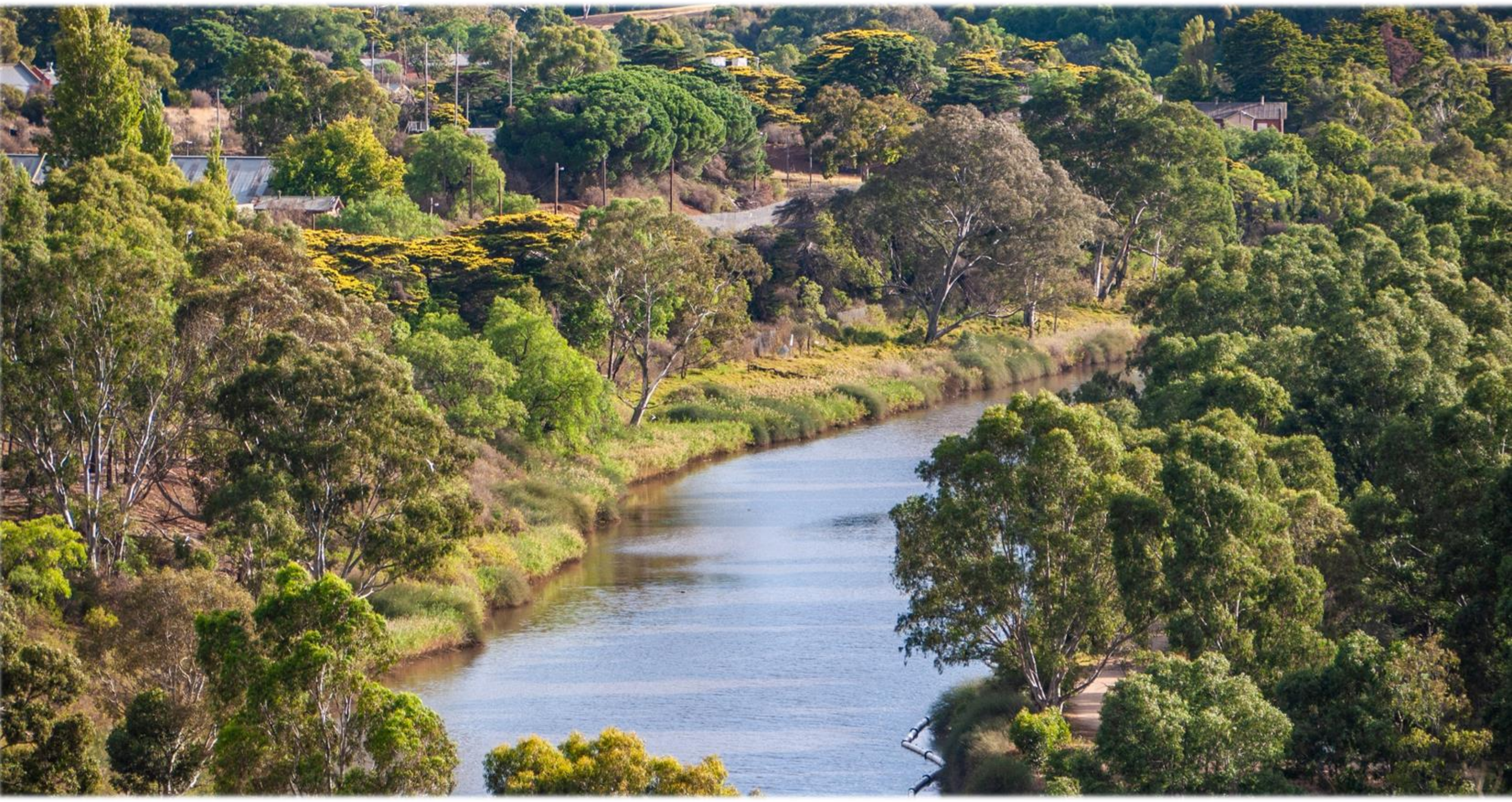

Water Resource Risks in the Maribyrnong and Moorabool Catchments

Overview of water resources modelling

Version 2

June 2025

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Contents

1. Introduction

This briefing paper has been prepared prior to a meeting with the Stakeholder Reference Group for the Water Resources Risks in the Maribyrnong and Moorabool Catchments project, which is scheduled for 20 June 2025.

The scope of the briefing paper and the scheduled meeting is:

- An overview of models used for water resources planning in the Maribyrnong and Moorabool basins (see Section 2)
- Modelling the impact of farm dams and other small water bodies (see Section 3)
- Climate change projections and scenarios (see Section 4) and
- Potential limitations and uncertainties in models (see Section 5)

2. Water resources planning and modelling overview

The study area for this project are the upper catchments of the Maribyrnong and Moorabool basins:

- Maribyrnong River catchment upstream of Keilor gauge (230200)
- Moorabool River catchment upstream of Batesford gauge (232202)

DEECA and Southern Rural Water review and update water resources plans for the basins and supply systems within their areas of responsibility. These plans are underpinned by water resources systems models. The models represent features such as catchment inflows, supply to licensed users, supply to meet environmental water needs, large dams and reservoirs and rules representing transfer of water to simulate a water resource system. Modelling in the Barwon-Moorabool and Maribyrnong systems is undertaken using the Source water resources modelling package, which is developed and supported by eWater. Source is the industry-standard software for modelling hydrology and water resources across Australia.

