CASE STUDY FACT SHEET

ELECTRICITY SECTOR CLIMATE INFORMATION PROJECT

Streamflow variability and hydropower: application of hydrological projections in assessing hydropower generation output

Introduction

Changing hydrological cycles associated with climate change may have implications for the safe and efficient operation of Australia's electricity networks. These risks should be assessed, and strategies for mitigation and adaptation should be integrated within ongoing planning and operational decision-making frameworks.

This Electricity Sector Climate Information (ESCI) case study is designed to demonstrate the use of the ESCI Climate Risk Assessment Framework and the selection and application of appropriate climate information for long-term risk decision-making for the sector.

This case study and other case studies from the project can be found at: www.climatechangeinaustralia.gov.au/en/projects/esci/esci-case-studies

Overview

This case study uses the ESCI Climate Risk Assessment Framework (Figure 1) to consider long-term hydrological projections and the potential impacts on hydropower generation and system security.

Figure 1 ESCI Climate Risk Assessment Framework, based on International Standard ISO 31000 'Risk Management' and Australian Standard AS 5334 'Climate change adaptation for settlements and infrastructure'.

The Electricity Sector Climate Information (ESCI) project was funded by the Department of Industry, Science, Energy and Resources (DISER) and was a collaboration between the Bureau of Meteorology (BOM), the Commonwealth Scientific & Industrial Research Organisation (CSIRO) and the Australian Energy Market Operator (AEMO). The ESCI website is at: www.climatechangeinaustralia.gov.au/esci. The ESCI project acknowledges the help of the National Hydrological Projections project and Hydro Tas in preparing this case study.

Australian Government Department of Industry, Science, Energy and Resources
Australian Government Bureau of Meteorology
CSIRO
AEMO

Understand context

Hydropower comprises 5–7 per cent of Australia's total electricity supply and has traditionally been the largest source of renewable energy in Australia, accounting for around 26 per cent of the renewable energy generated in 2019.[1] Hydropower offers both dispatchable power generation and deep energy storage. Pumped hydro energy storage (PHES) delivers system benefits by time-shifting energy supply and demand to complement variable generation.

Australia has over 100 operating hydroelectric power stations with a total installed capacity of approximately 7800 megawatts (MW), with three major pumped hydro energy storage (PHES) generators connected to the national electricity market. Most of the plants in the country are in the south-east, with 55 per cent of Australia's hydroelectric power plants based in New South Wales (NSW) and 29 per cent spread through Tasmania (TAS).

Hydropower is reliant on water availability as the fuel source. Australia's rainfall is highly variable and is strongly influenced by climate drivers such as the strength of the sub-tropical ridge, El Niño, La Niña, the Indian Ocean Dipole, and the Southern Annular Mode.[2] Despite the significant inter-annual variability, underlying long-term rainfall trends are emerging in some regions, including declines in south-eastern Australian rainfall over recent decades.

Projections for rainfall, and confidence in these vary across Australia (CSIRO and BoM 2015). Furthermore, changes in rainfall patterns can be highly localised, requiring high-resolution hydrological projection data to assess risks to hydropower adequately.

Stakeholders and decision criteria:

Hydropower generators will be interested in accessing information regarding future streamflow for planning purposes as dams are used not just to generate power but for environmental flows as well. Potential investors in PHES will also be interested in the potential risk to investment from changing streamflow into dams. AEMO will also be interested in possible long-term changes to dam inflows because of the role of hydropower in providing a reliable electricity supply by supplementing variable renewable energy sources such as wind and solar power.

Identify historical climate risk

Analysis of streamflow across the Australian national network of hydrologic reference stations (HRSs)[3] since the 1950s reveals a distinct pattern of spatial and temporal variation in streamflow across different hydroclimatic regions in Australia (Zhang et al. 2016). For the observation period, most of the stations in south-eastern Australia show a significant decreasing trend in annual streamflow. For example, a significant decrease in streamflow has been observed for the period 1957–2019 at Suggan Buggan River, part of the Snowy River catchment in NSW (Figure 2). In contrast, increasing trends in streamflow have been observed within the northern part of the continent. No strong evidence of trends was observed for stations in the central region of Australia and northern Queensland (Zhang et al. 2016).

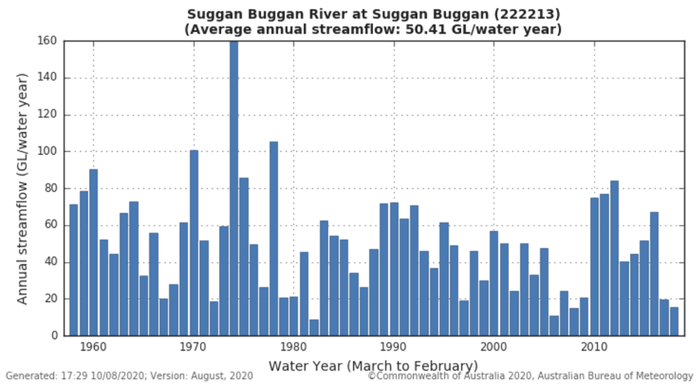


Figure 2 Annual streamflow (GL/water year) for Suggan Buggan from 1957–2019. (Source: http://www.bom.gov.au/water/hrs/#id=222213&panel=trend-explorer)

The diversity of trends across Australia is related to the wide variety of unique topographic features combined with variable climates and frequency in weather extremes result in diverse flow regime (Zhang et al. 2016). Streamflow into hydro dams is also highly variable in time with runoff at the Snowy River site shown over a period of two years in the late 1970s, exhibiting typical high inter-annual variability (Figure 3)

