



Australia's National
Science Agency

Future climate scenario modelling of instream and overbank flood recharge in the MDB integrating Basin scale river system model outputs

CSIRO report from Module 3a of the MDBA Sustainable Yields Project

Russell Crosbie, Guobin Fu, Matt Gibbs

February 2026



ISBN: 978-1-923558-18-2

Citation

Crosbie R, Fu G, Gibbs M (2026) Future climate scenario modelling of instream and overbank flood recharge in the MDB integrating Basin scale river system model outputs. CSIRO report from Module 3a of the MDBA Sustainable Yields Project CSIRO, Australia.

Copyright

© Commonwealth Scientific and Industrial Research Organisation 2025. To the extent permitted by law, all rights are reserved and no part of this publication covered by copyright may be reproduced or copied in any form or by any means except with the written permission of CSIRO.

Important disclaimer

CSIRO advises that the information contained in this publication comprises general statements based on scientific research. The reader is advised and needs to be aware that such information may be incomplete or unable to be used in any specific situation. No reliance or actions must therefore be made on that information without seeking prior expert professional, scientific and technical advice. To the extent permitted by law, CSIRO (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

CSIRO is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document please contact csiro.au/contact.

Contents

Acknowledgments.....	iv
Executive summary	v
1 Introduction	1
2 Methods.....	3
2.1 Change in overbank flood recharge under a future climate	3
2.2 Change in in-stream recharge under a future climate	8
3 Results	13
3.1 Change in overbank flood recharge under a future climate	13
3.2 Change in in-stream recharge under a future climate	18
4 Discussion	23
4.1 Comparison to previous work	23
4.2 Limitations	25
5 Summary and conclusions	27
References	31

Figures

Figure 1 Summary at the SDL resource unit scale of the change in diffuse, overbank flood and in-stream recharge under a 2050 (+1.5°C relative to 1990) future climate scenario.	vii
Figure 2 Groundwater SDL resource units	2
Figure 3 Locations of input data for the change in overbank flood recharge data	4
Figure 4 Not knowing x_w and h_w (Equation 4) becomes irrelevant as we can assume that their product is equal to Q_{FP} which can be estimated as the difference between Q_{OB} and Q_{BF}	6
Figure 5 Change in total flow from the river systems modelling for +1.5°C	7
Figure 6 Locations of input data for the change in in-stream recharge data	9
Figure 7 Schematic of a reduction in stage height and wetted perimeter for a future scenario with a reduction flow compared to a historical scenario	11
Figure 8 Change in overbank flood recharge for +1.5°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.	14
Figure 9 Change in overbank flood recharge for +1.0°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.	15
Figure 10 Change in in-stream recharge for +1.5°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.	18
Figure 11 Change in in-stream recharge for +1.0°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.	19
Figure 12 Comparison at the SDL resource unit scale between the change in overbank flood recharge derived from the Outlook river modelling and the SY2 river modelling.	23
Figure 13 Comparison at the SDL resource unit scale between the change in instream recharge derived from the Outlook river modelling and the SY2 river modelling.	24
Figure 14 Summary at the SDL resource unit scale of the change in diffuse, overbank flood and in-stream recharge under a +1.5°C (2050) scenario.....	28
Figure 15 Summary at the SDL resource unit scale of the change in diffuse, overbank flood and in-stream recharge under a +1.0°C (2030) scenario.....	29

Tables

Table 1 The change in diffuse, overbank flood and in-stream recharge under a 2050 climate (+1.5°C relative to a 1990 climate) for each SDL resource unit. The value outside of the brackets is the median case and inside the brackets the dry and wet cases. The numbers in grey for the change in in-stream recharge have reduced confidence due to assumptions in the methodology.....	vii
Table 2 Change in overbank flood recharge for +1.5°C by alluvial SDL resource unit (Figure 2) .	15
Table 3 Change in overbank flood recharge for +1.0°C by alluvial SDL resource unit (Figure 2) .	16
Table 4 Change in in-stream recharge for +1.5°C by alluvial SDL resource unit (Figure 2). SDL resource units with reduced confidence have their results greyed out.....	20
Table 5 Change in in-stream recharge for +1.0°C by alluvial SDL resource unit (Figure 2). SDL resource units with reduced confidence have their results greyed out.....	21

Acknowledgments

This work was funded by the MDBA as part of the Murray-Darling Basin Sustainable Yields project.

Executive summary

Modelling of historical and future diffuse, flood and overbank recharge was reported in Crosbie et al. (2025). Due to data availability at the time and the need to make use of these model outputs in the Sustainable Diversion Limit (SDL) assessment as part of the Basin Plan Review, the flood and overbank recharge reported in Crosbie et al (2025) utilised river system model outputs from (unpublished) 'Outlook' modelling. The current report uses updated river system model outputs from Module 2 of the Murray-Darling Basin Sustainable Yields (MDBSY) project to assess flood and overbank recharge. To facilitate comparison, the diffuse recharge results from Crosbie et al. (2025) are presented here in the 'Executive Summary' and 'Summary and conclusions' but the interested reader is directed to Crosbie et al. (2025) for full details of the diffuse recharge modelling.

The MDBSY project provides a whole-of-Basin assessment of the potential impacts of climate change on water resources. This project provides an input into the knowledge base required for the review of the Basin Plan in 2026. The project has been broken up into five modules, this report is part of Module 3, providing an update to the change in overbank flood and in-stream recharge based on the river systems modelling from Module 2.

Module 3a updates and extends the modelling conducted in the first MDBSY project in 2007 and the modelling conducted as an input to the Basin Plan in 2010.

The modelling considered three components of recharge separately. These are the:

- Diffuse recharge: recharge due to rainfall infiltrating through the soil
- Overbank flood recharge: recharge due to inundation from rivers breaking their banks
- In-stream recharge: recharge due to stream losses through the bed and banks

Each of these components will be assessed under a historical baseline climate and a range of future climates (recharge due to irrigation has not been considered here).

The future climate scenarios were developed and reported on in Module 1 of the MDBSY project and consisted of 120 different future climates produced from 47 Coupled Model Intercomparison Project Phase 6 (CMIP6) global climate models (GCMs). These had up to three runs each from different Shared Socioeconomic Pathways (SSPs) (not all GCMs had all SSPs so there are 120 future climates not 141). Each GCM output was scaled for +1.5°C since 1990 for global warming to be representative of a ~2050 climate and +1.0°C of global warming to be representative of a ~2030 climate. The historical climate sequence (132 years from 1891-2023) from SILO (Scientific Information for Land Owners) was scaled based on the GCM results to create the future climate time series.

The change in diffuse recharge under a future climate was modelled using WAVES in a very similar manner to the previous 2007 and 2010 studies. The change in overbank flood recharge and in-stream recharge was not considered in the 2007 and 2010 studies, they have been modelled in the present study from the output of the river system models from Module 2.

The reporting of the baseline recharge and the change in recharge under future climates was conducted at the Sustainable Diversion Limit (SDL) resource unit scale. There are 80 SDL resource units, but some are buried and are not directly recharged. Interaquifer leakage is best assessed using a numerical groundwater model and so has not been considered here. This leaves 68 SDL resource units with a surface expression that will be reported on for diffuse recharge. The overbank flood recharge only applies to alluvial aquifers and so was reported for 37 alluvial SDL resource units. The in-stream recharge is only calculated in alluvial aquifers that are dominated by losing streams, this was 32 SDL resource units.

The three components of recharge considered had differing responses to the future climate for both the +1.5°C and +1.0°C future climates relative to 1990. The change in overbank flood recharge generally had the greatest decrease in recharge for the dry and median cases but in the wet case had little change in the southern Basin. The change in in-stream recharge had very similar patterns to the overbank flood recharge but the changes were not as extreme, it had less of a decrease in the dry case and less of an increase in the wet case (particularly in the northern Basin). The change in diffuse recharge was different, with large areas of the Basin (or nearly all in the +1.0°C case) showing an increase in recharge for the median case.

Under the +1.5°C future climate scenario (2050), 76% of SDL resource units had an increase in diffuse recharge for the median case, one SDL resource unit had an increase in overbank flood recharge and none of the SDL resource units had an increase for in-stream recharge (Figure 1, Table 1). Under the dry future case, all SDL resource units had a decrease for all three components of recharge. For the wet future case, all SDL resource units had an increase in diffuse and overbank flood recharge, though two SDL resource units had a decrease for the in-stream recharge component.

Under the +1.0°C future climate scenario (2030), all except one SDL resource unit had an increase in diffuse recharge for the median case whereas none of the SDL resource units had an increase in in-stream recharge and only one SDL resource unit has an increase in overbank flood recharge. Under the dry future case, 57% of SDL resource units had an increase in diffuse recharge but none of the SDL resource units had an increase in overbank flood or in-stream recharge. For the wet future case none of the SDL resource units had a decrease in diffuse or overbank flood recharge and two SDL resource units had a decrease in in-stream recharge.

To understand the impact of these changes in recharge upon the water resource requires knowing what the dominant recharge mechanism is. For example, an alluvial SDL resource unit might have a projected increase in diffuse recharge and decrease in overbank flood recharge for the median scenario. If the recharge volume is dominated by infrequent flood events, then that SDL resource unit is more likely to see a decrease in recharge in the future. In some SDL resource units, the estimated change in recharge is straightforward, particularly non-alluvial SDL resource units that only have a diffuse source of recharge. In SDL resource units that have a combination of diffuse, overbank flood and in-stream recharge the estimated change in total recharge is not simple and probably best assessed through a numerical groundwater model.

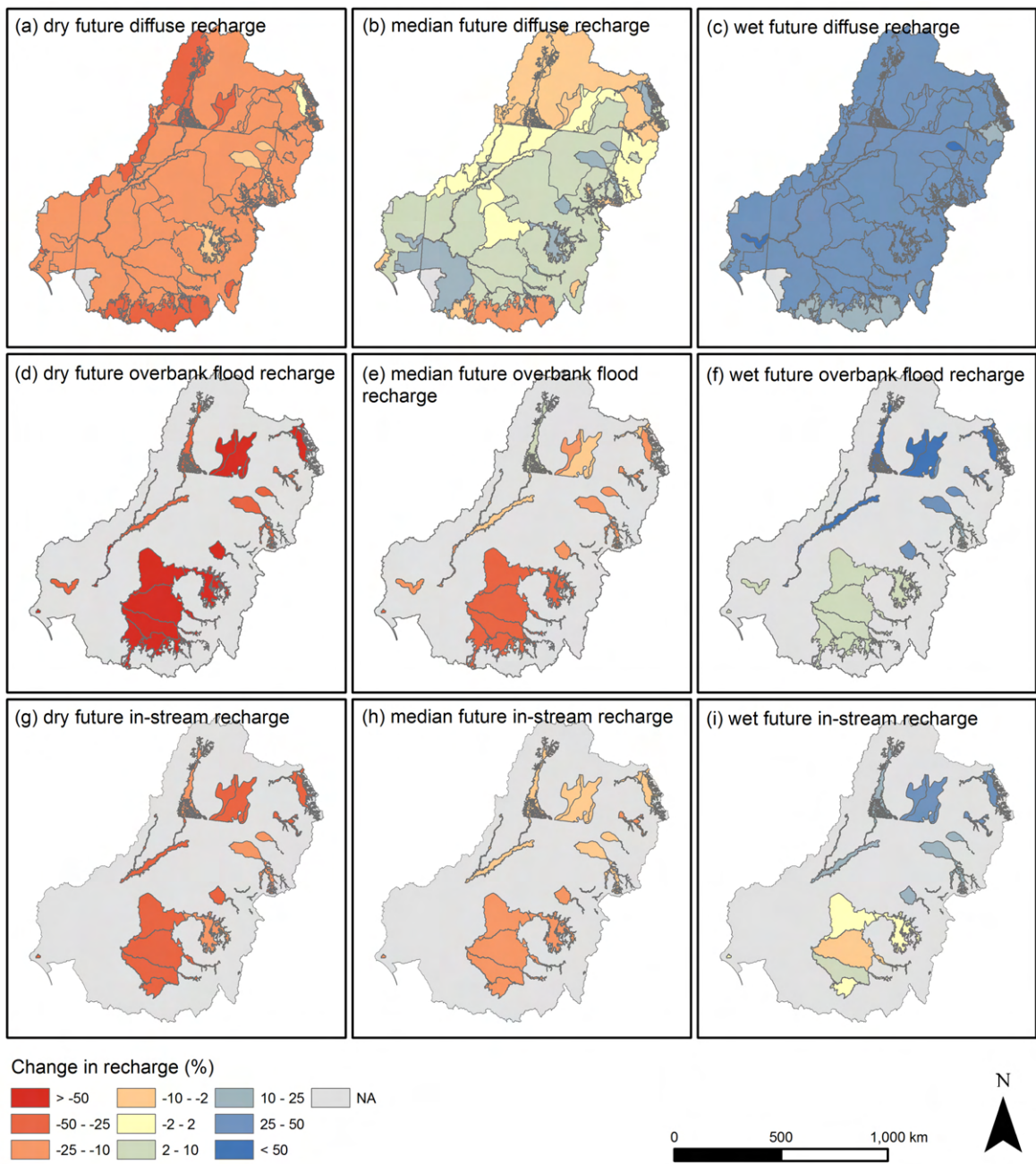


Figure 1 Summary at the SDL resource unit scale of the change in diffuse, overbank flood and in-stream recharge under a 2050 (+1.5°C relative to 1990) future climate scenario.

Table 1 The change in diffuse, overbank flood and in-stream recharge under a 2050 climate (+1.5°C relative to a 1990 climate) for each SDL resource unit. The value outside of the brackets is the median case and inside the brackets the dry and wet cases. The numbers in grey for the change in in-stream recharge have reduced confidence due to assumptions in the methodology.