DEECA have developed water resources planning models, using the Source modelling package, for the Barwon-Moorabool and Maribyrnong basins. These models are used by DEECA, in consultation with stakeholders, to:

- Inform planning and development of water resources allocation policies
- Assess volumes, reliability and pattern of delivery of environmental flows
- Assess yields to bulk entitlement holders (such as Barwon Water and Melbourne Water) and the reliability of those yields
- Assess the impacts on water availability of larger scale Integrated Water Management projects in urban areas
- Assess the impacts of climate change and climate variability on these factors

A map of the subcatchments represented in the Maribyrnong Source model is shown in Figure 2-1. The Keilor streamflow gauge (230200) is at the downstream boundary of subcatchment F19, so subcatchment F20 is not included in the scope of the current project, even though it is within the extent of the water resources planning model (Source – see below) for the Maribyrnong system.

A map of the Moorabool portion of the Barwon-Moorabool Source model is shown in Figure 2-2. The Source model for the Barwon-Moorabool system includes catchments in the Barwon part of the system that outside of the Moorabool catchment, which are not shown on Figure 2-2. Within the Barwon part of the system, part of the model and inputs were developed as part of the Ballarat Source model (for Central Highlands Water, CHW), which are labelled site 1 to 19 and shown in orange on Figure 2-2. Inputs for some Moorabool subcatchments, labelled F12 to F20 and shown in blue on Figure 2-2, were developed as part of a separate project. Inflows for CHW sites 14 to 19 are included in the Barwon Moorabool Source model but are outside of the Moorabool basin. Similarly, subcatchment F12 for inflows to Stony Creek reservoir are also outside of the Moorabool basin.

