maximum entitlements for extreme scenarios. 	<ul style="list-style-type: none"> • NSW town water extraction – not considered due to its small volume in part due to assumption in declining Cooma population. • NSW irrigation demand – not considered due to unable to model future scenarios within the timeframe of this assessment

6.4.4 Indicator values sensitive to analysis period

All mean annual indicator values (e.g. annual average number of days with water restrictions) were generated based on the modelled period 1980-2016. This period was selected because the current version of Source model only captures this period. However, it is acknowledged that the mean annual indicator values are likely to change when using a different period. For example, the MDBA typically uses the 1890-2019 climate period as the baseline. The average condition in the last 30 years (as used in this assessment) is drier than the average condition in the last 100 years (as used by MDBA and Icon Water). This may be due to a climatic shift towards a drier climate in the last few decades, or it may be by chance that the last few decades are drier than normal. Currently, there is no consensus on which climatic period best captures the climate variations when testing climate change.

Future work could include extending the Source model and subsequent vulnerability assessment from the 1980 – 2016 period to 1890 – 2022 period. This will allow us to capture a greater range of weather variability and provide a greater confidence in some statistics such as time spent in temporary water restrictions. It will also allow us to capture the most recent severe drought (2017-19) and wet (2020-2023) climatic conditions. Introducing stochastic data will capture additional weather variability that may not occur historically.

6.4.5 Future work on Source modelling

Work to improve Source model is already underway, including better representation of water demands and dam operations, improved calibration of urban catchments, and extending the modelled period. Updating the assessment of vulnerability indicators based on improved Source model is recommended for the next phase of vulnerability assessment.

7 Conclusion

The assessment identified substantial relative vulnerabilities in ACT's potable, non-potable and environmental water supply in 2050, assuming current water supply network (infrastructure and operating rules) and per capita water demand.

On average, the region is projected to experience 30% reduction in flows under the moderate climate change and growth scenario, and 45% reduction under the more extreme climate change and growth scenario. ACT's potable water supply may run critically low (14% or zero depending on scenarios), with the costs of temporary water restrictions reaching approximately AUD\$100 million per year under the moderate climate change and growth scenario, and approximately AUD\$300 million per year under the more extreme climate change and growth scenario. Non-potable water supply is projected to be less reliable in most sub-catchments, with supply projected to reduce by 40% to 80% depending on scenarios. In the ACT, environmental water is protected above consumptive water. However, components of environmental water, especially riffle maintenance flows, are likely to be compromised under the 2050 scenarios. The Murrumbidgee River and

CABINET

unregulated waterways (e.g. Paddys, Gudgenby Rivers) are projected to have greater reductions in environmental water supply.

Developing effective policy, water infrastructure and changing human behaviours take time. This assessment highlights the needs to adapt to the new norms of diminishing water resources, and the urgency of identifying and implementing proactive policy, management and infrastructure options. This will require coordinated efforts in the water sector, continued evaluation and modelling of water resources, and effective management of risks to balance the needs of water users and environment. Solutions that increase climate resilience, such as supply augmentation and diversification, and demand management actions such as water efficiency measures and water recycling/reuse, will be important.

The next phase of the vulnerability assessment will focus on supporting the creation and assessment of adaptation options and pathways through stakeholder participation. These activities will be central part of the endeavours to safeguard ACT's water security.