SDL Resource Unit	Diffuse (%)	Overbank flood (%)	In-stream (%)
Adelaide Fold Belt MDB (GS10)	-0.4 (-26.9 — 43.8)	NA	NA
Angas Bremer (Quaternary Sediments) (GS1a)	11.8 (-11.5 — 38.8)	-44.6 (-85.1—3)	-21.6 (-41.2—1.4)
Australian Capital Territory (Groundwater) (GS52)	-4.2 (-25.5 — 23)	NA	NA
Bell Valley Alluvium (GS11)	9.5 (-15.2 — 40.4)	-25.7 (-60.8—30.9)	-10 (-23.7—11.8)

Belubula Alluvium (GS12)	16.7 (-4.3 — 47.6)	-35.3 (-61.2—3)	-21.1 (-39.5—1.8)
Billabong Creek Alluvium (GS13)	9.6 (-12.1 — 35.1)	-26.7 (-57.1—7.5)	-23.2 (-40.2—3.6)
Castlereagh Alluvium (GS14)	7.7 (-13.3 — 44.2)	-37.2 (-73.8—65.1)	-5.1 (-13.2—5.8)
Condamine Fractured Rock (GS53)	-4.7 (-23.5 — 18.7)	NA	NA
Coolaburragundy–Talbragar Alluvium (GS15)	13.5 (-6.6 — 48.5)	-21.8 (-57.3—31.6)	-15.8 (-37—20.9)
Cudgong Alluvium (GS16)	0.6 (-21.1 — 31.7)	-27.3 (-69.4—38.1)	-18.2 (-44.7—23.6)
Eastern Mount Lofty Ranges (GS2)	-2.3 (-22.5 — 24.1)	NA	NA
Goulburn-Murray: Highlands (GS8b)	-10.8 (-29.1 — 10.7)	NA	NA
Goulburn-Murray: Sedimentary Plain (GS8c)	3.4 (-18.1 — 26.3)	-43.4 (-74.7—4.3)	NA
Goulburn-Murray: Shepparton Irrigation Region (GS8a)	5.1 (-16.3 — 29.7)	-36.7 (-66.6—2.6)	-15.3 (-29.3—1.4)
Gunnedah-Oxley Basin MDB (GS17)	4.9 (-14.4 — 42.7)	NA	NA
Inverell Basalt (GS18)	5.9 (-10.7 — 38.9)	NA	NA
Kanmantoo Fold Belt MDB (GS19)	0.1 (-24.8 — 45.9)	NA	NA
Lachlan Fold Belt MDB (GS20)	2.4 (-18.1 — 29.2)	NA	NA
Lake George Alluvium (GS21)	6.4 (-13 — 33.6)	-31.1 (-59.4—2)	-11 (-21.5—0.5)
Liverpool Ranges Basalt MDB (GS22)	-2.1 (-20.5 — 33.5)	NA	NA
Lower Darling Alluvium (GS23)	-0.7 (-24.9 — 39.3)	-20.3 (-51—31)	NA
Lower Gwydir Alluvium (GS24)	13.2 (-3.1 — 53.8)	-12.5 (-48.4—48)	-6.4 (-22.6—15.2)
Lower Lachlan Alluvium (GS25)	2 (-17.2 — 37.1)	-31.2 (-57—2.4)	-16.3 (-32.3—1.2)
Lower Macquarie Alluvium (GS26)	10.7 (-12.4 — 48.3)	-21.4 (-55—25.8)	-12.5 (-31.5—15)
Lower Murray Shallow Alluvium (GS27a)	9.2 (-11.1 — 37)	-48.4 (-83.4—7.3)	-21.2 (-40.2—4.6)
Lower Murrumbidgee Shallow Alluvium (GS28a)	4.3 (-15.6 — 34.4)	-41 (-68.8—2.6)	-20.2 (-33.6—2.6)
Lower Namoi Alluvium (GS29)	12.3 (-6.4 — 48.7)	-14.9 (-45.3—29.4)	-7.6 (-23—15)
Mallee (Pliocene Sands) (GS3a)	14.5 (-14.7 — 41.7)	NA	NA
Manilla Alluvium (GS30)	9 (-5.4 — 43.7)	-13.7 (-55.3—50.4)	NA
Marne Saunders (Fractured Rock) (GS4a)	1.1 (-26.6 — 33.3)	NA	NA
Mid–Murrumbidgee Alluvium (GS31)	11.4 (-8.1 — 37)	-39 (-66.9—7.7)	-15.6 (-25.5—-2.5)
New England Fold Belt MDB (GS37)	-1.9 (-16.9 — 28.9)	NA	NA
NSW Border Rivers Alluvium (GS32)	7.3 (-11.7 — 38.5)	-11.5 (-47—41.1)	-11.9 (-38.9—49.5)
NSW Border Rivers Tributary Alluvium (GS33)	7.9 (-8.8 — 41.3)	-14.6 (-51.4—38.6)	-6.1 (-21.4—13.4)
NSW GAB Central Shallow (GS36)	1.5 (-26.7 — 49.1)	NA	NA
NSW GAB Surat Shallow (GS34)	9.6 (-10.4 — 48.6)	NA	NA
NSW GAB Warrego Shallow (GS35)	0.7 (-24.5 — 49.6)	NA	NA
Orange Basalt (GS39)	7.8 (-14.9 — 37.9)	NA	NA
Peake–Roby–Sherlock (unconfined) (GS5a)	13 (-10.7 — 34.9)	NA	NA
Peel Valley Alluvium (GS40)	9.1 (-5.5 — 39.9)	-22.2 (-60.8—37.7)	-10.5 (-29—18.8)
Queensland Border Rivers Alluvium (GS54)	3 (-15.6 — 35)	-11.5 (-47—41.1)	-11.9 (-38.9—49.5)
Queensland Border Rivers Fractured Rock (GS55)	-2.8 (-19.5 — 24)	NA	NA
Queensland MDB: deep (GS56)	-4.6 (-23.5 — 27.8)	NA	NA
SA Murray (GS6)	8.6 (-17.5 — 39.1)	NA	NA
SA Murray Salt Interception Schemes (GS7)	21.1 (-11.8 — 51.2)	-17.7 (-35.3—6.5)	NA
Sediments above the Great Artesian Basin: Border Rivers-Moonie (GS57)	5.8 (-13.1 — 36.5)	NA	NA
Sediments above the Great Artesian Basin: Condamine–Balonne (GS58)	0.7 (-19.2 — 30.8)	NA	NA

Sediments above the Great Artesian Basin: Warrego–Paroo–Nebine (GS60)	-5.4 (-27.6 — 39.7)	NA	NA
St George Alluvium: Condamine–Balonne (shallow) (GS61a)	0.8 (-19.5 — 35.1)	-7.6 (-57.1—62.9)	-4.2 (-35.8—38.1)
St George Alluvium: Moonie (GS62)	9.3 (-13 — 40.1)	-9 (-53—50)	-4.2 (-31.4—34.6)
St George Alluvium: Warrego-Paroo-Nebine (GS63)	-4.6 (-25.7 — 34.5)	-11.4 (-74.9—73.7)	-5.5 (-36.3—35.7)
Sydney Basin MDB (GS41)	-1.7 (-22.8 — 34.2)	NA	NA
Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a)	17.6 (-1.4 — 39.6)	-10.9 (-65.2—68)	-5.9 (-31.2—30.8)
Upper Condamine Alluvium (Tributaries) (GS64b)	11.7 (-8.1 — 35)	-9.2 (-57—56.8)	-4.4 (-32.3—31.5)
Upper Condamine Basalts (GS65)	4.2 (-14.3 — 30.7)	NA	NA
Upper Darling Alluvium (GS42)	1 (-22.5 — 43.5)	-8.8 (-49.9—69.2)	-5.5 (-25.5—21.8)
Upper Gwydir Alluvium (GS43)	5.9 (-9.8 — 38.9)	-16.6 (-53.3—57.3)	-7.9 (-25.9—18.6)
Upper Lachlan Alluvium (GS44)	13 (-5.9 — 43.7)	-34.8 (-61.7—3.4)	-10.9 (-21.9—1.3)
Upper Macquarie Alluvium (GS45)	12.5 (-11 — 47.4)	-32.8 (-68.9—53.9)	-7.3 (-18.3—8.9)
Upper Murray Alluvium (GS46)	11.5 (-8.3 — 35.7)	-26.7 (-57.1—7.5)	NA
Upper Namoi Alluvium (GS47)	13.5 (-3.3 — 47.7)	-10 (-31.1—22.6)	-6 (-15.9—11.4)
Upper Namoi Tributary Alluvium (GS48)	6.8 (-9.3 — 39.3)	-20.8 (-59.3—38)	-10.6 (-31.5—20.5)
Warrego Alluvium (GS66)	-4.7 (-25.1 — 40.8)	3.7 (-49.9—137)	-2 (-20—20.7)
Warrumbungle Basalt (GS49)	-3.8 (-24.7 — 37.2)	NA	NA
Western Porous Rock (GS50)	3.7 (-23.4 — 41.6)	NA	NA
Wimmera-Mallee: Highlands (GS9a)	-3.7 (-26 — 22.3)	NA	NA
Wimmera-Mallee: Sedimentary Plain (GS9b)	10.4 (-14.5 — 39.2)	NA	NA
Young Granite (GS51)	13.8 (-6.3 — 41.6)	NA	NA

1 Introduction

The Murray-Darling Basin Sustainable Yields project will provide a whole-of-Basin assessment of the potential impacts of climate change on water resources. This study provides an input into the knowledge base required for the Review of the Basin Plan in 2026.

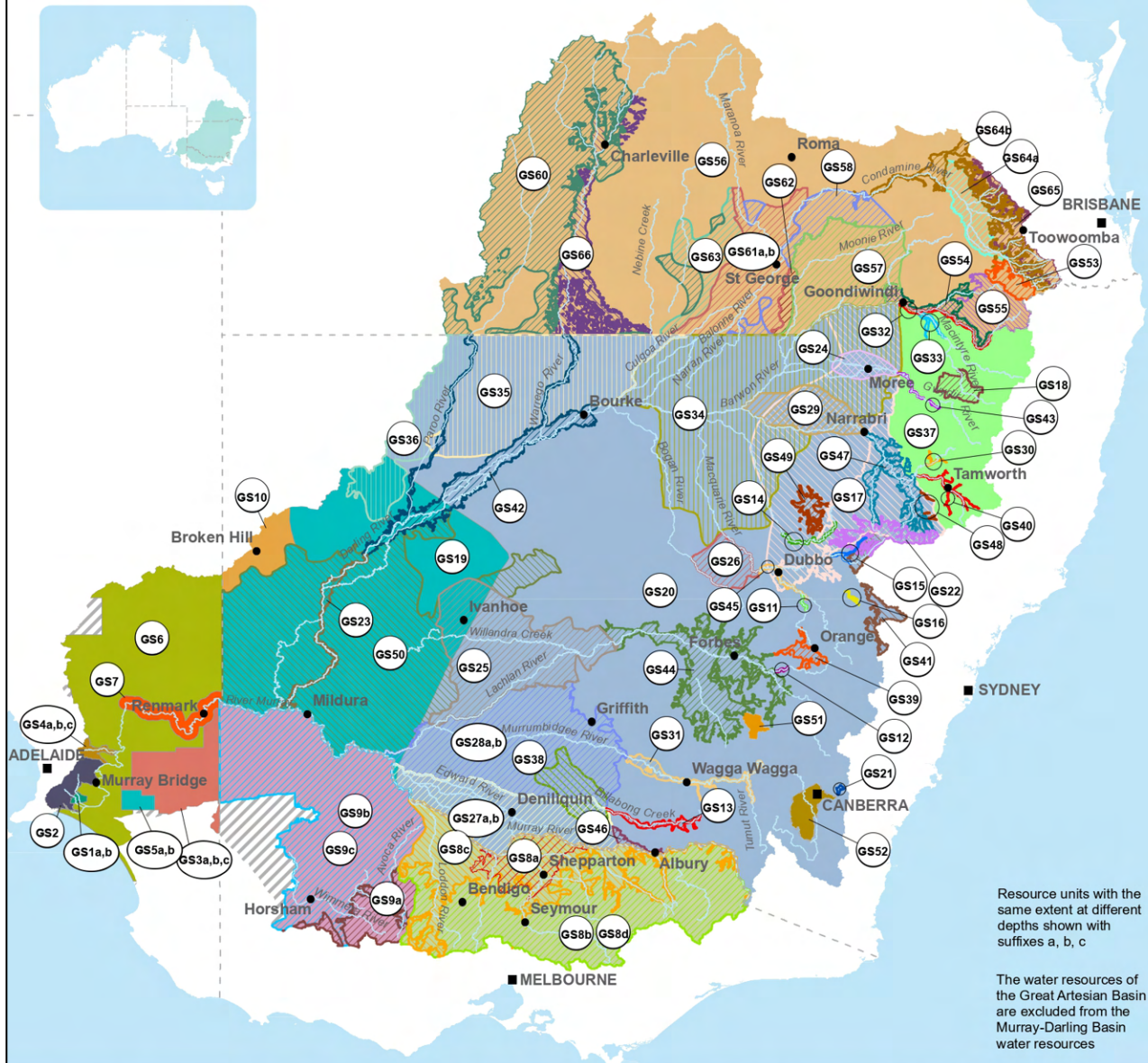
The study has been broken up into five modules:

1. Development of a suite of Basin-scale future hydroclimate projections
2. Updated model reference scenarios for the Murray–Darling Basin (MDB), incorporating future hydroclimate projections into river system modelling
3. Improved understanding of groundwater through groundwater recharge modelling, and surface water interception including farm dams
4. Furthering our knowledge of ecological thresholds of change across the Basin
5. First Nations People and Water Country: Response to flows increasing First Nations led initiatives in the Basin

This report is part of Module 3, focused on modelling the impact of climate change on overbank flood and in-stream groundwater recharge. It is an update to Crosbie et al. (2025); replacing the river flow projections from the Outlook modelling with those from Module 2 of the Sustainable Yields Project.

The reporting of the change in recharge under future climates is conducted at the SDL resource unit scale (Figure 2). There are 80 SDL resource units, but some are buried and are not directly recharged, and others are not in alluvial areas. The overbank flood recharge and in-stream recharge only apply to alluvial aquifers with a surface expression and so are reported for these 37 SDL resource units.