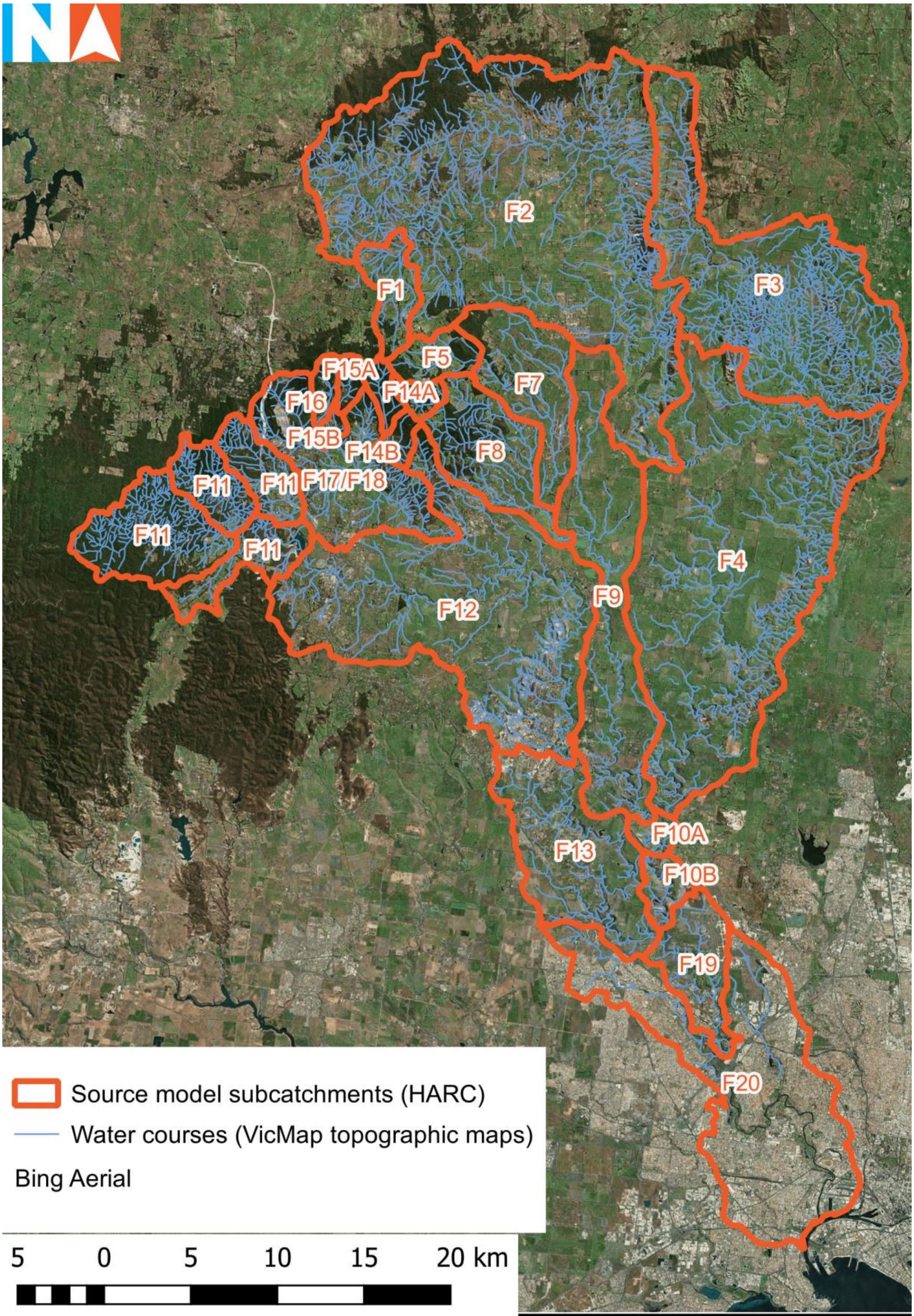

Figure 2-1 Maribyrnong subcatchment map

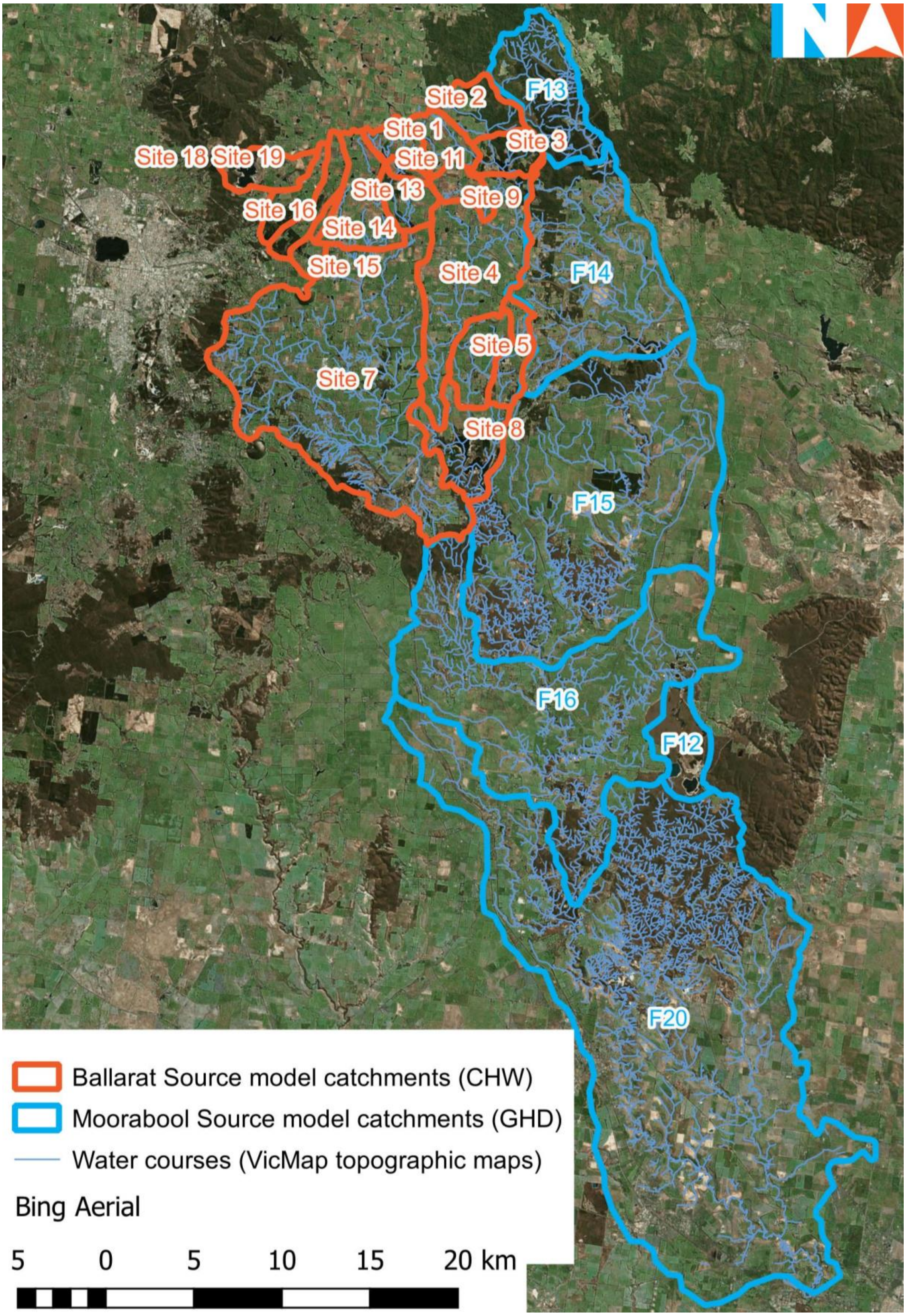

Figure 2-2 Moorabool subcatchment map

Figure 2-3 shows a schematic diagram of the Maribyrnong system Source model (DELWP and HARC, 2021; HARC, 2023a, 2023b). The level of detail represented within the model is demonstrated by the number of components of the model, such that it is difficult to read the details of any one component at this high level. A higher resolution version of the model schematic can be provided on request, to permit zooming-in on a particular part of the model. The different types of nodes within the Source model are provided in the legend of Figure 2-3. The dashed connector arrows represent flows of water within the system. The Maribyrnong Source model runs on a daily timestep, representing the status of the system for every day in the period between January 1900 and June 2021.

Figure 2-4 shows a schematic diagram of the Barwon-Moorabool system Source model (SKM, 2006; HARC, 2019, 2024; DELWP and GHD, 2022; Central Highlands Water and HARC, 2023). As with the diagram of the Maribyrnong Source model, a higher resolution version of the model schematic can be provided on request, to permit zooming-in on a particular part of the model. The Barwon-Moorabool Source model runs on a daily timestep, representing the status of the system for every day in the period between January 1889 and June 2021. The dashed line in Figure 2-4 surrounds the Moorabool section of the model, which is in focus for this project.

Further details on farm dam impact modelling using STEDI are discussed in Section 3.