References

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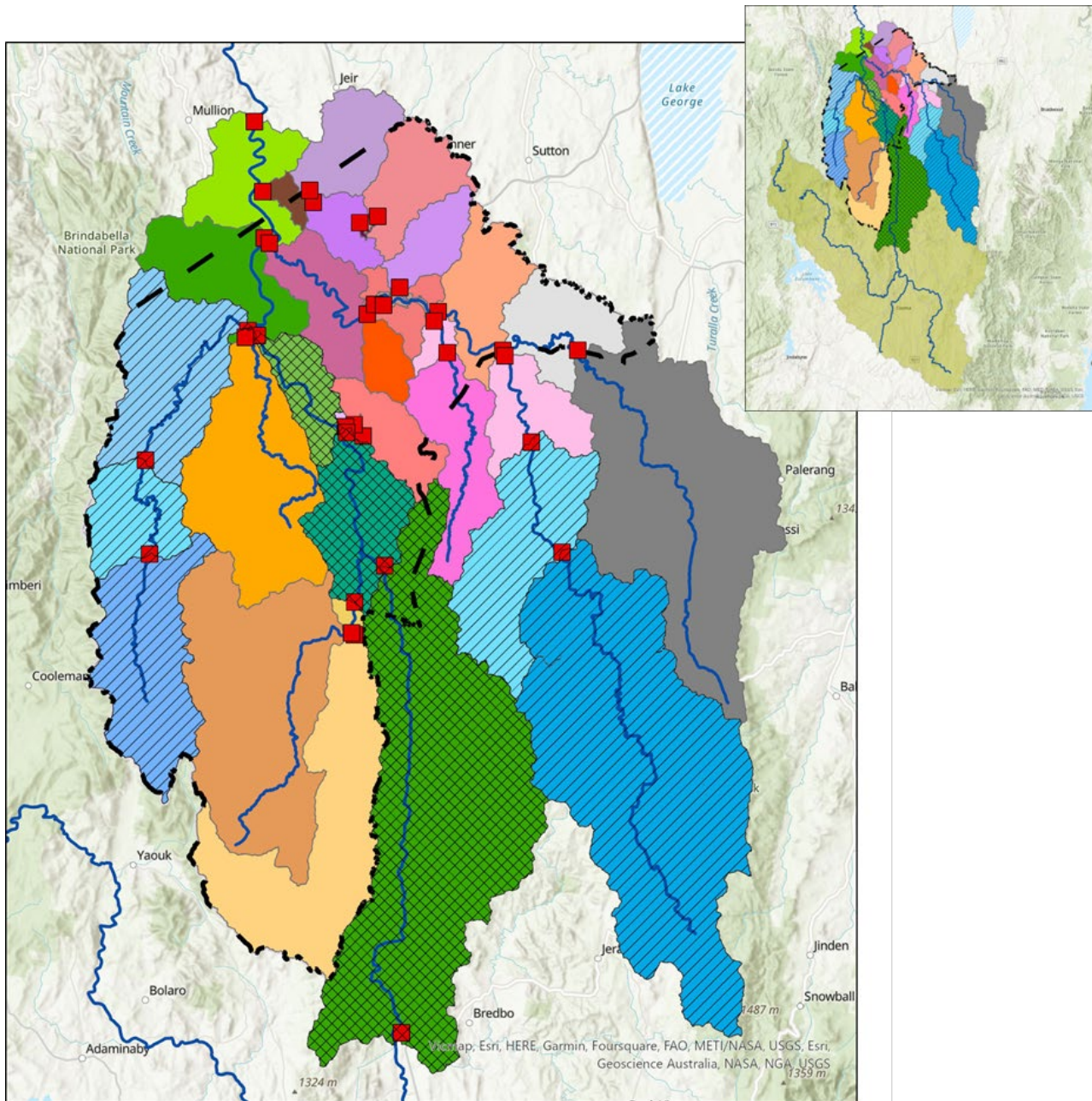
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Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D. and Veith, T.L., 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE*, 50(3), pp.885-900.

CABINET

Appendix 1: VA sites (in red squares) and corresponding catchments (polygons)

Parallel hatching indicates areas with potable water take; cross hatching indicates both potable and non-potable take; solid fill indicates areas with non-potable water take. Top right map shows regional upper Murrumbidgee sub-catchments.