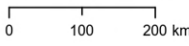
Groundwater SDL Resource Units



Resource units with the same extent at different depths shown with suffixes a, b, c

The water resources of the Great Artesian Basin are excluded from the Murray-Darling Basin water resources

<ul style="list-style-type: none"> ■ capital city ● main town - - - state border — main rivers 	<ul style="list-style-type: none"> Angas Bremer (Quaternary Sediments) (GS1a) Angas Bremer (Murray Group Limestone) (GS1b) Eastern Mount Lofty Ranges (GS2) Mallee (Pliocene Sands) (GS3a) Mallee (Murray Group Limestone) (GS3b) Mallee (Renmark Group) (GS3c) Mame Saunders (Fractured Rock) (GS4a) Mame Saunders (Murray Group Limestone) (GS4b) Mame Saunders (Renmark Group) (GS4c) Peake-Roby-Sherlock (unconfined) (GS5a) Peake-Roby-Sherlock (confined) (GS5b) SA Murray (GS6) SA Murray Salt Interception Schemes (GS7) Goulburn-Murray: Shepparton Irrigation Region (GS8a) Goulburn-Murray: Highlands (GS8b) Goulburn-Murray: Sedimentary Plain (GS8c) Goulburn-Murray: deep (GS8d) Wimmera-Mallee: Highlands (GS9a) Wimmera-Mallee: Sedimentary Plain (GS9b) Wimmera-Mallee: deep (GS9c) 	<ul style="list-style-type: none"> Adelaide Fold Belt MDB (GS10) Bell Valley Alluvium (GS11) Bekubula Alluvium (GS12) Billabong Creek Alluvium (GS13) Castlereagh Alluvium (GS14) Coolaburragunyah-Talbragar Alluvium (GS15) Cudjiegong Alluvium (GS16) Gunnedah-Oxley Basin MDB (GS17) Inverell Basalt (GS18) Kamranto Fold Belt MDB (GS19) Lachlan Fold Belt MDB (GS20) Lake George Alluvium (GS21) Liverpool Ranges Basalt MDB (GS22) Lower Darling Alluvium (GS23) Lower Gwydir Alluvium (GS24) Lower Lachlan Alluvium (GS25) Lower Macquarie Alluvium (GS26) Lower Murray Shallow Alluvium (GS27a) Lower Murray Deep Alluvium (GS27b) Lower Murrumbidgee Shallow Alluvium (GS28a) Lower Murrumbidgee Deep Alluvium (GS28b) Lower Namoi Alluvium (GS29) 	<ul style="list-style-type: none"> Manilla Alluvium (GS30) Mid-Murrumbidgee Alluvium (GS31) NSW Border Rivers Alluvium (GS32) NSW Border Rivers Tributary Alluvium (GS33) NSW GAB Surat Shallow (GS34) NSW GAB Warrego Shallow (GS35) NSW GAB Central Shallow (GS36) New England Fold Belt MDB (GS37) Oaklands Basin (GS38) Orange Basalt (GS39) Peel Valley Alluvium (GS40) Sydney Basin MDB (GS41) Upper Darling Alluvium (GS42) Upper Gwydir Alluvium (GS43) Upper Lachlan Alluvium (GS44) Upper Macquarie Alluvium (GS45) Upper Murray Alluvium (GS46) Upper Namoi Alluvium (GS47) Upper Namoi Tributary Alluvium (GS48) Warumbungle Basalt (GS49) Western Porous Rock (GS50) Young Granite (GS51) 	<ul style="list-style-type: none"> Australian Capital Territory (Groundwater) (GS52) Condamine Fractured Rock (GS53) Queensland Border Rivers Alluvium (GS54) Queensland Border Rivers Fractured Rock (GS55) Queensland MDB: deep (GS56) Sediments above the Great Artesian Basin: Border Rivers-Moonie (GS57) Sediments above the Great Artesian Basin: Condamine-Balonne (GS58) Sediments above the Great Artesian Basin: Warrego-Paroo-Nebine (GS60) St George Alluvium: Condamine-Balonne (shallow) (GS61a) St George Alluvium: Condamine-Balonne (deep) (GS61b) St George Alluvium: Moonie (GS62) St George Alluvium: Warrego-Paroo-Nebine (GS63) Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a) Upper Condamine Alluvium (Tributaris) (GS64b) Upper Condamine Basalts (GS65) Warrego Alluvium (GS66) Hot Basin groundwater resources Excluded under Water Regulations 2012
--	--	---	--	--



Sources: Geoscience Australia © Topo 250K data (Series 3), Geoscience Australia © Topo 2.5 million data (2003), Murray-Darling Basin Authority © Groundwater SDL Resource Units. Map amended:2020.

Figure 2 Groundwater SDL resource units

2 Methods

The methods used here for estimating the change in overbank flood and in-stream recharge are the same as used in Crosbie et al. (2025), the difference is in the source of the projections of river flows under the future climate with those used here from Module 2 of the Sustainable Yields project.

2.1 Change in overbank flood recharge under a future climate

2.1.1 Input data

The method used to estimate the change in overbank flood recharge is based on that used across NSW for a single dry future climate scenario (Crosbie et al. 2023). It requires:

- Daily modelled river flows under the baseline and future scenarios,
- Rating curves at the gauges to convert the daily flows to a stage height,
- An estimate of the stage height at which flooding occurs.

The change in overbank flood recharge has been evaluated using the outputs of the river system modelling from Module 2. River systems models exist for all catchments within the Basin. These river systems models have been linked to inform whole-of-basin outcome assessments. The runoff inputs were scaled for the future climate using bi-annual scaling factors derived from runoff modelling in Module 1 (Chiew et al. 2025). The model results are available for a wet, median and dry scenario.

The stage height at which flooding occurs is assumed to equal the BoM's minor flood level. This is defined as (BoM 2024a): *“Causes inconvenience. Low-lying areas next to watercourses are inundated. Minor roads may be closed and low-level bridges submerged.”* These flood levels are published for each state in the MDB (BoM 2013; BoM 2024a; BoM 2024b; BoM 2024c).

The gauges with flood heights along with the river model nodes are shown in Figure 3. This shows that there are 146 gauges with flood heights available and 149 locations with river model output data. However, there are only 47 gauges that have been used for calculating the change in recharge. The lower number of gauges available for calculating the change in overbank flood recharge is due to the requirement of having the flood height gauge and model output gauge at the same location along with having a rating curve available.

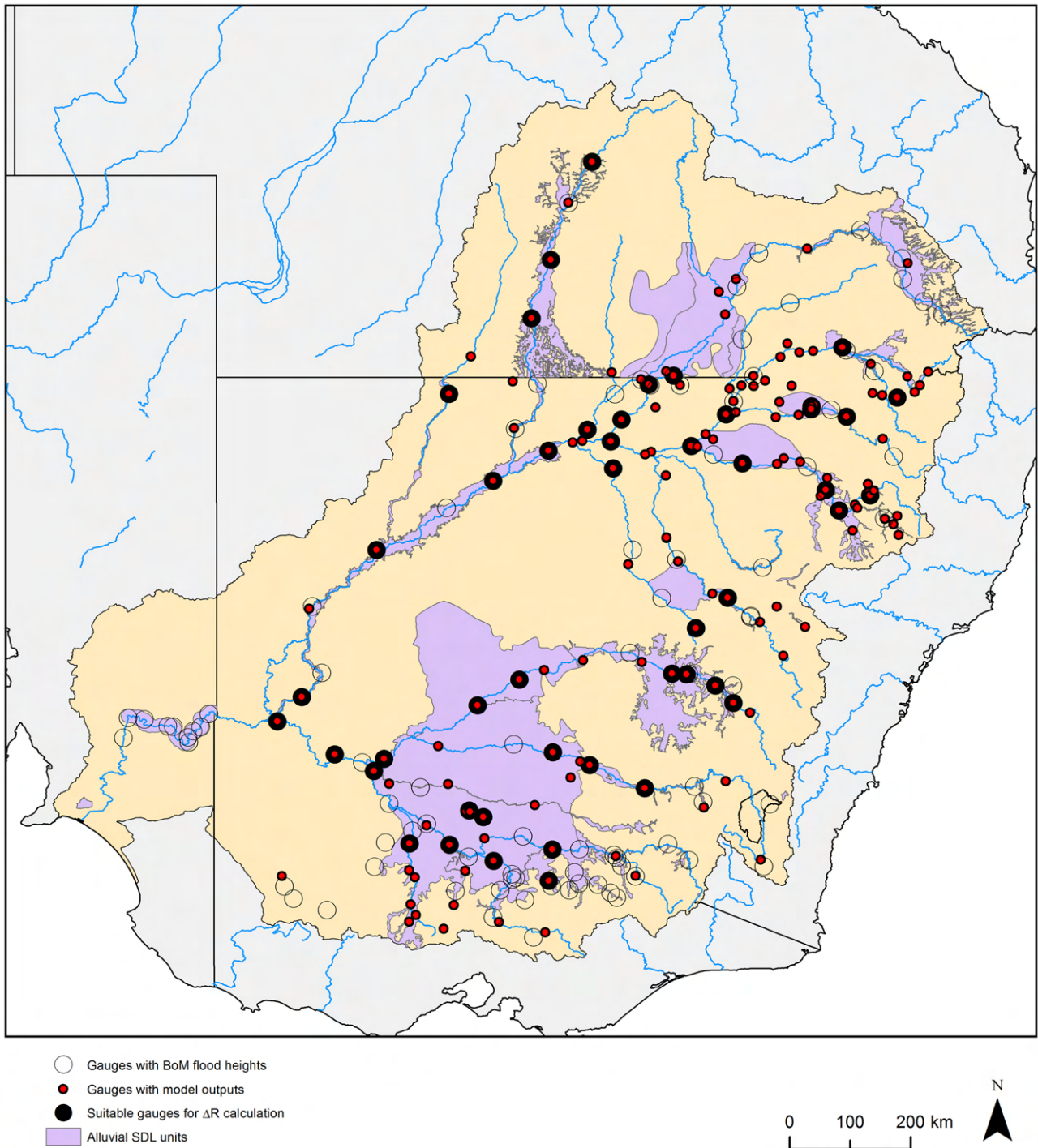


Figure 3 Locations of input data for the change in overbank flood recharge data

2.1.2 Calculation of the change in overbank flood recharge

Doble et al. (2012) showed that the recharge due to overbank flooding can be estimated as the minimum of the potential infiltration and the ability of the aquifer to store and transmit water away from the flood zone. At its simplest, recharge is at a maximum rate when the water table is deep and there is storage available. The recharge rate then decreases when the water table rises to the surface and becomes limited by the groundwater flow in the horizontal direction. Assuming that there is storage available in the aquifer, the overbank recharge can be estimated from Darcy's law in a similar manner to the in-stream recharge Doble et al. (2012):

$$I = K_c x_w \left(\frac{h_w}{d_c} + 1 \right) t_w \quad \text{Equation 1}$$

where x_w is the width of the flooding, h_w is the depth of the flooding across the floodplain and t_w is the duration of the flooding in days. As with the instream recharge, we do not know the hydraulic conductivity of the floodplain soils or the thickness of the clogging layer across the floodplain at the landscape scale so we cannot estimate the magnitude of the infiltration. There is the further complication that we do not know the width or depth of the flooding. While remote sensing can be used to generate the area of flooding (Mueller et al. 2016), and this has been used to estimate recharge from flooding (Doble et al. 2014), it can only be applied retrospectively to historical events. For predictive modelling using the future climate scenarios a model is needed that relates river flow to flood extent and depth (e.g. Teng et al. (2019)), with such work currently being undertaken across the MDB and likely to become available over the next few years. Until the results of such detailed modelling are available, we can also use the simulated volume of overbank flow as a method to derive change in the overbank recharge (ΔR_{OB}):

$$\Delta R_{OB}(\%) = 100 \left(\frac{\left[x_{wF} \left(\frac{h_{wF}}{d_c} + 1 \right) \right] - \left[x_{wH} \left(\frac{h_{wH}}{d_c} + 1 \right) \right]}{\left[x_{wH} \left(\frac{h_{wH}}{d_c} + 1 \right) \right]} \right) \quad \text{Equation 2}$$

If d_c is assumed to be very small compared to h_w then:

$$d_c \rightarrow 0, \frac{\left[x_{wF} \left(\frac{h_{wF}}{d_c} + 1 \right) \right] - \left[x_{wH} \left(\frac{h_{wH}}{d_c} + 1 \right) \right]}{\left[x_{wH} \left(\frac{h_{wH}}{d_c} + 1 \right) \right]} \rightarrow \frac{\left[x_{wF} \cdot h_{wF} \right] - \left[x_{wH} \cdot h_{wFH} \right]}{\left[x_{wH} \cdot h_{wFH} \right]} \quad \text{Equation 3}$$

then we are left with:

$$\Delta R_{OB}(\%) = 100 \left(\frac{\left[x_{wF} \cdot h_{wF} \right] - \left[x_{wH} \cdot h_{wH} \right]}{\left[x_{wH} \cdot h_{wH} \right]} \right) \quad \text{Equation 4}$$

We still don't know the extent of the flooding (x_w) or the depth of flooding on the floodplain (h_w) but the product of these two unknowns is the volume of water on the floodplain (Q_{FP}).

$$Q_{FP} = x_w \cdot h_w \quad \text{Equation 5}$$

$$\Delta R_{OB}(\%) = \alpha \times \Delta Q$$

Equation 8

where α is a scaling factor.

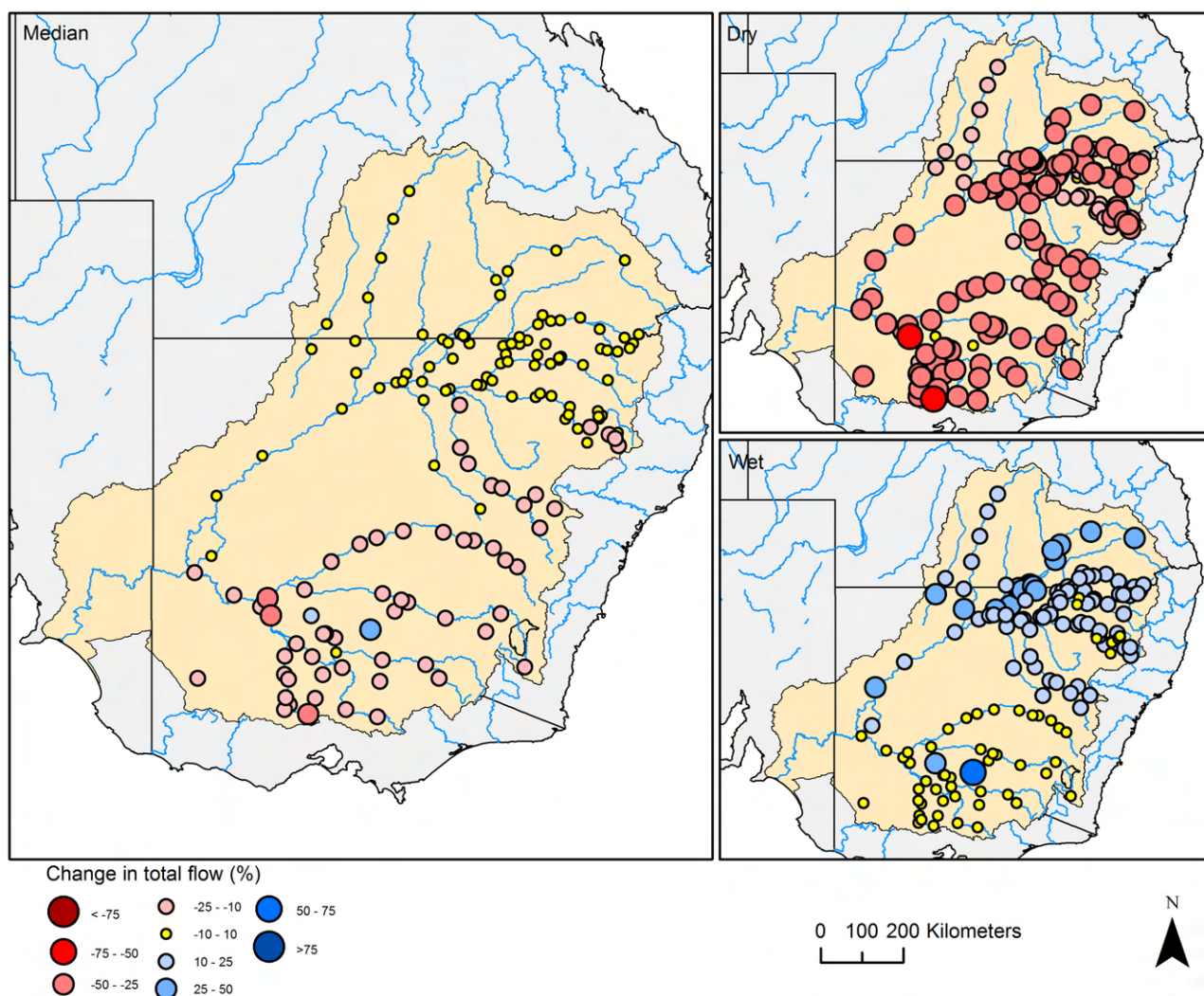


Figure 5 Change in total flow from the river systems modelling for +1.5°C

2.1.4 Aggregating the change in overbank flood recharge from the gauge to the SDL resource unit

The change in overbank flood recharge is calculated at the scale of the gauging station, a point location on the stream network. The result that is needed to assess the change in the water resource is an areal change in recharge at the scale of the SDL resource unit. Every point estimate of the change in overbank recharge within a 1 km buffer of the SDL resource unit was averaged to get a representative change in overbank recharge at the SDL resource unit scale. The estimates of the change in overbank recharge calculated using Equation 7 were weighted twice as high as those

calculated using Equation 8 as they were more directly calculated from the river model outputs. For those SDL resource units that did not have any point estimates of the change in overbank flood recharge the nearest gauge was used.