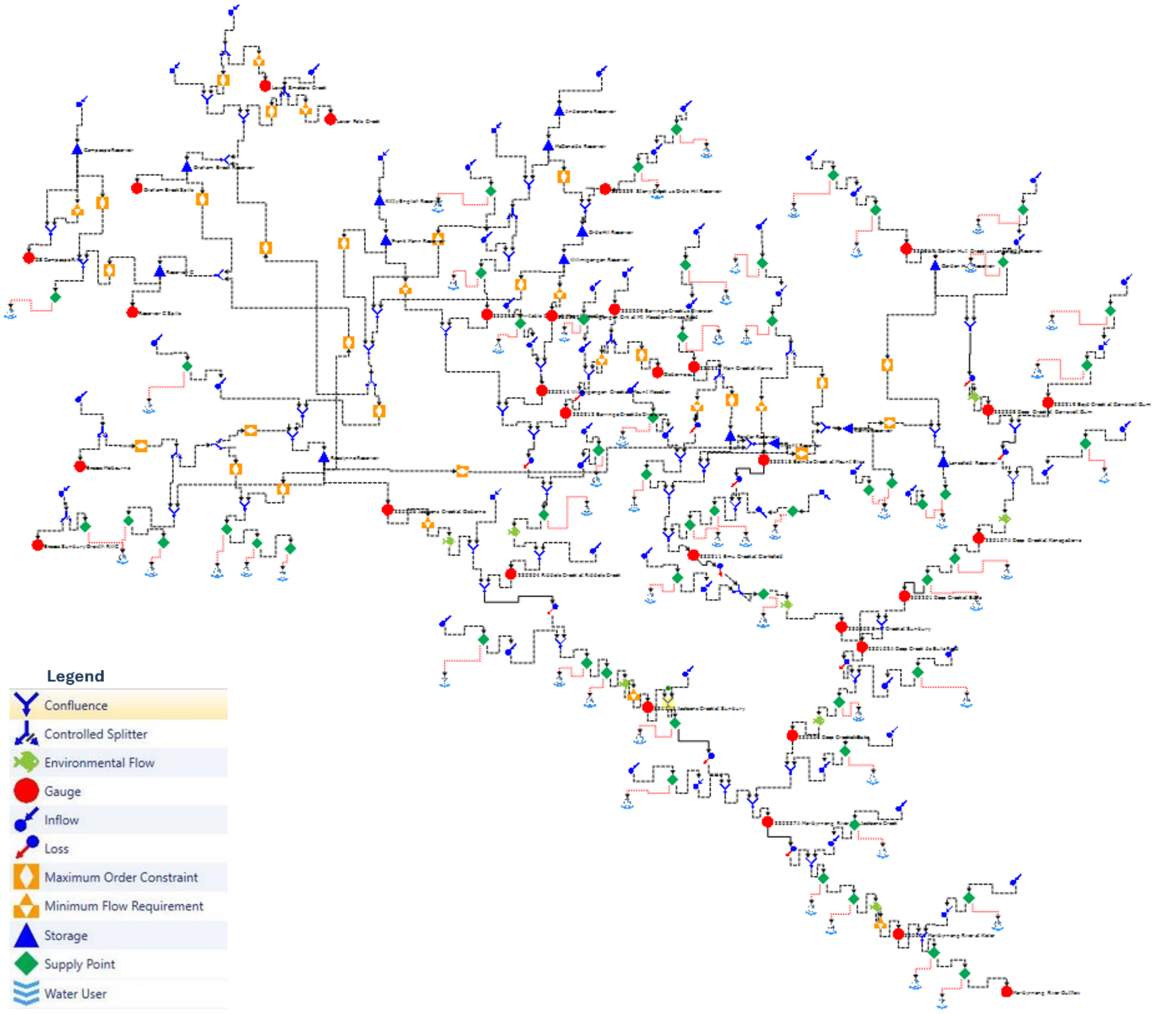

Figure 2-3 Schematic of Maribyrnong Source model

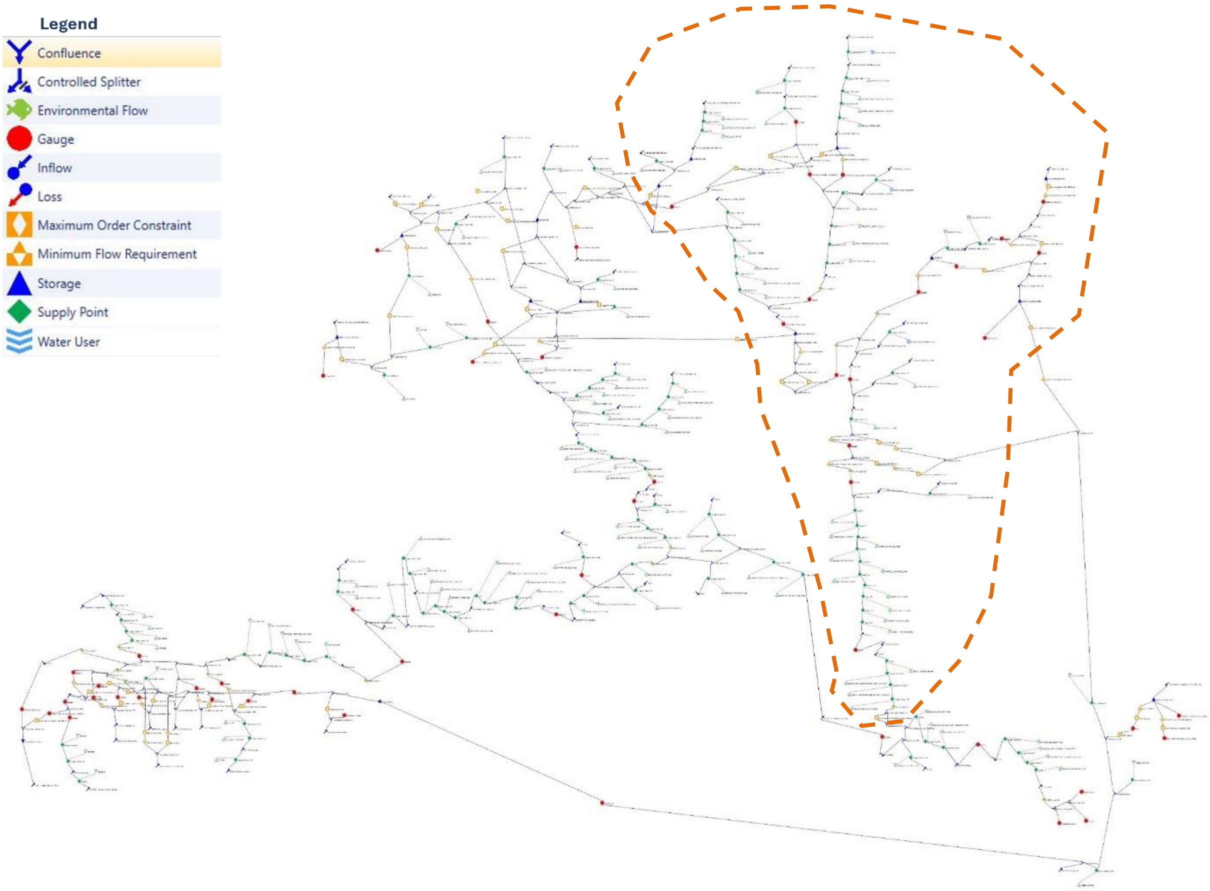

Figure 2-4 Schematic of Barwon-Moorabool Source model, with the Moorabool section enclosed within the dashed line

3. Modelling farm dams and other small water bodies

3.1 Modelling method in STEDI

The Source models for the Barwon-Moorabool and Maribyrnong systems incorporate, either explicitly or implicitly, water that is taken and used by licensed and domestic and stock (D&S) users in these systems. Water take from farm dams in each of the major subcatchments of these systems are explicitly modelled using the Spatial Tool for Estimation of Dam Impacts (STEDI) model.

STEDI is used to explicitly model farm dam impacts in 21 subcatchments of the Maribyrnong system and 17 subcatchments of the Moorabool system. STEDI is used to model current farm dam impacts, which are assumed to continue forward into the future. STEDI is also used to estimate the historical impact of farm dams, which has evolved over time, which are then added back to the streamflow time series that were recorded at flow gauges.

The conceptual structure of the STEDI model is shown in Figure 3-1. The water balance for each farm dam is characterised by inflows; net evaporation: the difference between evaporation from the dam surface area and rainfall