VA sites					
	Bendora catchment		Lake Ginninderra		Naas River
	Central Molonglo Kowen		Lake Tuggeranong		Paddys River
	Corin catchment		Lake Tuggeranong inflows		Sullivans Creek
	Cotter catchment		Lower Ginninderra		Tuggeranong Creek catchment
	Gogong dam outflow		Lower Molonglo		Upper Ginninderra
	Gudgenby catchment		Lower Queanbeyan		Upper Gudgenby
	Jerrabomberra Headwaters		Mid Ginninderra		Upper Molonglo
	Jerrabomberra Wetlands		Mid Murrumbidgee ACT		Upper Murrumbidgee upstream ACT Border
	Lake Burley Griffin		Molonglo inflow to LBG		Upper Queanbeyan River
	Lake Burley Griffin inflows		Murrumbidgee river ACT outflow		Walleroo
			Murrumbidgee river upstream Cotter		Yarralumla Creek
			Murrumbidgee river upstream Tuggeranong cmt		

CABINET

Appendix 2: Major differences between the Current and future scenarios.

Scenario	Climate inputs	Population	ACT land use change	Non-potable water take	NSW Development
Current	Historical climate inputs during 1980-2016.	Current population in ACT and Queanbeyan	Current land use	Current	NA
Middle of the Road	Historical data multiplied by monthly scaling factors generated from NARClIM 1.5, RCP 4.5, Access1.0K model.	Projected population in 2050 in ACT and Queanbeyan, assuming moderate growth rate	Current land use + Moderate level development for Western Edge and Eastern Broadacre	Current	NA
High Emissions	Historical data multiplied by monthly scaling factors generated from NARClIM 1.5, RCP 8.5, Access1.3K model	As “Middle of the Road”	As “Middle of the Road”	Max entitlement	NA
Enduring Drought	Historical climate inputs during the millennium drought (1/1/1999 – 31/12/2009)	As “Middle of the Road”	As “Middle of the Road”	Max entitlement	NA
High Emissions High Growth	Climate inputs as S3.	Projected population in 2050 at high growth rate, in ACT, Queanbeyan and other surrounding NSW towns what may use ACT water supply	Current land use + High level development at Western Edge and Eastern Broadacre	Max entitlement	Include farm dam interceptions

CABINET

Appendix 3: Summary of ACT Environmental Flow Guidelines for non-drinking water catchments.