2.2 Change in in-stream recharge under a future climate

2.2.1 Input data

The method used to estimate the change in in-stream recharge is based on that used across NSW for a single dry future climate scenario (Crosbie et al. 2023). It requires:

- Daily modelled river flows under the baseline and future scenarios
- Rating curves at the gauges to convert the daily flows to a stage height
- A cross section of the river channel to estimate the wetted perimeter

The change in in-stream recharge has been evaluated using the outputs of the river systems modelling from Module 2. River systems models exist for all catchments within the Basin. These river systems models have been linked to inform whole-of-basin outcome assessments. The runoff inputs were scaled for the future climate using bi-annual scaling factors derived from runoff modelling in Module 1 (Chiew et al. 2025). The model results are available for a wet, median and dry scenario. The rating curves and cross sections were obtained from the state agencies where publicly accessible.

The gauges where all the data is available for calculating the change in in-stream recharge are shown in Figure 6. This shows that of the 149 locations with river model output data there are 99 that are suitable for calculating the in-stream recharge.

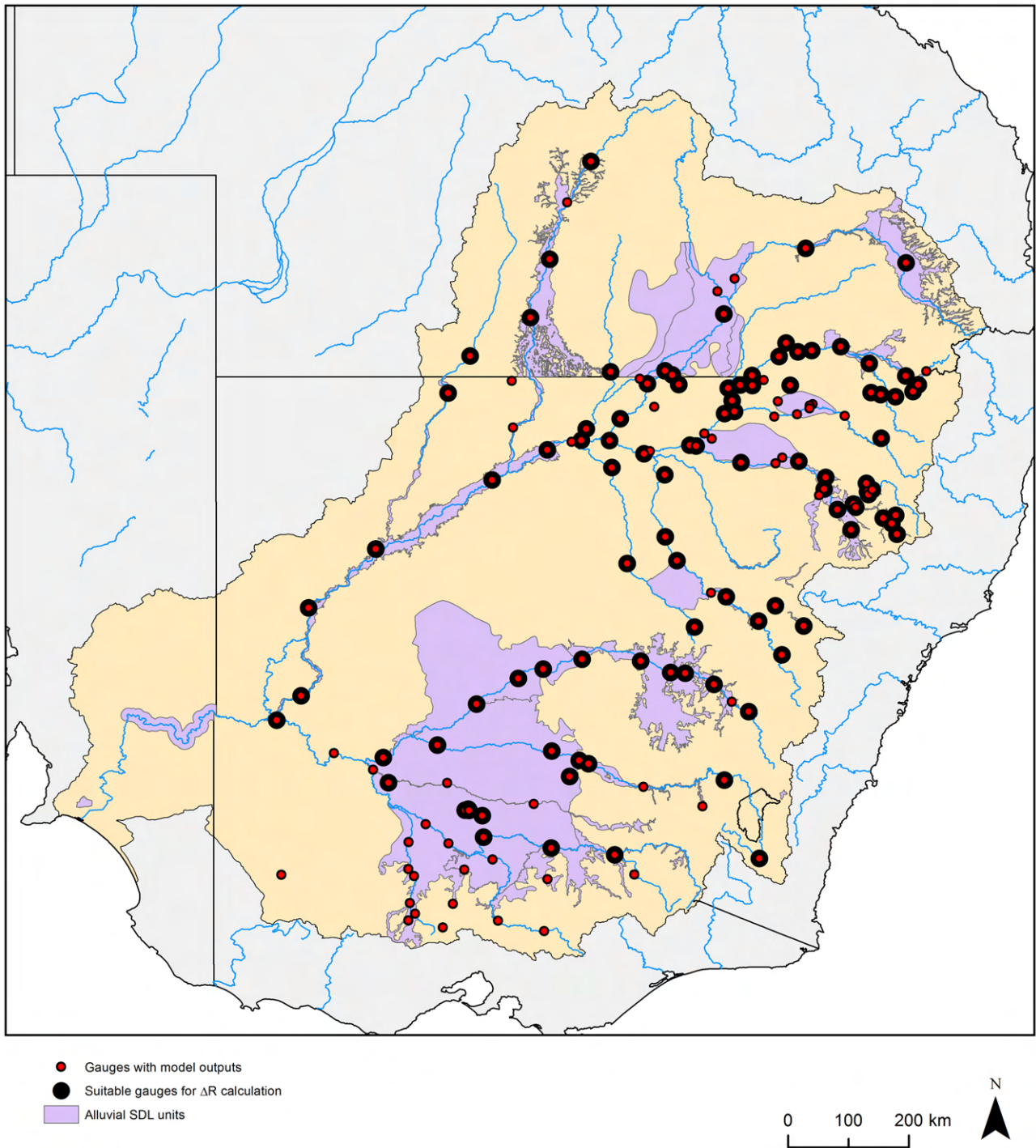


Figure 6 Locations of input data for the change in in-stream recharge data

2.2.2 Change in in-stream recharge

Recharge through the stream bed is generally considered as two endmembers (although there is a transition between them): losing disconnected streams and losing connected streams. The losing disconnected stream is the simpler case of the two.

In a losing disconnected stream, the infiltration (I) from the river will only be limited by the conductance of the riverbed, the depth to the water table is too great to limit the infiltration

(Brunner et al. 2009). In these circumstances the infiltration can be calculated based on Darcy's law (Crosbie et al. 2014):

$$I = K_c WP \left(\frac{0.5h + d_c + h_{mis}}{d_c} \right) t \quad \text{Equation 9}$$

where K_c is the hydraulic conductivity of the clogging layer, WP is the wetted perimeter, h is the stage height, d_c is the depth of the clogging layer, h_{mis} is the soil suction at the base of the clogging layer and t is time. As we don't know the hydraulic conductivity of the clogging layer or its thickness on a whole of river reach basis, our ability to calculate the magnitude of the infiltration is limited. In this case we are interested in the proportional change in the infiltration between the future (F) and historical (H) scenarios:

$$\frac{I_F}{I_H} = \frac{K_c WP_F \left(\frac{0.5h_F + d_c + h_{mis}}{d_c} \right) t}{K_c WP_H \left(\frac{0.5h_H + d_c + h_{mis}}{d_c} \right) t} \quad \text{Equation 10}$$

If we then make the assumption that K_c and d_c do not change between the two scenarios and that d_c and h_{mis} are very small, we are left with the ratio of future to historical infiltration equal to the ratio of the future to historical wetted perimeter multiplied by the stage height:

$$\frac{I_F}{I_H} = \frac{WP_F h_F}{WP_H h_H} \quad \text{Equation 11}$$

If the infiltration through the riverbed is assumed to become recharge, then the change in in-stream recharge as a percentage becomes:

$$\Delta R_{IS}(\%) = 100 \left(\frac{(WP_F h_F) - (WP_H h_H)}{WP_H h_H} \right) \quad \text{Equation 12}$$

This is illustrated in Figure 7 for a case where there is a reduction in flow in a future scenario and as a consequence there is a reduction in the stage height and the wetted perimeter. The calculation of $WP \times h$ (Equation 12) is conducted daily before being averaged annually to allow the

calculation of an annual change in recharge. The annual changes are not reported here and are averaged over the simulation period.

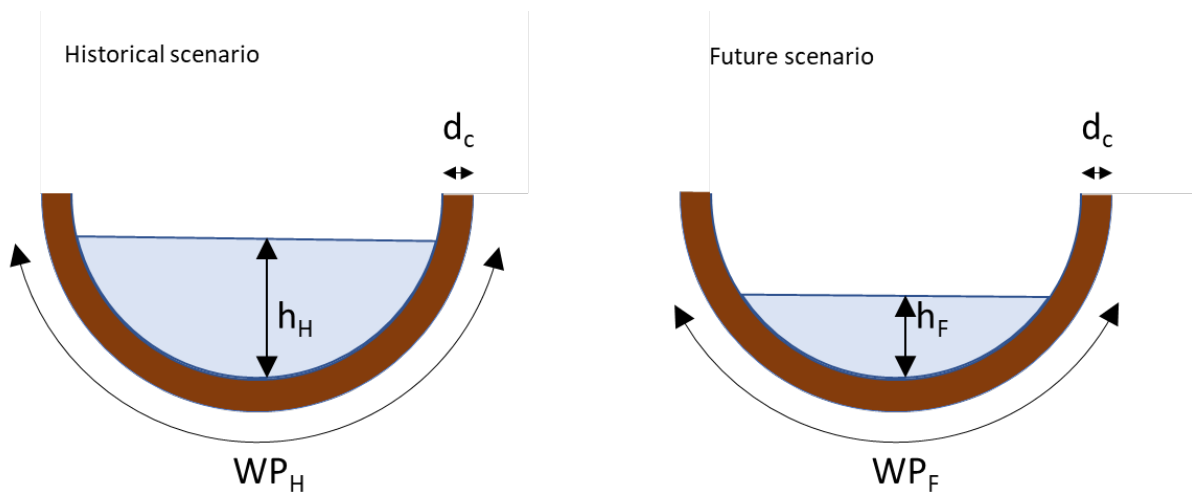


Figure 7 Schematic of a reduction in stage height and wetted perimeter for a future scenario with a reduction flow compared to a historical scenario

In a losing connected stream, the pressure at the base of the clogging layer (γ_p) is above atmospheric pressure and so Equation 9 becomes:

$$I = K_c WP \left(\frac{0.5h + d_c - \gamma_p}{d_c} \right) t \quad \text{Equation 13}$$

If we make the same assumptions that were made for the losing disconnected case, with the additional assumption that the water table does not change position between scenarios from being very close to the base of the clogging layer (i.e. γ_p does not change and is very small) then the losing connected case collapses back to the same result as the losing disconnected case and the change in recharge between the historical and future scenarios can be calculated using Equation 12. This is a gross simplification that will lead to an error in the change in recharge if the water table depth beneath the river is reduced under a future climate, this is because for a given stage height the infiltration will change linearly with a change in water table position (Brunner et al. 2009).

2.2.3 Scaling the results across the Basin

Where we cannot calculate the change in in-stream recharge due to a lack of data, the results can be upscaled using a suitable covariate. If a suitable relationship can be identified between the change in in-stream recharge and the change in flow, then the change in in-stream recharge can be estimated at the remaining gauge locations that have been modelled (Figure 6). The pilot testing on the NSW gauges demonstrated a linear relationship between the change in in-stream recharge and the change in total flow.

$$\Delta R_{IS}(\%) = \alpha \times \Delta Q \quad \text{Equation 14}$$

where α is a scaling factor.

2.2.4 Aggregating the change in in-stream recharge from the gauge to the SDL resource unit

The change in in-stream recharge is calculated at the scale of the gauging station, a point location on the stream network. The result that is needed to assess the change in the water resource is an areal change in recharge at the scale of the resource SDL unit. Every point estimate of the change in in-stream recharge within a 1 km buffer of the SDL resource unit was averaged to get a representative change in in-stream recharge at the SDL resource unit scale. The estimates of the change in in-stream recharge calculated using Equation 12 were weighted twice as high as those calculated using Equation 14 as they were more directly calculated from the river model outputs. For those SDL resource units that did not have any point estimates of the change in in-stream recharge the nearest gauge was used.

These values are only reported for the losing streams, they become meaningless for the SDL resource units classified as gaining or variable-connected (see Crosbie et al. (2025)).

3 Results

The results section is organised in the same manner as the methods section reporting on the change in overbank flood and in-stream recharge using the stream flow projections from Module 2 of the Sustainable Yields project.

3.1 Change in overbank flood recharge under a future climate

3.1.1 Results at the gauge scale

The results of the change in overbank flood recharge for +1.5°C (Figure 8) and +1.0°C (Figure 9) show larger reductions in the southern Basin for the dry and median scenario and a larger increase in the northern Basin for the wet scenario. The median case has a mean of -20% for the +1.5°C scenario and -13% for the +1.0°C scenario. There is a wide range between the dry and wet cases with a mean of -56% and +33% for the +1.5°C case and -49% and +22% for the +1.0°C case.