directly falling on the dam; extractions from the dam to supply demands; seepage losses and spills. Spills from upstream dams may be intercepted by dams that are further downstream. Low-flow bypasses may be installed on some or all dams in a catchment, which will divert inflows up the flow capacity of the bypass around the dam, although low flow bypasses are currently relatively uncommon in the Maribyrnong and Moorabool catchments. Farm dams in a catchment have a cumulative impact, which affects the overall hydrograph of inflows at locations further down the catchment.

Inflows to runoff dams may be contributed by surface runoff from the upstream catchment area, capture of excess runoff from irrigated areas upstream of the dam, discharge from groundwater via springs, diversion from a nearby stream, pumping from groundwater and/or spills from upstream dams. Water that may otherwise have flowed into a farm dam may also be intercepted by features in the catchment upstream of the dam, such as natural lakes, depressions or wetlands. Gauging of inflows to individual runoff dams is rare and spatial and temporal variations in the above aspects contribute uncertainty to estimates of inflows to individual dams.

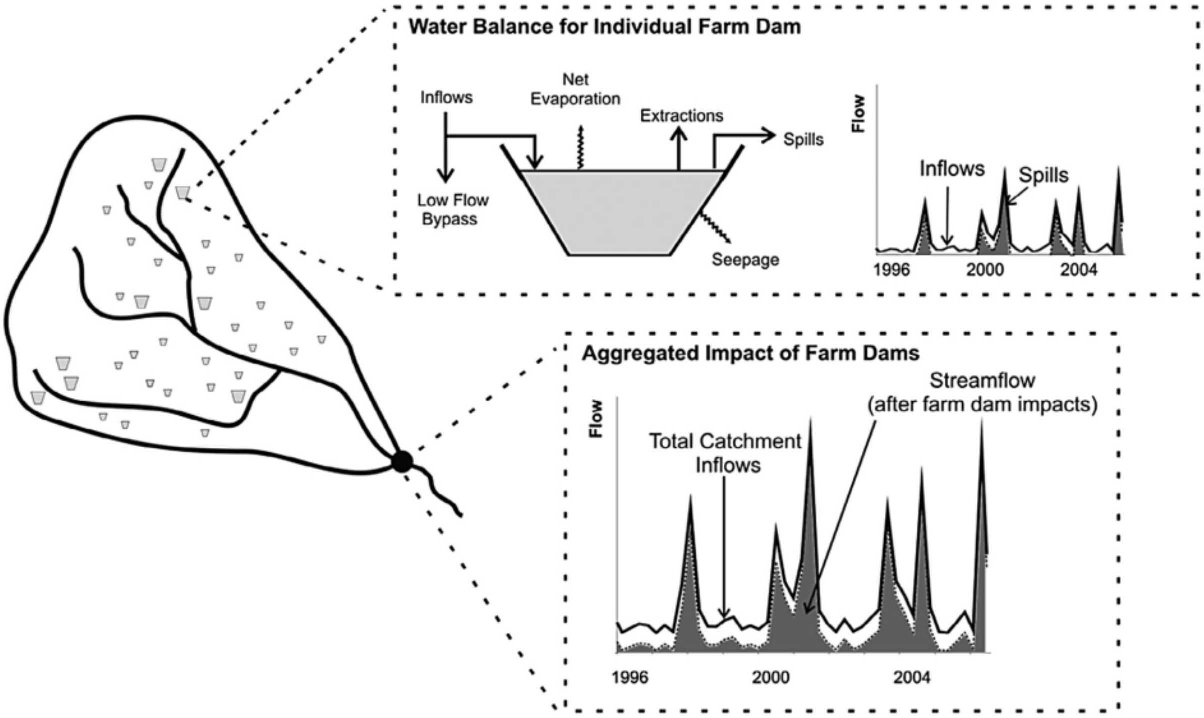

Figure 3-1 Conceptual representation of farm dam impacts in the STEDI model (from Fowler et al., 2016)