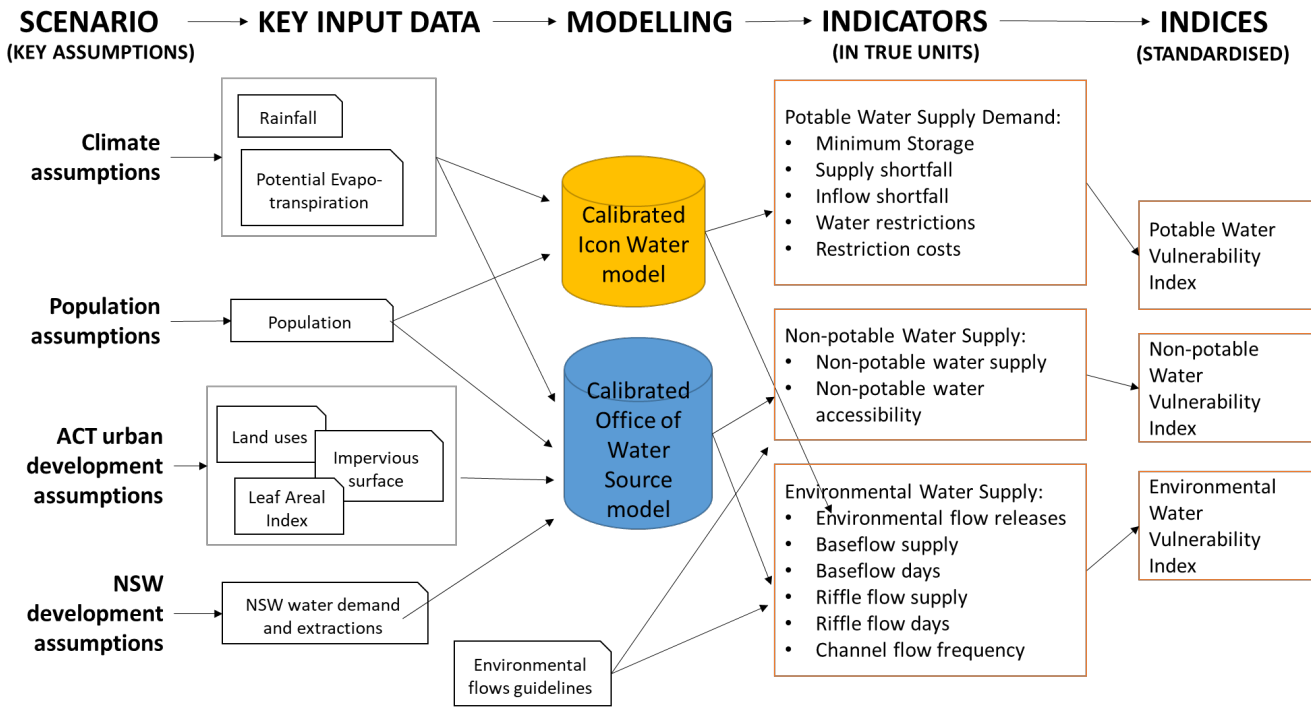
Type of systems	Waterways	Reaches	Baseflow	Riffle Maintenance Flow	Pool Maintenance Flow	Channel maintenance flow	Water supply drought flow Stage 1	Water supply drought flow Stage 2	Non-potable water
Modified ecosystems (Conservation catchments, Drainage and Open Space catchments)	All Waterways not included in the other three categories. Includes the Paddys, Murrumbidgee and Molonglo rivers, and Lake Burley Griffin. Naas and Gudgenby rivers downstream of Namadgi National Park	Murrumbidgee River (ACT reaches)	Maintain 80th percentile monthly flow November – May, and 90th percentile monthly flow June – October inclusive	Protect a minimum of 195 ML/d natural flow for a period of 1 day, once every 30 days.	NA	Maintain 1.5-2.0 annual recurrence interval flood event	Protect natural flows at Angle Crossing as shown in Icon Water Management Plan (2018)	Protect natural flows at Angle Crossing as shown in Icon Water Management Plan (2018)	Abstraction will be restricted to a long-term average of 10% of the flow above the 80th percentile flow
		Other Modified Reaches	Maintain 80th percentile monthly flow in all months.	NA	NA	Maintain 1.5-2.0 annual recurrence interval flood event	NA	NA	
Urban ecosystems (Drainage and Open Space catchments and Urban Areas)	Waterways within the urban area, excluding the Molonglo River.	Urban streams (lined and unlined)	Maintain 80th percentile modelled natural monthly flow	NA	NA	Maintain 1.5-2.0 annual recurrence interval flood event	NA	NA	

CABINET

<p>Natural ecosystems (Conservation catchments)</p>	<p>Waterways in Namadgi National Park, excepting the Cotter River catchment. Waterbodies in Tidbinbilla Nature Reserve.</p>	<p>All natural reaches</p>	<p>Maintain 80th percentile monthly flow in all months.</p>	<p>NA</p>	<p>NA</p>	<p>Maintain 1.5-2.0 annual recurrence interval flood event</p>	<p>NA</p>	<p>NA</p>	
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Appendix 4: Process of generating supply vulnerability indices.

The scenarios determined major assumptions around climate and growth (population, ACT and NSW development). These assumptions informed key input data for the Icon Water and OoW models. These models predicted flows, and together with the environmental flow guidelines, generated indicator values. These indicator values were then standardised and aggregated to vulnerability indices.



Appendix 5: Process of standardisation and aggregation to convert indicator to Index

The indicator values are in true units, while the vulnerability *index* ranges from 0 to 1. The index value (scaled between 0 – 1) provides a relative measure of change compared to the current long-term average condition.

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