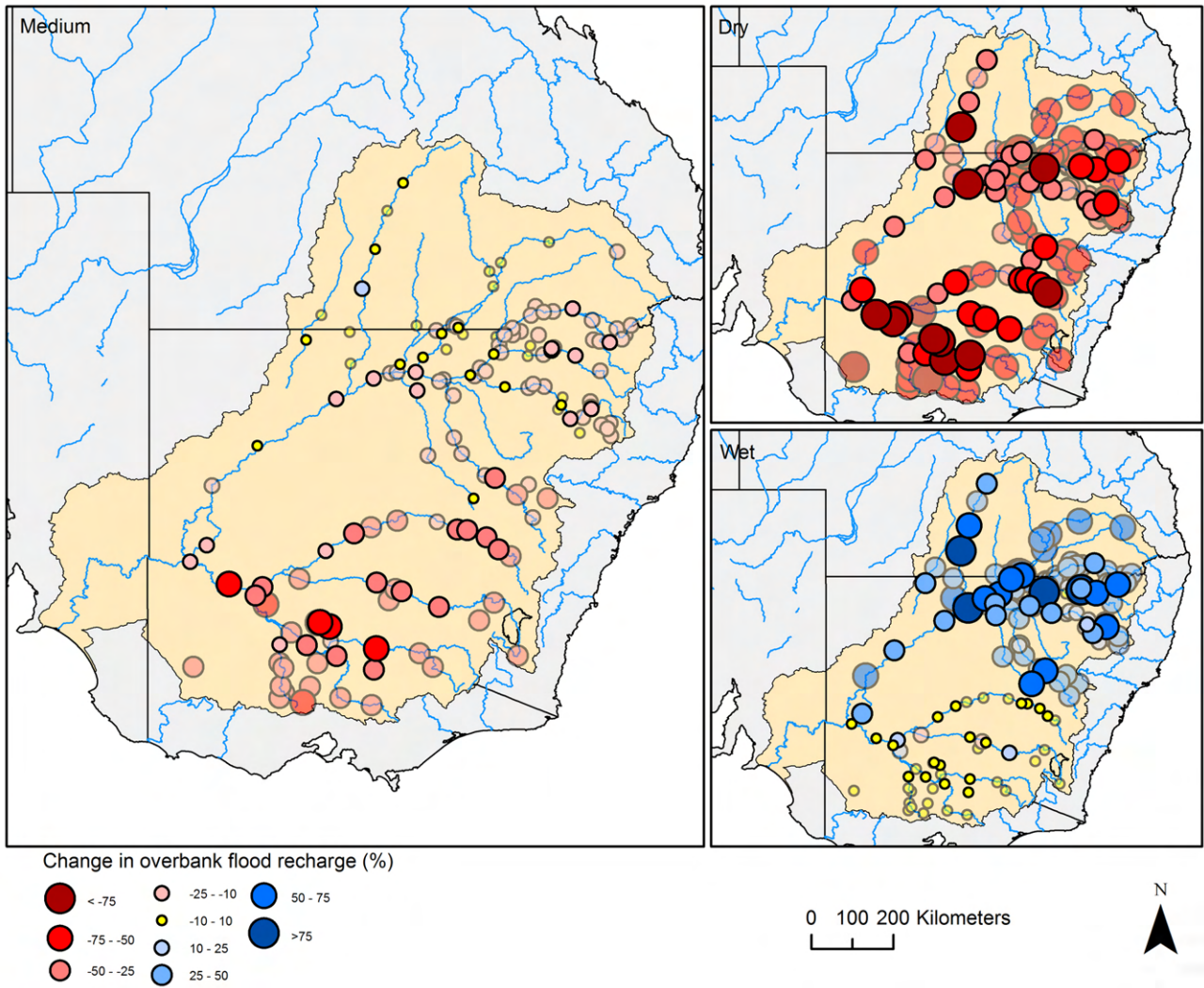


Figure 8 Change in overbank flood recharge for +1.5°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.

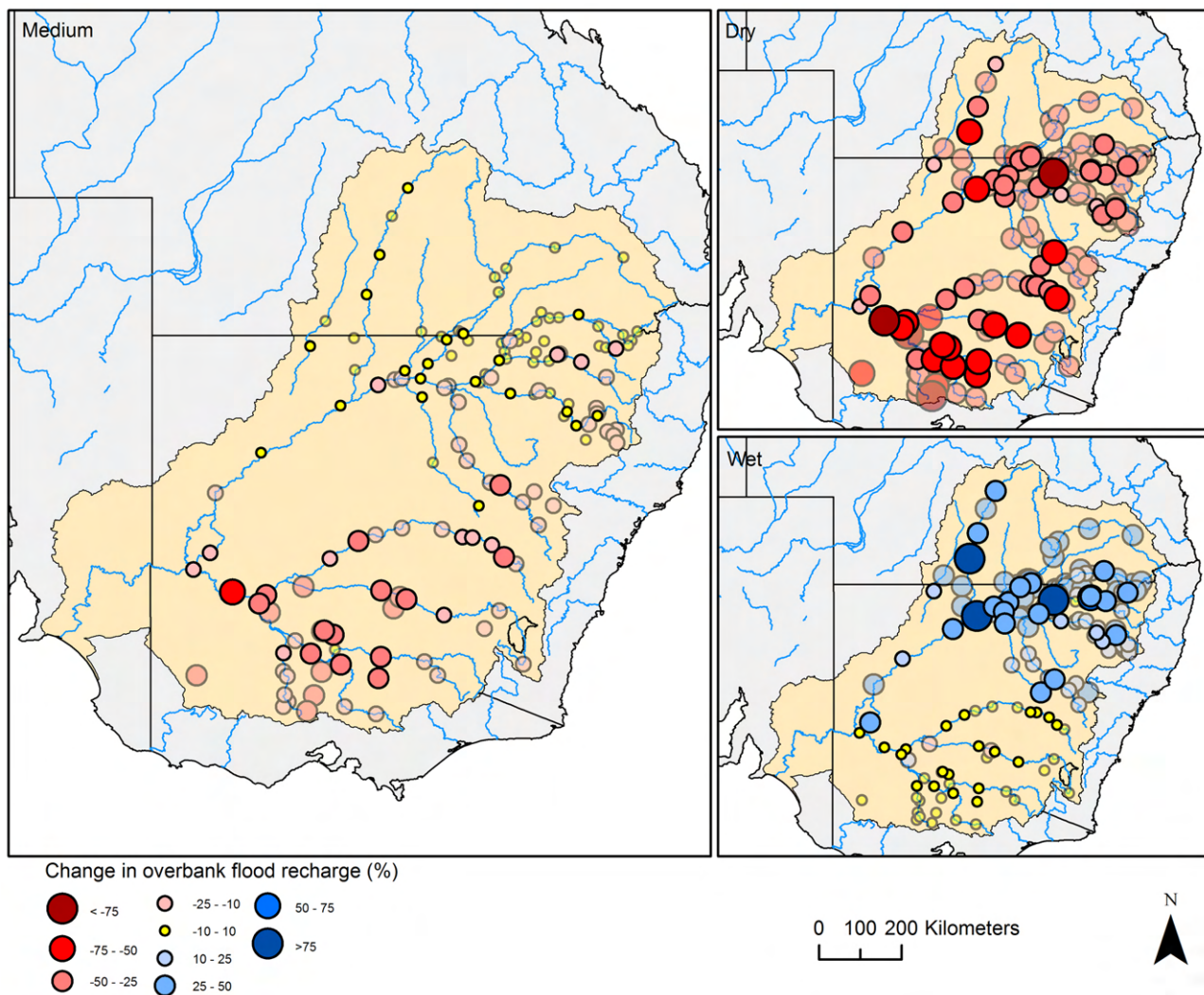


Figure 9 Change in overbank flood recharge for +1.0°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.

3.1.2 Results at SDL resource unit scale

The point scale estimates of the change in overbank flood recharge have been aggregated from the gauge to the SDL resource unit scale and the results shown in Table 2 for the +1.5°C scenario and Table 3 for the +1.0°C scenario. For the median scenario all SDL resource units show a reduction in overbank flood recharge except for Warrego Alluvium. The Lower Murray Shallow Alluvium has the greatest change in overbank flood recharge of -48% for the +1.5°C scenario and -33.6% for the +1.0°C scenario whereas the Warrego Alluvium has the least change at +4% for the +1.5°C scenario and +2% for the +1.0°C scenario.

Table 2 Change in overbank flood recharge for +1.5°C by alluvial SDL resource unit (Figure 2)

JURISDICT	SDL NAME	Dry (%)	Med (%)	Wet (%)
NSW	Bell Valley Alluvium (GS11)*	-60.8	-25.7	30.9

NSW	Belubula Alluvium (GS12)*	-61.2	-35.3	3.0
NSW	Billabong Creek Alluvium (GS13) *	-57.1	-26.7	7.5
NSW	Castlereagh Alluvium (GS14)*	-73.8	-37.2	65.1
NSW	Coolaburragundy-Talbragar Alluvium (GS15) *	-57.3	-21.8	31.6
NSW	Cudgegong Alluvium (GS16)*	-69.4	-27.3	38.1
NSW	Lake George Alluvium (GS21) *	-59.4	-31.1	2.0
NSW	Lower Darling Alluvium (GS23)	-51.0	-20.3	31.0
NSW	Lower Gwydir Alluvium (GS24)	-48.4	-12.5	48.0
NSW	Lower Lachlan Alluvium (GS25)	-57.0	-31.2	2.4
NSW	Lower Macquarie Alluvium (GS26)	-55.0	-21.4	25.8
NSW	Lower Murray Shallow Alluvium (GS27a)	-83.4	-48.4	7.3
NSW	Lower Murrumbidgee Shallow Alluvium (GS28a)	-68.8	-41.0	2.6
NSW	Lower Namoi Alluvium (GS29)	-45.3	-14.9	29.4
NSW	Manilla Alluvium (GS30)	-55.3	-13.7	50.4
NSW	Mid-Murrumbidgee Alluvium (GS31)	-66.9	-39.0	7.7
NSW	NSW Border Rivers Alluvium (GS32)	-47.0	-11.5	41.1
NSW	NSW Border Rivers Tributary Alluvium (GS33)	-51.4	-14.6	38.6
NSW	Peel Valley Alluvium (GS40)	-60.8	-22.2	37.7
NSW	Upper Darling Alluvium (GS42)	-49.9	-8.8	69.2
NSW	Upper Gwydir Alluvium (GS43)	-53.3	-16.6	57.3
NSW	Upper Lachlan Alluvium (GS44)	-61.7	-34.8	3.4
NSW	Upper Macquarie Alluvium (GS45)	-68.9	-32.8	53.9
NSW	Upper Murray Alluvium (GS46)	-57.1	-26.7	7.5
NSW	Upper Namoi Alluvium (GS47)	-31.1	-10.0	22.6
NSW	Upper Namoi Tributary Alluvium (GS48) *	-59.3	-20.8	38.0
QLD	Queensland Border Rivers Alluvium (GS54)	-47.0	-11.5	41.1
QLD	St George Alluvium: Condamine-Balonne (shallow) (GS61a)	-57.1	-7.6	62.9
QLD	St George Alluvium: Moonie (GS62) *	-53.0	-9.0	50.0
QLD	St George Alluvium: Warrego-Paroo-Nebine (GS63) *	-74.9	-11.4	73.7
QLD	Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a)	-65.2	-10.9	68.0
QLD	Upper Condamine Alluvium (Tributaries) (GS64b)	-57.0	-9.2	56.8
QLD	Warrego Alluvium (GS66)	-49.9	3.7	137.0
SA	Angas Bremer (Quaternary Sediments) (GS1a) *	-85.1	-44.6	3.0
SA	SA Murray Salt Interception Schemes (GS7)*	-35.3	-17.7	6.5
VIC	Goulburn-Murray: Shepparton Irrigation Region (GS8a)	-66.6	-36.7	2.6
VIC	Goulburn-Murray: Sedimentary Plain (GS8c)	-74.7	-43.4	4.3

* SDL resource units that had no calculated change in overbank flood recharge estimates, they have been estimated from the nearest gauge.

Table 3 Change in overbank flood recharge for +1.0°C by alluvial SDL resource unit (Figure 2)

JURISDICT	SDL NAME	Dry (%)	Med (%)	Wet (%)
NSW	Bell Valley Alluvium (GS11)*	-40.7	-17.2	20.6
NSW	Belubula Alluvium (GS12)*	-44.4	-24.0	1.9

NSW	Billabong Creek Alluvium (GS13) *	-37.3	-18.9	6.2
NSW	Castlereagh Alluvium (GS14)*	-57.0	-27.0	41.6
NSW	Coolaburragundy-Talbragar Alluvium (GS15) *	-37.9	-14.7	21.1
NSW	Cudgegong Alluvium (GS16)*	-46.5	-18.4	25.3
NSW	Lake George Alluvium (GS21) *	-40.3	-21.4	0.5
NSW	Lower Darling Alluvium (GS23)	-34.8	-13.7	19.9
NSW	Lower Gwydir Alluvium (GS24)	-34.1	-8.9	32.0
NSW	Lower Lachlan Alluvium (GS25)	-39.9	-21.7	1.6
NSW	Lower Macquarie Alluvium (GS26)	-35.8	-13.9	17.3
NSW	Lower Murray Shallow Alluvium (GS27a)	-63.7	-33.6	6.6
NSW	Lower Murrumbidgee Shallow Alluvium (GS28a)	-51.2	-28.3	0.8
NSW	Lower Namoi Alluvium (GS29)	-30.3	-10.0	19.7
NSW	Manilla Alluvium (GS30)	-41.8	-8.8	33.2
NSW	Mid-Murrumbidgee Alluvium (GS31)	-49.1	-24.9	4.8
NSW	NSW Border Rivers Alluvium (GS32)	-31.9	-7.8	27.2
NSW	NSW Border Rivers Tributary Alluvium (GS33)	-34.3	-9.7	25.7
NSW	Peel Valley Alluvium (GS40)	-40.8	-14.9	25.1
NSW	Upper Darling Alluvium (GS42)	-35.3	-6.2	43.0
NSW	Upper Gwydir Alluvium (GS43)	-39.0	-12.1	37.2
NSW	Upper Lachlan Alluvium (GS44)	-44.4	-23.9	2.2
NSW	Upper Macquarie Alluvium (GS45)	-51.2	-23.4	34.7
NSW	Upper Murray Alluvium (GS46)	-37.3	-18.9	6.2
NSW	Upper Namoi Alluvium (GS47)	-21.3	-6.8	14.6
NSW	Upper Namoi Tributary Alluvium (GS48) *	-39.7	-13.9	25.3
QLD	Queensland Border Rivers Alluvium (GS54)	-31.9	-7.8	27.2
QLD	St George Alluvium: Condamine-Balonne (shallow) (GS61a)	-38.8	-5.2	41.6
QLD	St George Alluvium: Moonie (GS62) *	-35.3	-6.0	33.1
QLD	St George Alluvium: Warrego-Paroo-Nebine (GS63) *	-50.1	-7.6	49.1
QLD	Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a)	-44.5	-7.4	44.8
QLD	Upper Condamine Alluvium (Tributaries) (GS64b)	-38.4	-6.1	37.7
QLD	Warrego Alluvium (GS66)	-37.0	2.3	81.6
SA	Angas Bremer (Quaternary Sediments) (GS1a) *	-57.9	-30.4	2.0
SA	SA Murray Salt Interception Schemes (GS7)*	-24.4	-11.9	4.2
VIC	Goulburn-Murray: Shepparton Irrigation Region (GS8a)	-48.0	-24.8	2.5
VIC	Goulburn-Murray: Sedimentary Plain (GS8c)	-56.4	-29.8	3.6

* SDL resource units that had no calculated change in overbank flood recharge estimates, they have been estimated from the nearest gauge.