3.2 Improvement of previous STEDI models in the Maribyrnong and Moorabool basins

STEDI models apply data on the maximum surface area of water bodies in the catchment captured from aerial photography or satellite imagery, to estimate the maximum storage volume of each farm dam. There are uncertainties in estimating the volume of each water body and in being sure about which water bodies are farm dams and which are other water bodies, such as natural wetlands or wastewater treatment ponds. The STEDI models also make assumptions about the demand that is extracted from each farm dam for use in each year (normally as a function of each dam's estimated storage volume), the catchment area upstream of each farm dam (which influences the volume of inflow that each dam captures), rainfall on and evaporation from the surface area of each dam and the spatial connectivity of dam impacts in each subcatchment.

The existing Maribyrnong and Moorabool Source models available to inform this current stud include STEDI models to represent the small catchment dams in each subcatchment. That is, there are 21 existing STEDI models for catchments in the Maribyrnong system and 17 existing STEDI models for subcatchments in the Moorabool system. All of these models are "level 1" STEDI models, which make relatively simple assumptions about the spatial arrangement and catchment areas of each individual farm dams. These level 1 STEDI models currently make simplifying assumptions that ignore the spatial connectivity of farm dams in each subcatchment (i.e. ignoring the fact that dams are often in chains along a stream, where one farm dam may fill and then water spilling from that dam, along with local inflows, would be captured by dams that are further downstream along the chain) and that the local catchment area draining to each farm dam is a simple linear function of the storage volume of the dam (i.e. the upstream catchment area for each dam is not known; instead it is assumed that farm dams with larger volumes collect runoff from a larger upstream area). The level 1 STEDI models also assume that the mean annual usage from each D&S farm dam is 50% of the estimated dam storage volume and that mean annual usage from each irrigation farm dam is 84% of the estimated dam storage volume. The estimated storage volume of each farm dam is derived from the surface area of each dam (as collected from DELWP, 2012 spatial data layer) using a prediction equation (Fowler *et al.*, 2016).

Level 2 STEDI models are currently being set up for every subcatchment in the Maribyrnong and Moorabool basin. These level 2 STEDI models will explicitly represent the catchment draining to every water body in the catchment. The level 2 STEDI models may also allow for demand factors to be applied to a wider range of types of water bodies. Proposed demand factors by water body type are shown in Table 3-1. Note that all water bodies lose water via evaporation but gain water via direct rainfall on their surface. Once the STEDI models have been updated from level 1 to level 2 models, the daily time series of net demand and net inflow from the STEDI models will be updated in the Source models. This should improve the accuracy of estimation of inflows to each farm dam and the representation of connectivity between farm dams within each Source subcatchment.

Table 3-1 Proposed demand factors for water bodies in level 2 STEDI models

Water body type	Ratio of mean annual demand to storage volume
Licensed irrigation dams	0.84
Domestic and stock unlicensed dams	0.5
Quarry pits	0
Natural pools and wetlands	0
Aesthetic lakes	0
Wastewater treatment lagoons	0 (and no external catchment inflows or overflows)

3.3 Data on farm dams and water bodies

The key Victorian statewide data source is the *Farm Dams Boundaries* data set[1]. Although it is dated 2019, the mapping for the Maribyrnong and Moorabool catchments was completed using imagery captured in 2009 -2010. The attributes of the dataset were updated in 2018 to improve interpretation and usability. The data set includes licensed and unlicensed dams, mapped via manual interpretation with polygon boundaries to represent the extent of each dam when full. Attribution includes a flag for farm dams and runoff dams, date of source aerial imagery and licensing status, surface area and calculated volume (where the volume is estimated by applying the equation from Fowler et al., 2016).

To identify changes in farm dams (decommissioned & newly established) post-2009, Digital Earth Australia (DEA) Water Observation From Space (WOFS) data set was utilised. Dams that consistently lacked water in recent observations were flagged for potential removal. Additional water bodies appearing in the dataset after 2009 were identified, as these could be newly constructed water bodies or water bodies that were missed when the DELWP (2012) dataset was compiled. Each identified

[1] State Government of Victoria, Department of Energy, Environment and Climate Action. Farm Dam Boundaries

change was subjected to review through comparing historical and recent aerial imagery. The volume of these newly constructed dams was estimated using the same methodology as that used in the stakeholder provided datasets (Fowler *et al.*, 2016).

Based on the metadata, the WOFS data was collected on 31 December 2023 and published on 7 March 2024 Geoscience Australia DEA data hub. The currency of the satellite imagery from Google Earth covering the study area as:

- **Maribyrnong Catchment –** captured between September 2023 to February 2024.
- **Moorabool Catchment –** captured between January and February 2024.

Stakeholder provided farm dam information was incorporated into this study. Cross-checking with the recent satellite imagery was performed to confirm the existence and current status of the farm dams reported by stakeholders. Collectively, these additions significantly enhanced the comprehensiveness of this study, ensuring that developments after the publication of the DELWP (2012) dataset were accurately captured. The updated dataset provided a more precise foundation for analysing the impact of farm dams on water resources within the catchments.