3.2 Change in in-stream recharge under a future climate

3.2.1 Results at the gauge scale

The results of the change in instream recharge have larger reductions in the southern Basin for the dry and median scenario and a larger increase in the northern Basin for the wet scenario (Figure 10). The median case has a mean of -10% for the +1.5°C scenario and -6% for the +1.0°C scenario. There is also a wide range between the dry and wet scenarios with a mean of -27% and +14% for the +1.5°C scenario and -18% and +10% for the +1.0°C scenario.

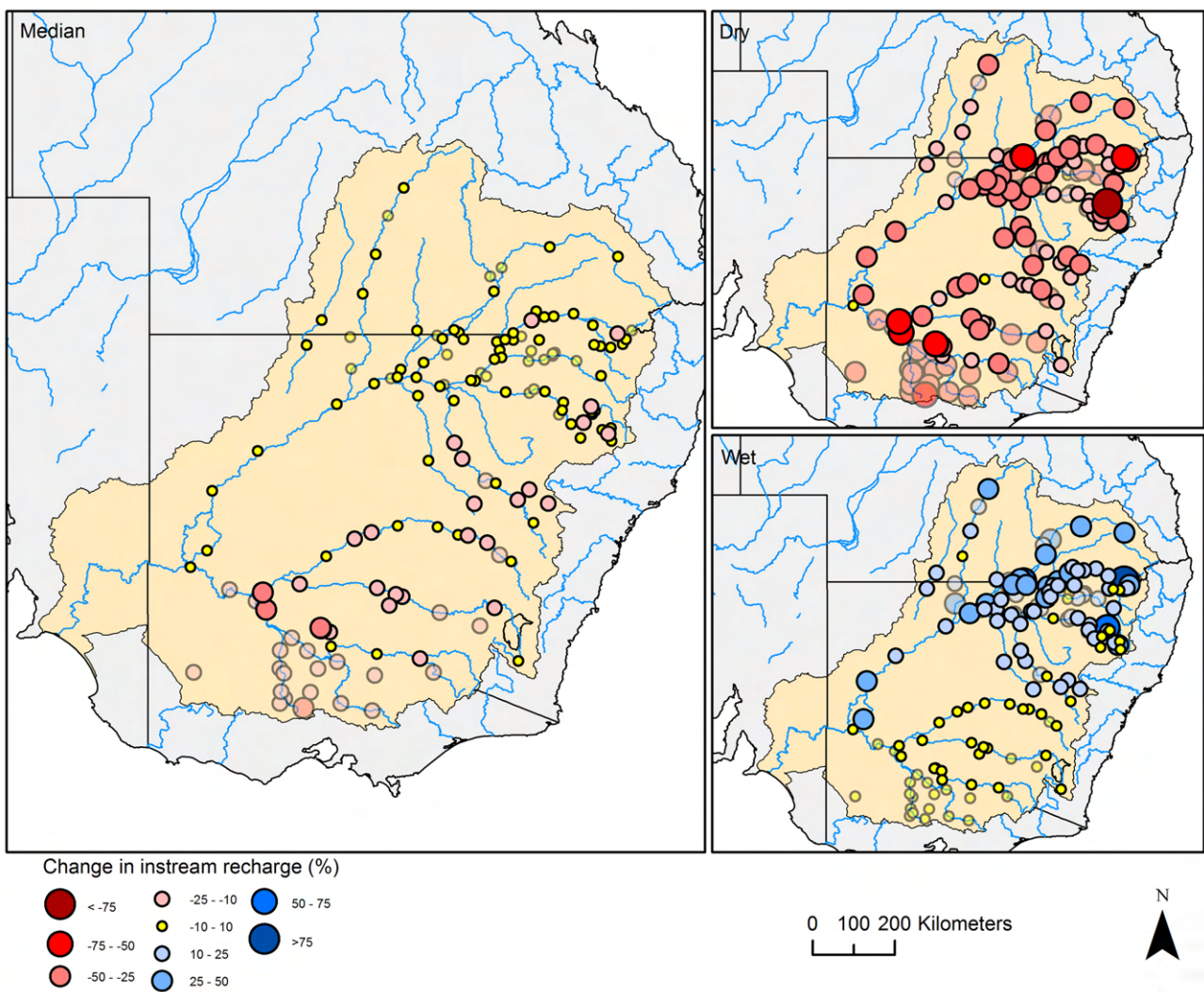


Figure 10 Change in in-stream recharge for +1.5°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.

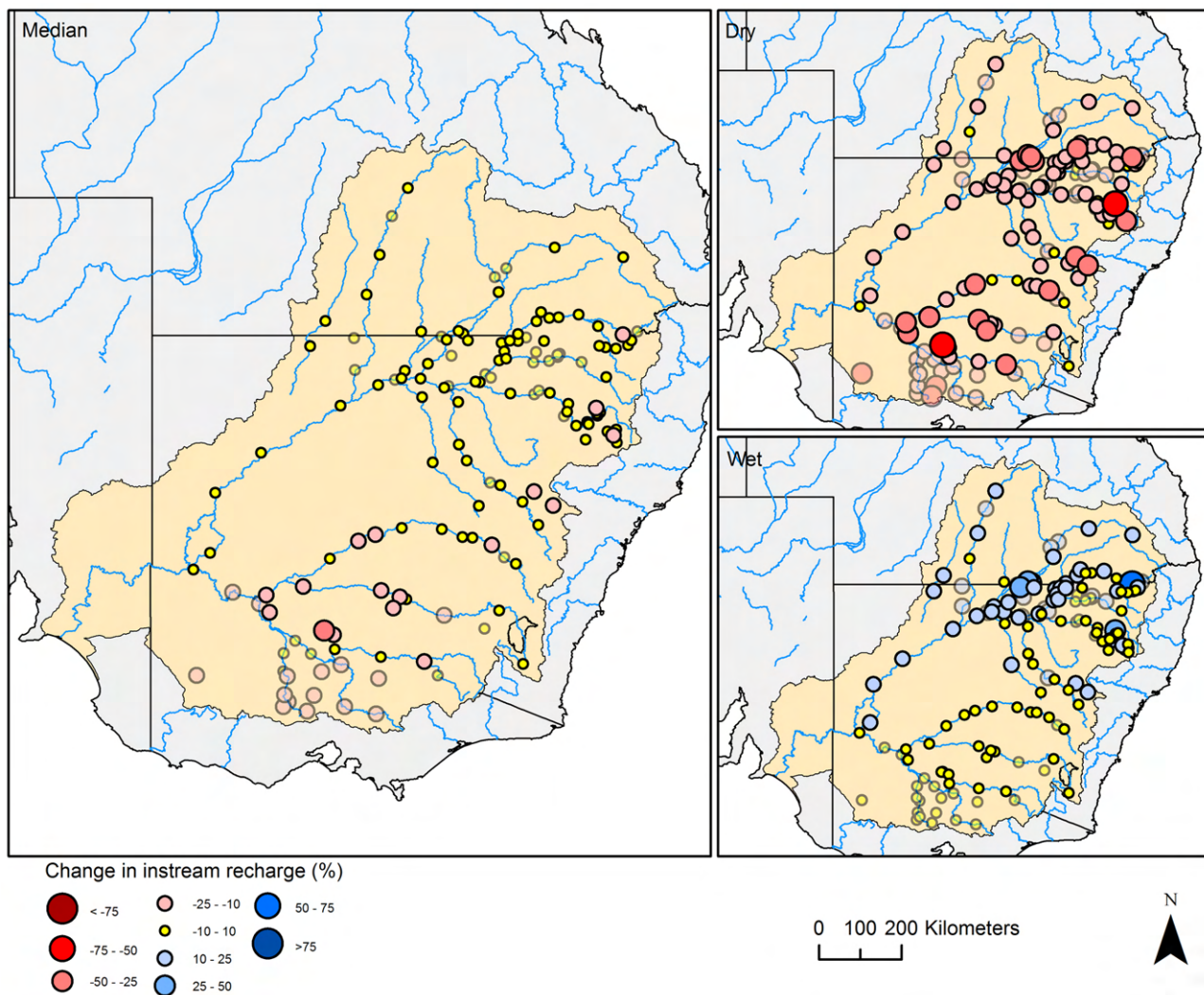


Figure 11 Change in in-stream recharge for +1.0°C at the gauge scale. Solid colours are calculated from the river mode outputs, semi-transparent colours are upscaled based on the change in flow.

3.2.2 Results at SDL resource unit scale

The point scale estimates of the change in in-stream recharge have been aggregated from the gauge to the SDL resource unit scale and the results shown in Table 4 for the +1.5°C scenario and Table 5 for the +1.0°C scenario. There are five SDL resource units where the surface water – groundwater interactions have been assessed as either gaining or variable-connected (Crosbie et al. 2025), these SDL resource units do not have a change in in-stream value calculated as it would be meaningless due to the groundwater discharging to the river rather than the river recharging the groundwater. Of the 37 alluvial SDL resource units, 21 have been assessed as losing-disconnected and meet the assumptions of the method. The remaining 11 SDL resource units have been assessed as losing-connected and rely on an assumption that the groundwater level will remain the same under the future climate, this is unlikely and so these SDL resource units have their results greyed out in the tables as having reduced confidence in the results.

For the median scenario all SDL resource units show a reduction in in-stream recharge. The Billabong Creek Alluvium has the greatest change in in-stream recharge of -23% for the +1.5°C

scenario and -16% for the +1.0°C scenario whereas the Warrego Alluvium has the least change at -2% for the +1.5° scenario and -1% for the +1.0° scenario.

Table 4 Change in in-stream recharge for +1.5°C by alluvial SDL resource unit (Figure 2). SDL resource units with reduced confidence have their results greyed out.

JURISDICT	SDL NAME	Dry (%)	Med (%)	Wet (%)
NSW	Bell Valley Alluvium (GS11)*	-23.7	-10.0	11.8
NSW	Belubula Alluvium (GS12)*	-39.5	-21.1	1.8
NSW	Billabong Creek Alluvium (GS13) *	-40.2	-23.2	3.6
NSW	Castlereagh Alluvium (GS14)*	-13.2	-5.1	5.8
NSW	Coolaburragundy-Talbragar Alluvium (GS15) *	-37.0	-15.8	20.9
NSW	Cudgegong Alluvium (GS16)*	-44.7	-18.2	23.6
NSW	Lake George Alluvium (GS21) *	-21.5	-11.0	0.5
NSW	Lower Darling Alluvium (GS23)		gaining	
NSW	Lower Gwydir Alluvium (GS24)	-22.6	-6.4	15.2
NSW	Lower Lachlan Alluvium (GS25)	-32.3	-16.3	1.2
NSW	Lower Macquarie Alluvium (GS26)	-31.5	-12.5	15.0
NSW	Lower Murray Shallow Alluvium (GS27a)	-40.2	-21.2	4.6
NSW	Lower Murrumbidgee Shallow Alluvium (GS28a)	-33.6	-20.2	-2.6
NSW	Lower Namoi Alluvium (GS29)	-23.0	-7.6	15.0
NSW	Manilla Alluvium (GS30)		variable - connected	
NSW	Mid-Murrumbidgee Alluvium (GS31)	-25.5	-15.6	-2.5
NSW	NSW Border Rivers Alluvium (GS32)	-38.9	-11.9	49.5
NSW	NSW Border Rivers Tributary Alluvium (GS33)	-21.4	-6.1	13.4
NSW	Peel Valley Alluvium (GS40)	-29.0	-10.5	18.8
NSW	Upper Darling Alluvium (GS42)	-25.5	-5.5	21.8
NSW	Upper Gwydir Alluvium (GS43)	-25.9	-7.9	18.6
NSW	Upper Lachlan Alluvium (GS44)	-21.9	-10.9	1.3
NSW	Upper Macquarie Alluvium (GS45)	-18.3	-7.3	8.9
NSW	Upper Murray Alluvium (GS46)		variable - connected	
NSW	Upper Namoi Alluvium (GS47)	-15.9	-6.0	11.4
NSW	Upper Namoi Tributary Alluvium (GS48) *	-31.5	-10.6	20.5
QLD	Queensland Border Rivers Alluvium (GS54)	-38.9	-11.9	49.5
QLD	St George Alluvium: Condamine-Balonne (shallow) (GS61a)	-35.8	-4.2	38.1
QLD	St George Alluvium: Moonie (GS62) *	-31.4	-4.2	34.6
QLD	St George Alluvium: Warrego-Paroo-Nebine (GS63) *	-36.3	-5.5	35.7
QLD	Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a)	-31.2	-5.9	30.8
QLD	Upper Condamine Alluvium (Tributaries) (GS64b)	-32.3	-4.4	31.5
QLD	Warrego Alluvium (GS66)	-20.0	-2.0	20.7
SA	Angas Bremer (Quaternary Sediments) (GS1a) *	-41.2	-21.6	1.4
SA	SA Murray Salt Interception Schemes (GS7)		gaining	
VIC	Goulburn-Murray: Shepparton Irrigation Region (GS8a)	-29.3	-15.3	1.4

VIC	Goulburn-Murray: Sedimentary Plain (GS8c)	variable - connected		
------------	---	----------------------	--	--

* SDL resource units that had no calculated change in in-stream recharge estimates, they have been estimated from the nearest gauge.

Table 5 Change in in-stream recharge for +1.0°C by alluvial SDL resource unit (Figure 2). SDL resource units with reduced confidence have their results greyed out.

JURISDICT	SDL NAME	Dry (%)	Med (%)	Wet (%)
NSW	Bell Valley Alluvium (GS11)*	-15.9	-6.7	8.1
NSW	Belubula Alluvium (GS12)*	-27.5	-13.6	1.2
NSW	Billabong Creek Alluvium (GS13) *	-30.6	-15.9	3.5
NSW	Castlereagh Alluvium (GS14)*	-8.5	-3.3	4.0
NSW	Coolaburragundy-Talbragar Alluvium (GS15) *	-25.6	-10.8	13.8
NSW	Cudgegong Alluvium (GS16)*	-30.8	-12.2	15.4
NSW	Lake George Alluvium (GS21) *	-14.3	-7.6	0.1
NSW	Lower Darling Alluvium (GS23)		gaining	
NSW	Lower Gwydir Alluvium (GS24)	-14.8	-4.3	10.2
NSW	Lower Lachlan Alluvium (GS25)	-21.5	-11.0	0.9
NSW	Lower Macquarie Alluvium (GS26)	-20.4	-8.3	10.0
NSW	Lower Murray Shallow Alluvium (GS27a)	-28.7	-14.7	4.0
NSW	Lower Murrumbidgee Shallow Alluvium (GS28a)	-24.5	-13.4	-3.7
NSW	Lower Namoi Alluvium (GS29)	-15.4	-5.1	10.0
NSW	Manilla Alluvium (GS30)	variable - connected		
NSW	Mid-Murrumbidgee Alluvium (GS31)	-18.6	-10.4	-4.0
NSW	NSW Border Rivers Alluvium (GS32)	-28.4	-9.9	33.6
NSW	NSW Border Rivers Tributary Alluvium (GS33)	-14.0	-4.0	9.1
NSW	Peel Valley Alluvium (GS40)	-19.6	-7.2	12.4
NSW	Upper Darling Alluvium (GS42)	-17.0	-3.7	14.5
NSW	Upper Gwydir Alluvium (GS43)	-17.3	-5.3	12.4
NSW	Upper Lachlan Alluvium (GS44)	-14.5	-7.1	0.9
NSW	Upper Macquarie Alluvium (GS45)	-12.0	-4.8	6.0
NSW	Upper Murray Alluvium (GS46)	variable - connected		
NSW	Upper Namoi Alluvium (GS47)	-10.8	-4.1	7.3
NSW	Upper Namoi Tributary Alluvium (GS48) *	-20.7	-7.3	13.4
QLD	Queensland Border Rivers Alluvium (GS54)	-28.4	-9.9	33.6
QLD	St George Alluvium: Condamine-Balonne (shallow) (GS61a)	-25.2	-2.8	25.0
QLD	St George Alluvium: Moonie (GS62) *	-21.4	-3.1	22.7
QLD	St George Alluvium: Warrego-Paroo-Nebine (GS63) *	-24.3	-3.7	23.8
QLD	Upper Condamine Alluvium (Central Condamine Alluvium) (GS64a)	-21.5	-3.9	20.5
QLD	Upper Condamine Alluvium (Tributaries) (GS64b)	-22.4	-3.4	21.3
QLD	Warrego Alluvium (GS66)	-13.5	-1.3	13.9
SA	Angas Bremer (Quaternary Sediments) (GS1a) *	-28.0	-14.7	0.9
SA	SA Murray Salt Interception Schemes (GS7)	gaining		
VIC	Goulburn-Murray: Shepparton Irrigation Region (GS8a)	-20.3	-10.1	1.3
VIC	Goulburn-Murray: Sedimentary Plain (GS8c)	variable - connected		

* SDL resource units that had no calculated change in in-stream recharge estimates, they have been estimated from the nearest gauge.

4 Discussion

4.1 Comparison to previous work

4.1.1 Change in overbank flood recharge under a future climate

The only comparable work prior to this study that has been conducted on the change in overbank flood recharge is from NSW using a single dry scenario (Crosbie et al. 2023). This study compared a 2060-2079 future dry climate to a baseline 1990-2009 climate and had similar results to those shown here for the dry scenario. The previous study also had much greater reductions in the southern Basin of 50 to 90% than the northern Basin with 25 to 50%. The NSW study did not have a median or wet future so these cannot be compared.

Initially in the project, Crosbie et al. (2025) used the Outlook river modelling as the input to estimate the change in overbank flood recharge, this has been updated here to use the river modelling from module 2. A comparison at the SDL resource unit scale is shown in Figure 12. This shows that overall the results are very similar, as shown by the regression line through the points being very close to the 1:1 line. However, there is a bit of scatter around the line indicating that there are differences at the SDL unit scale but there is no systematic bias between the two river model output sources used to estimate the change in overbank flood recharge.

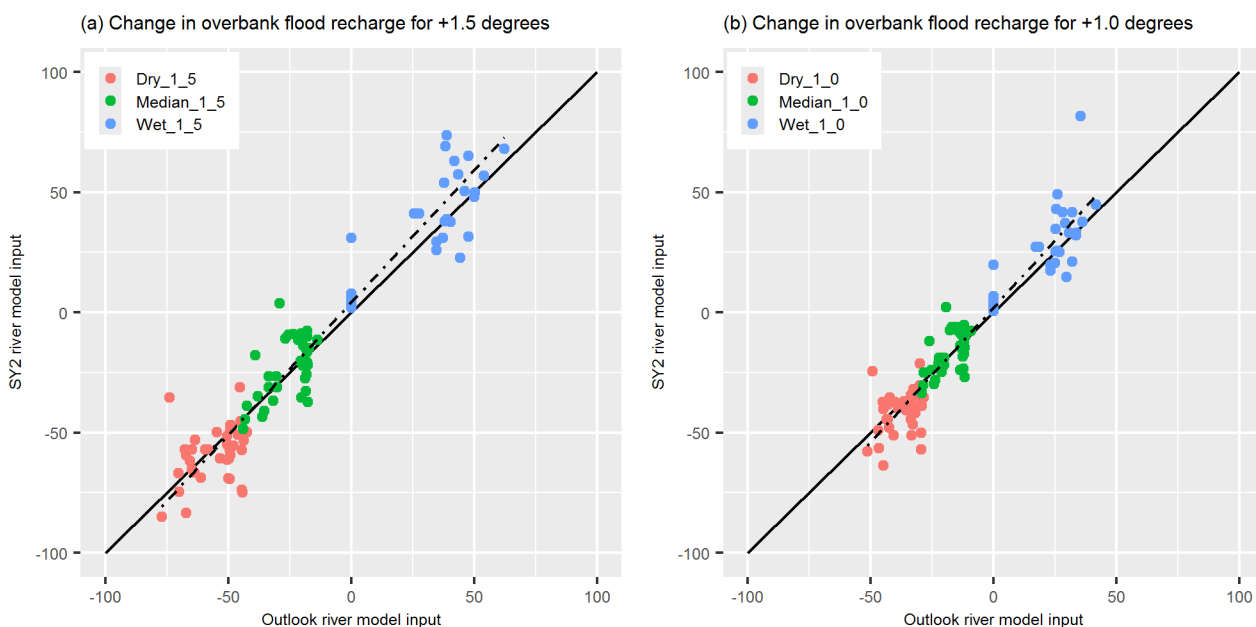


Figure 12 Comparison at the SDL resource unit scale between the change in overbank flood recharge derived from the Outlook river modelling and the SY2 river modelling.

4.1.2 Change in in-stream recharge under a future climate

The only comparable work that has been conducted prior to this study on the change in in-stream recharge is from NSW using a single dry scenario (Crosbie et al. 2023). This study compared a 2060-2079 future dry climate to a baseline 1990-2009 climate and had similar results to those shown here for the dry scenario. The previous study also had a greater reduction in in-stream recharge than the dry scenario in the current study, this is not unexpected as it is the driest GCM rather than the 90th percentile and is projected further into the future. The NSW study did not have a median or wet future so these cannot be compared.

Initially in the project, Crosbie et al. (2025) used the Outlook river modelling as the input to estimate the change in instream recharge, this has been updated to use the river modelling from module 2. A comparison at the SDL resource unit scale is shown in Figure 12. This shows that overall the results are very similar, as shown by the regression line through the points being very close to the 1:1 line. However, there is a bit of scatter around the line indicating that there are differences at the SDL unit scale but there is no systematic bias between the two river model output sources used to estimate the change in instream recharge.

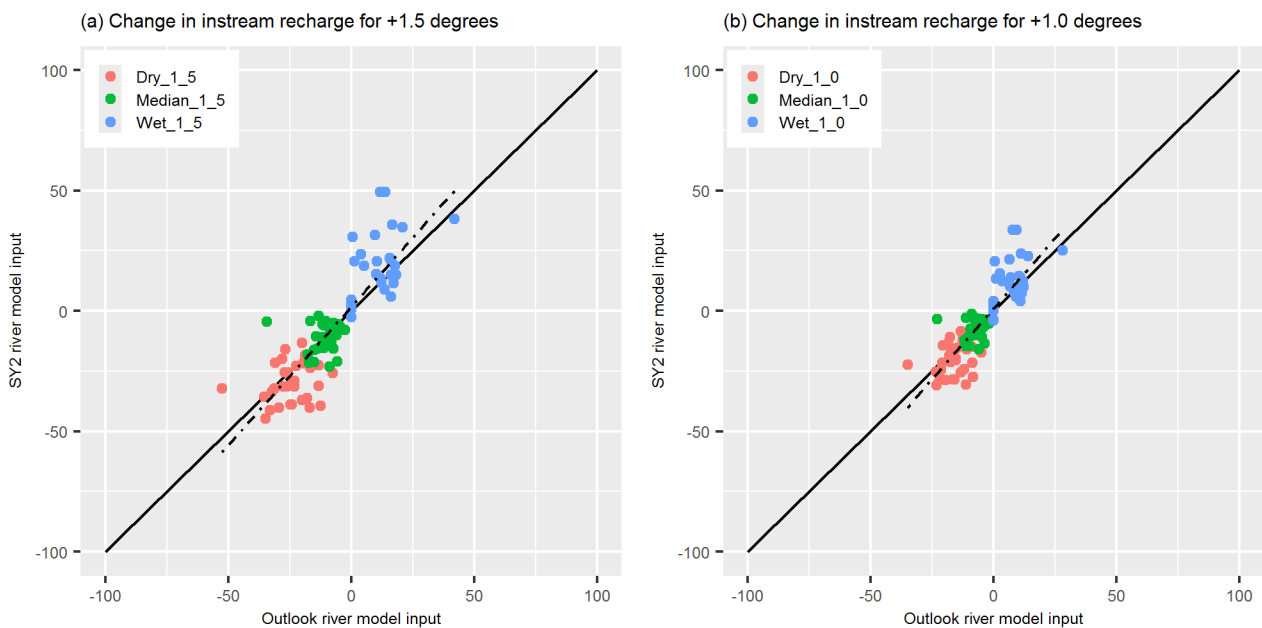


Figure 13 Comparison at the SDL resource unit scale between the change in instream recharge derived from the Outlook river modelling and the SY2 river modelling.

4.2 Limitations

4.2.1 Change in overbank flood recharge under a future climate

The change in the overbank flood recharge estimates presented here are dependent on the outputs of the river modelling. These river model outputs have not been assessed here for their suitability for estimating the change in overbank flood recharge.

The change in overbank flood recharge calculations are at a point scale at the gauge, and then assumed to be representative of that river reach. We know that the flood response can be different when different areas are inundated but that is not incorporated here. This variation in response is very important for estimating the magnitude of the overbank flood recharge but it is assumed that it becomes less important for estimating the change in overbank flood recharge at the SDL resource unit scale (Equation 7).

To incorporate the change in overbank flood recharge into a numerical groundwater model would require the spatial distribution of the flood extent and depth. This is available for the historical climate from the remote sensing observations (Teng et al. 2022; Ticehurst et al. 2022) but not the future climate yet (although is an area of current research).

4.2.2 Change in in-stream recharge under a future climate

The change in the in-stream recharge estimates presented here are dependent on the outputs of the river modelling. These river model outputs have not been assessed here for their suitability for estimating the change in in-stream recharge.

The change in in-stream recharge is calculated at a point scale from the gauges and then assumed that this series of points is representative at the SDL resource unit scale. We know that there is heterogeneity within the bed and banks of streams, but this is cancelled out within the calculations as hydraulic properties are not featured within Equation 12. The magnitude of the (unknown) in-stream recharge will change along the stream reach but the change in in-stream recharge as a percentage is fairly consistent, this can be seen in the similarity in the results for adjacent gauges. For SDL resource units that are mostly losing-disconnected the assumptions used here seem robust.

For losing-connected streams the assumption had to be made that the water table was at the base of the stream bed and that it did not change between the historical and future climate scenarios. If the water table is above the stream bed (but below the stream stage i.e. losing conditions) then the change in in-stream recharge will be underestimated here and conversely if the water table is below the stream stage the change in in-stream recharge will be overestimated. The implication of this assumption is relatively minor compared to the assumption that the groundwater level does not change. Crosbie et al. (2023) investigated this assumption for two gauges in the Namoi and Murrumbidgee catchments. They found that with a 0.1 m reduction in the regional groundwater level, with a reduction in river flow under a dry future climate, that there was still a reduction in recharge under the future climate, but the magnitude of the reduction was much reduced. The reduction in groundwater level increased the hydraulic gradient between the surface water and groundwater and therefore increased the potential for recharge. It was further found that a

reduction in the regional groundwater level of 0.5 m was enough to cause an increase in the in-stream recharge for the future climate compared to the historical climate for a dry scenario with reduced stream flow.

For a losing-connected stream reach, the estimated change in in-stream recharge is unreliable and should be considered in light of the assumptions that were made in making the estimates. It is conceivable that the reductions in in-stream recharge calculated here for the dry and median scenarios would actually be increases in recharge if the regional water table were to fall under those future climates.

The change in in-stream recharge for losing-connected stream reaches would be more robustly estimated using a numerical groundwater model that has a river boundary condition that can adjust the conductance and stream stage based on the projected flow in the river.

5 Summary and conclusions

This report is part of Module 3 of the Sustainable Yields project, providing an update to the change in overbank flood and in-stream recharge based on the river systems modelling from Module 2. The diffuse recharge under historical and future climates along with the baseline overbank flood and in-stream recharge is reported in Crosbie et al. (2025). This summary considers the change in diffuse recharge and the baseline recharge from the previous report for completeness.

The historical diffuse recharge was estimated using the chloride mass balance method at ~10,000 points and upscaled to a regular grid across the Basin. The method used also accounted for the change in land use and subsequent increase in recharge after the native vegetation was cleared for agriculture. Across the Basin the mean diffuse recharge was estimated as 11.2 mm/yr with a very wide range from below 1 mm/yr to above 500 mm/yr. The uncertainty was accounted for as much as possible and the mean of the 5th and 95th percentiles were 8 and 16 mm/yr respectively.

The historic overbank flood recharge was estimated at a point scale using a modified water table fluctuation (WTF) method for the 2010/11 and 2022/23 floods. Overbank flood recharge with a median specific yield (0.1) ranged from 0 m to 1700 mm in 2010, and from 0 m to 2800 mm in 2020. Average overbank flood recharge was estimated to be 300 mm for both floods. With a higher specific yield of 0.3, average overbank flood recharge estimates increased to 900 mm for both 2010 and 2022 floods, and with a low specific yield of 0.03, average overbank flood recharge estimates were 100 mm for both 2010 and 2022 floods.

Due to unconstrained estimates of in-stream recharge being highly uncertain, this component of recharge was only assessed qualitatively. This was done assessing the difference in water levels between the streams and nearby bores. In this process there were 2 alluvial SDL resource units classed as gaining, 3 as variable-connected, 7 as losing-connected and 21 alluvial SDL resource units classed as losing-disconnected.