4. Modelling scenarios

The Source and STEDI models in the Barwon-Moorabool and Maribyrnong systems have been calibrated to recorded streamflow and climate data over the full historical period of record.

In accordance with the *Guidelines for assessing the impact of climate change on water availability in Victoria* (Department of Environment Land Water and Planning, 2020), the representation of current conditions uses data on inflows and climate for the full historical period but with data recorded prior to 1975 adjusted to be statistically equivalent to data from the post-1975period.

The proposed scenarios are as follows:

- **2009 / 2010 level of development scenario (Baseline):** updating the farm dam impacts in the baseline scenario models with farm dam impacts derived using the upgraded Level 2 STEDI models and water body inputs from the DELWP (2012) data set.
- **Unimpacted by farm dams scenario:** current Source models (from Baseline scenario) but with all farm dam impacts set to zero.
- **2025 level of development scenario:** updating the farm dam impacts from the 2009/2010 level of development scenario with farm dam impacts derived from the Level 2 STEDI models with current (2025) spatial data on water bodies.
- **2025 level of development with projected climate change scenario:** as for the previous scenario (using current spatial data on water bodies) but with all climate and inflow data re-scaled to represent the 2065 RCP 4.5 Medium sensitivity climate change projections (see Table 4-1).

Table 4-1 Projected changes in mean annual rainfall and inflows for 2065 Representative Concentration Pathway 4.5 W/m^2 (RCP 4.5) Medium climate change sensitivity scenario, relative to mid-point of post-1975 period (DELWP, 2020)

Projection	Maribyrnong mean annual rainfall	Moorabool mean annual rainfall	Maribyrnong mean annual streamflow	Moorabool mean annual streamflow
2065 RCP4.5Medium	-3.3%	-3.2%	-9.7%	-7.1%

All model scenarios will include the same assumptions for current large dams and water infrastructure, current licensed entitlements and demands and current operational and environmental flow rules.

The only differences between the first four scenarios will be in the impacts of farm dams on inflows for each subcatchment in the two systems.

5. Potential limitations of modelling

The following discussion provides an overview of the main limitations and sources of uncertainty in surface water interception models for farm dams.

Identification, location classification and extent of runoff dams – Modelling runoff dam impact requires an understanding of the number, location and extent (catchment area and surface area) of runoff dams. The spatial data analysis used for this purpose is influenced by the resolution and quality of the spatial imagery and data used, the period or periods for which data is available, the method of identification, the catchment conditions at the time of data acquisition, and the quality of any regulatory or other water body data available to support identification and classification.

Historical change in the number of dams – Modelling requires assumptions to be made about which of the dams were present over the period that was concurrent with modelled or gauged streamflow data for the catchment. There is often some uncertainty about the trajectory of runoff dam development over time, and this contributes uncertainty to how the model would scale impacts from historical periods, when there may have been fewer dams and with lower aggregate storage volume, to current and forecast future numbers and storage volumes of dams.

Runoff dam inflow – Uncertainties in spatial and temporal variations of inflow to runoff dams are influenced by catchment characteristics, including soils, vegetation cover, land use, agricultural practices, hydrogeology of underlying aquifers and stream networks. Uncertainty in the estimation of inflow has been reduced, at a catchment level, by calibrating a catchment model to gauged streamflows at several locations within the Maribyrnong and Moorabool catchments. However, a component of uncertainty will remain around the inflow to each dam, due to spatial and temporal variations in surface runoff and other inflows to each dam.

Spatial and temporal variation of rainfall and evapotranspiration within a catchment – Uncertainties in spatial and temporal variations of rainfall and evapotranspiration within a catchment contribute to uncertainties in spatial and temporal variations of inflow to runoff dams

Demands and usage – Demand and usage is not metered from D&S farm dams and from almost all other small water bodies in Victoria. The typical annual volume of usage and pattern of demand, across the year, is therefore estimated as a proportion of the estimated storage volume in the STEDI model. Demand is likely to vary significantly between dams and from year to year for each dam.

Storage volume – A contributor to uncertainty in the impact of runoff dams is the uncertainty in the volumetric storage capacity of each dam, as accurate survey data is rarely available for runoff dams and their storage volumes must therefore be estimated from their surface area.

Volume stored – Uncertainty in estimating the volume stored in each farm contributes to uncertainty in usage and net evaporation losses. It will also contribute to uncertainty in the estimation of inflow if the runoff dam storage volume is used as a predictor of the area of the upstream contributing catchment.

Net evaporation – Uncertainty in net evaporation from dams is typically viewed as a relatively small component of the overall uncertainty. This is because (a) direct rainfall on the surface area of the dams counterbalances much of the evaporation losses and (b) the total surface area of all runoff dams in a catchment is a small proportion of the overall catchment area.

Seepage losses – Seepage losses from runoff dams are difficult to estimate and often ignored in models of runoff dam impacts.

Groundwater flows / Ingress – While typically assumed to be negligible due to the use of clay, plastic or geo-textile liners, inflow from groundwater can impact the overall water balance of runoff dams, i.e., the volume stored and, therefore, influences the uncertainty outlined above.

Losses and hydrologic connection: seepage rates from dams and each dam's location in the landscape can contribute significantly, in some cases, to take by runoff dams. It is difficult to generalise dam characteristics across a region and levels of hydrologic connection to downstream waterways may vary significantly between dams in a catchment. . The modelling assumes that all of the modelled impact at each individual dam translates directly to an impact on flows in the waterway, but in many cases, particularly during dry times, the level of hydrologic connection will be significantly less than 100%.