The total recharge could not be estimated as the in-stream recharge was not quantified and the recharge due to irrigation was not considered within this project.

Under the +1.5°C future climate scenario (2050), 76% of SDL resource units had an increase in diffuse recharge for the median case, one SDL resource unit had an increase in overbank flood recharge and none of the SDL resource units had an increase in in-stream recharge (Figure 14). Under the dry future case, all SDL resource units had a decrease in recharge for all three components of recharge. In contrast to the dry future case, in the wet future case, none of the SDL resource units had a decrease in recharge for diffuse or instream recharge and two SDL resource units had a decrease in overbank flood recharge.

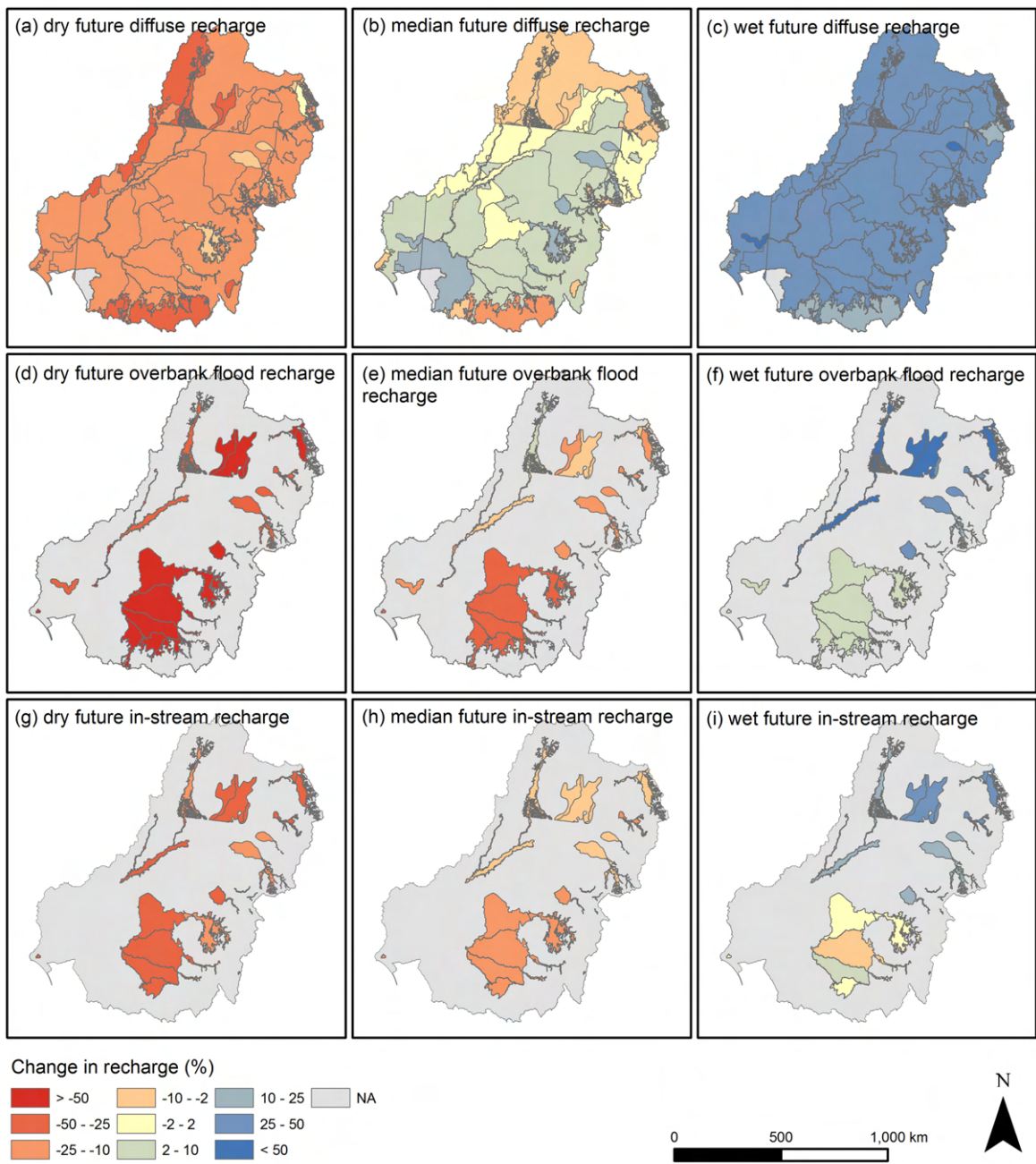


Figure 14 Summary at the SDL resource unit scale of the change in diffuse, overbank flood and in-stream recharge under a +1.5°C (2050) scenario.

Under the +1.0°C future climate scenario (2030), all except one SDL resource unit had an increase in diffuse recharge for the median case whereas none of the SDL resource units had an increase in in-stream recharge and only one SDL resource unit has an increase in overbank flood recharge (Figure 15). Under the dry future case, 57% of SDL resource units had an increase in diffuse recharge but none of the SDL resource units had an increase in overbank flood or in-stream recharge. For the wet future case none of the SDL resource units had a decrease in diffuse or overbank flood recharge and two SDL resource units had a decrease in in-stream recharge.

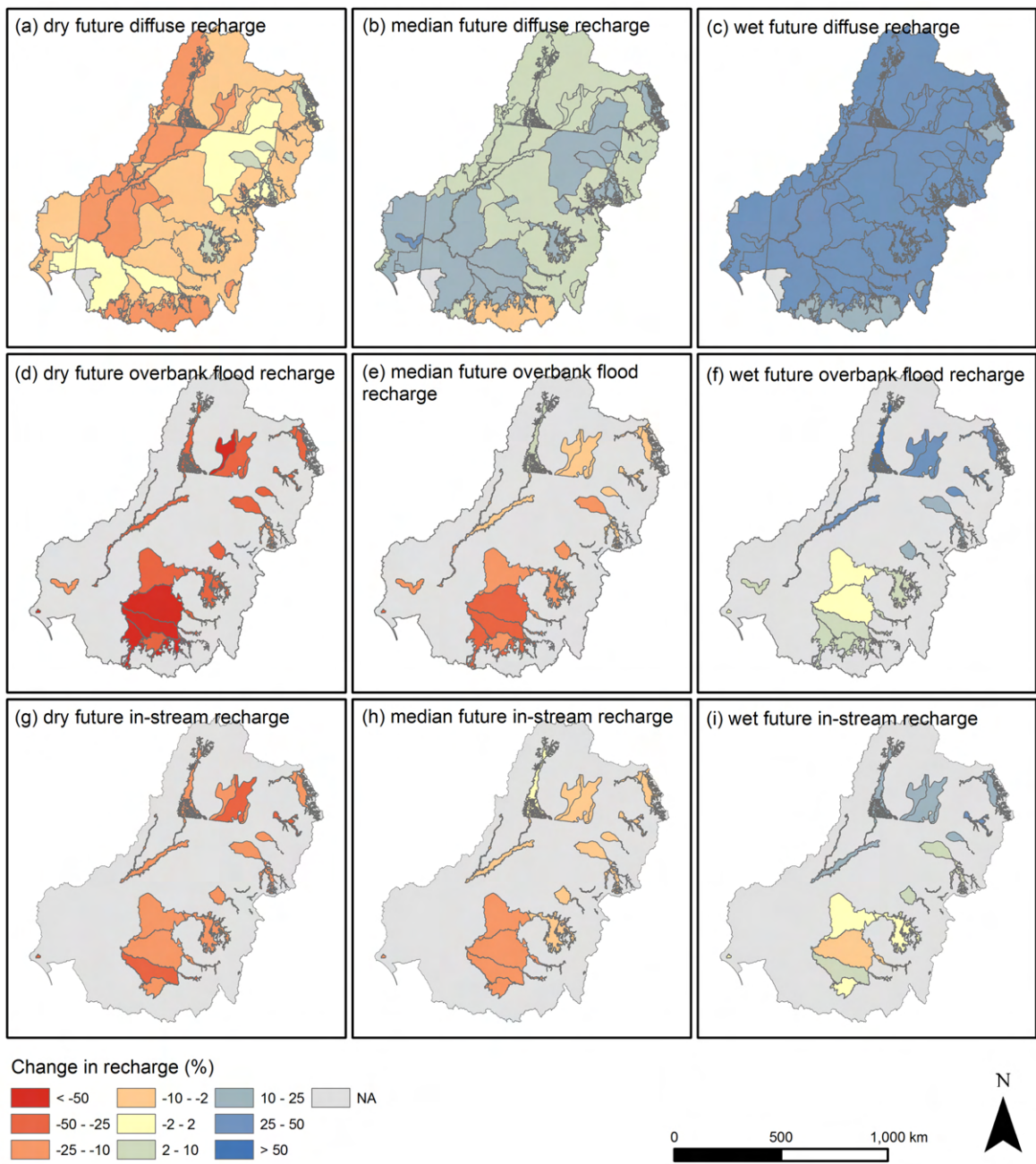


Figure 15 Summary at the SDL resource unit scale of the change in diffuse, overbank flood and in-stream recharge under a +1.0°C (2030) scenario.

The three components of recharge considered had differing responses to the future climate for both the +1.5°C and +1.0°C future climates relative to 1990. The change in overbank flood recharge generally had the greatest decrease in recharge for the dry and median cases but in the wet case had little change in the southern Basin. The change in in-stream recharge had very similar patterns to the overbank flood recharge but the changes were not as extreme, it had less of a decrease in the dry case and less of an increase in the wet case (particularly in the northern Basin). The change in diffuse recharge was different, with large areas of the Basin (or nearly all in the +1.0°C case) showing an increase in recharge for the median case.

These results provide a range of changes in recharge for different components for different periods into the future. To understand the impact of these changes in recharge upon the water resource requires that the dominant recharge mechanism be known. For example, an alluvial SDL resource unit might have a projected increase in diffuse recharge and decrease in overbank flood recharge for the median scenario. If the recharge volume is dominated by infrequent flood events, then that SDL resource unit is more likely to see a decrease in recharge in the future. In some SDL resource units, the estimated change in recharge is straightforward particularly non-alluvial SDL resource units that only have a diffuse source of recharge. In SDL resource units that have a combination of diffuse, overbank flood and in-stream recharge, the estimated change in total recharge is not simple and probably best assessed through a numerical groundwater model.

References

- BoM, 2013. Service Level Specification for Flood Forecasting and Warning Services for Victoria – Version 3.5. Bureau of Meteorology.
- BoM, 2024a. Service Level Specification for Flood Forecasting and Warning Services for New South Wales and the Australian Capital Territory – Version 3.15. Bureau of Meteorology.
- BoM, 2024b. Service Level Specification for Flood Forecasting and Warning Services for Queensland – Version 3.5. Bureau of Meteorology.
- BoM, 2024c. Service Level Specification for Flood Forecasting and Warning Services for South Australia – Version 3.5. Bureau of Meteorology.
- Brunner, P., P. G. Cook & C. T. Simmons, 2009. Hydrogeologic controls on disconnection between surface water and groundwater. *Water Resources Research* 45(1):W01422 doi:10.1029/2008wr006953.
- Chiew, F. H. S., A. Devanand, Z. Khan, H. Zheng, N. J. Potter, D. E. Robertson, M. R. Grose, D. A. Post & G. Fu, 2025. Hydroclimate Projections for the Murray-Darling Basin. CSIRO report from Module 1 of the MDBA Sustainable Yields Project, 117 pp.
- Crosbie, R., R. Doble, G. Fu, P. Campos Teixeira, T. Pickett, A. Devanand, C. Ticehurst, M. Gibbs, W. Gunner & D. Gonzalez, 2025. Groundwater recharge modelling of the Murray-Darling Basin under historical and future climate conditions. CSIRO report from Module 3a of the MDBA Sustainable Yields Project CSIRO, Australia.
<https://www.mdba.gov.au/sites/default/files/publications/SY-groundwater-recharge-modelling-of-the-Murray-Darling-Basin.pdf>.
- Crosbie, R. S., S. P. Charles, G. Fu, W. Dawes, R. Rojas, G. A. Hodgson, D. W. Rassam, K. Barry & T. Pickett, 2023. Impact of climate change on groundwater in NSW: Assessment of the sensitivity of recharge and groundwater resources to a projected drying climate CSIRO, Australia. .
- Crosbie, R. S., A. R. Taylor, A. C. Davis, S. Lamontagne & T. Munday, 2014. Evaluation of infiltration from losing-disconnected rivers using a geophysical characterisation of the riverbed and a simplified infiltration model. *Journal of Hydrology* 508:102-113 doi:http://dx.doi.org/10.1016/j.jhydrol.2013.07.045.
- Doble, R., R. Crosbie, L. Peeters, K. Joehnk & C. Ticehurst, 2014. Modelling overbank flood recharge at a continental scale. *Hydrol Earth Syst Sci* 18(4):1273-1288 doi:10.5194/hess-18-1273-2014.
- Doble, R. C., R. S. Crosbie, B. D. Smerdon, L. Peeters & F. J. Cook, 2012. Groundwater recharge from overbank floods. *Water Resources Research* 48(9):W09522 doi:10.1029/2011wr011441.
- Mueller, N., A. Lewis, D. Roberts, S. Ring, R. Melrose, J. Sixsmith, L. Lymburner, A. McIntyre, P. Tan, S. Curnow & A. Ip, 2016. Water observations from space: Mapping surface water from 25years of Landsat imagery across Australia. *Remote Sensing of Environment* 174:341-352 doi:https://doi.org/10.1016/j.rse.2015.11.003.
- Teng, J., D. Penton, C. Ticehurst, A. Sengupta, A. Freebairn, S. Marvanek, D. King & C. Pollino, 2022. Two-monthly Maximum Flood Water Depth Spatial Timeseries for the MDB. v20. CSIRO. Data Collection. .
- Teng, J., J. Vaze, S. Kim, D. Dutta, A. J. Jakeman & B. F. W. Croke, 2019. Enhancing the Capability of a Simple, Computationally Efficient, Conceptual Flood Inundation Model in Hydrologically

Complex Terrain. *Water Resources Management* 33(2):831-845 doi:10.1007/s11269-018-2146-7.

Ticehurst, C., J. Teng & A. Sengupta, 2022. Development of a Multi-Index Method Based on Landsat Reflectance Data to Map Open Water in a Complex Environment. *Remote Sensing* 14(5):1158.

**As Australia's national science
agency and innovation catalyst,
CSIRO is solving the greatest
challenges through innovative
science and technology.**

CSIRO. Unlocking a better future
for everyone.

Contact us

1300 363 400

+61 3 9545 2176

[csiro.au/contact](https://www.csiro.au/contact)

[csiro.au](https://www.csiro.au)