Spatial resolution of flow regimes from Source models - Source models are focussed on assessing flow regimes and environmental water deliveries for the major streams in each system, which generally run from downstream of the major reservoirs. Spatial and temporal variations in water takes across the catchments may present different levels of risk to in-stream flows and environmental values in the tributary streams that are not explicitly represented in the Source models.

Climate change projections - There are large variations in projected mean annual rainfall and runoff between climate change projection scenarios. The low projection scenarios show projected increases in rainfall and runoff for the Maribyrnong and Moorabool basins, whilst the high projection scenarios project decreases in runoff of up to 45% to 55% by 2065 under the high climate change projection for RCP8.5. The proposed 2065 RCP 4.5 medium scenario allows provides for a reasonable assessment of the sensitivity of how the influence of farm dams might be modulated by projected climate change.

Changes in catchment response after the Millennium drought –. In some catchments, runoff decreased more than expected for the given amount of rainfall during and after the Millennium Drought, as shown in Figure 5-1. The reductions in runoff generation are widespread across central and Western Victoria and are observed in unimpacted catchments where flow conditions are not impacted by farm dam growth, changes in land use, extractions or other flow regulation. About one-third of the Victorian catchments studied are still in this drought-like state, including catchments in the upper Maribyrnong and other catchments in the vicinity of this study.

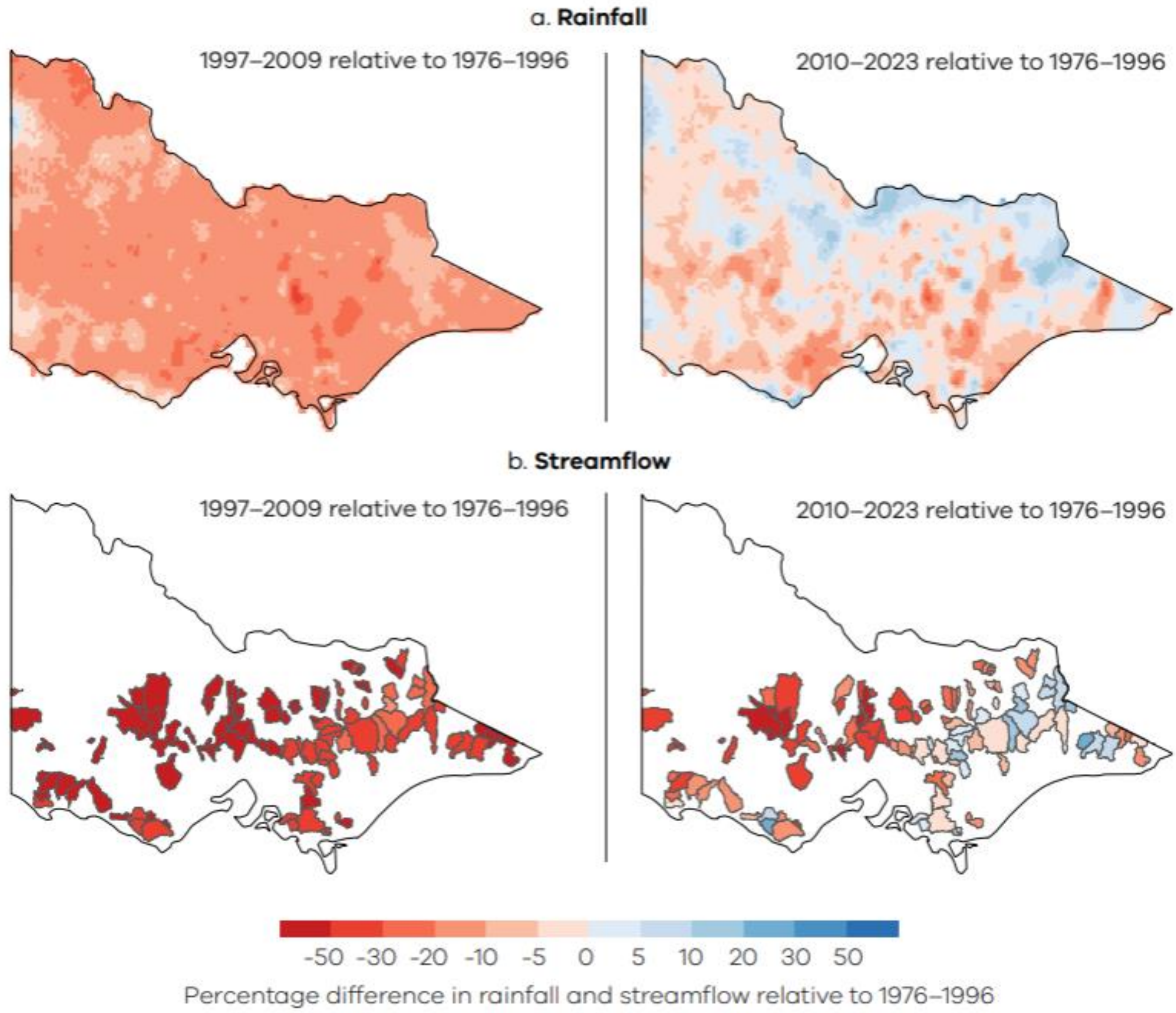

Figure 5-1 Percentage change in observed mean rainfall (a) and mean streamflow (b) in 1997–2009 during the Millennium Drought (left column) and in 2010–2023 after the drought (right column) relative to 1976–96 (pre-drought). Blue colours represent increased rainfall and streamflow, while red colours represent a reduction. (Source: CSIRO)

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