1 Clean Energy Council (2018). Hydro. https://www.cleanenergycouncil.org.au/resources/technologies/hydroelectricity.

2 See ESCI Glossary for definitions of terms.

3 Bureau of Meteorology (2020). Hydrologic Reference Stations. http://www.bom.gov.au/water/hrs/.

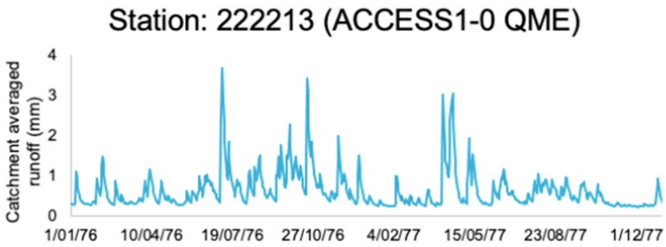


Figure 3 Example runoff time-series from station 222213 at Suggan Buggan River in the Snowy River Catchment (based on AWRA simulation using ACCESS1-0 and bias corrected using the QME bias correction method).

Analyse future climate risk

The projected changes to temperature, rainfall, soil moisture will add new dimensions to streamflow across the country with catchments assessed shown in Figure 4.

Historical analyses and future projections have been provided by the National Hydrological Projections project [4],[5]. Hydrological projections for root-zone soil moisture, runoff and potential evapotranspiration were developed to the year 2100 for two emission scenarios (RCP4.5 and RCP8.5), four global climate models and one downscaling method.

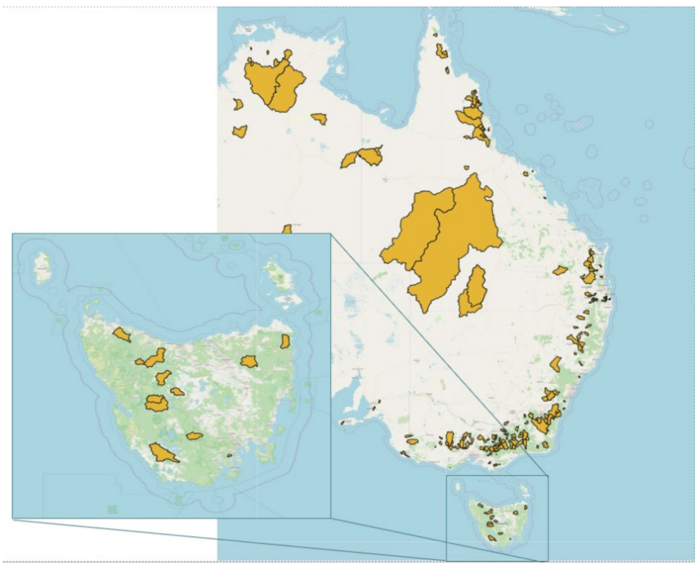


Figure 4 Catchment boundaries used to extract time-series from gridded runoff projections data. The ESCI website allows users to choose time-series for each of these catchments. (Source: National Hydrological Projections project)

Downscaled projection data at 5 km spatial resolution and daily temporal resolution were aggregated over four time slices:

- 2030 (2016–2045)
- 2050 (2036–2065)
- 2070 (2056–2085)
- 2085 (2070–2099).

Time-series of the weighted mean streamflow for each catchment Figure 4 were extracted from gridded runoff projections data (2006–2099).

Projections of streamflow for the catchments

In accordance with the observed trends, assessment of these catchments indicate that streamflow is expected to increase in many tropical catchments and decline in Australia's south-eastern catchments (despite the initial increase across parts of western VIC and eastern TAS) throughout this century, with median projected changes illustrated in Figure 5.

For more detailed catchment scale assessments, modelled historical and future time-series data are available (e.g. Figure 6). Importantly, the range of model results (dashed lines), as well as median change, are evident. In this example, runoff into the Wivenhoe catchment appears to have no increase or decreasing trend (on average), while the variability of runoff also appears to remain similar through the time-series. For the Derwent catchment, however, there appears to be a decrease in runoff (on average) through to the end of the century.

4 Although the 1986–2005 period is used for most parts of ESCI as the reference historical baseline (consistent with Climate Change in Australia), the Hydrological Project has uses 1976–2005 as a baseline for change calculations.

5 See ESCI Key Concept—National hydrological projections.

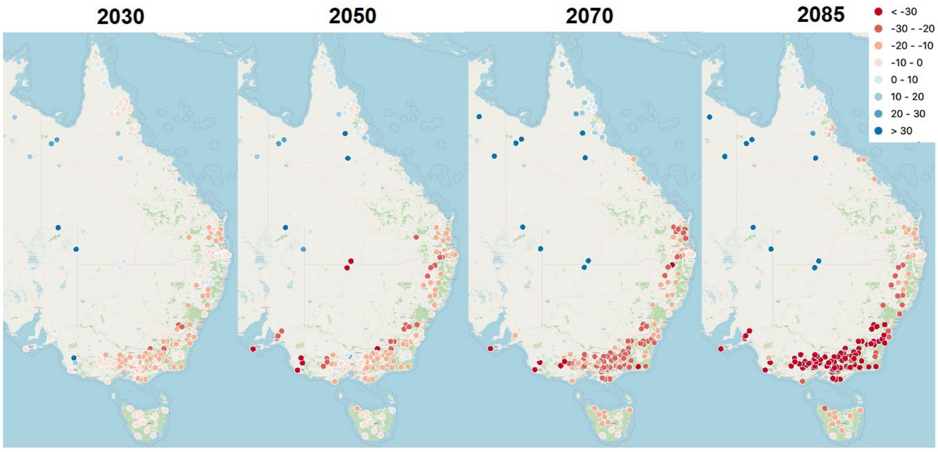
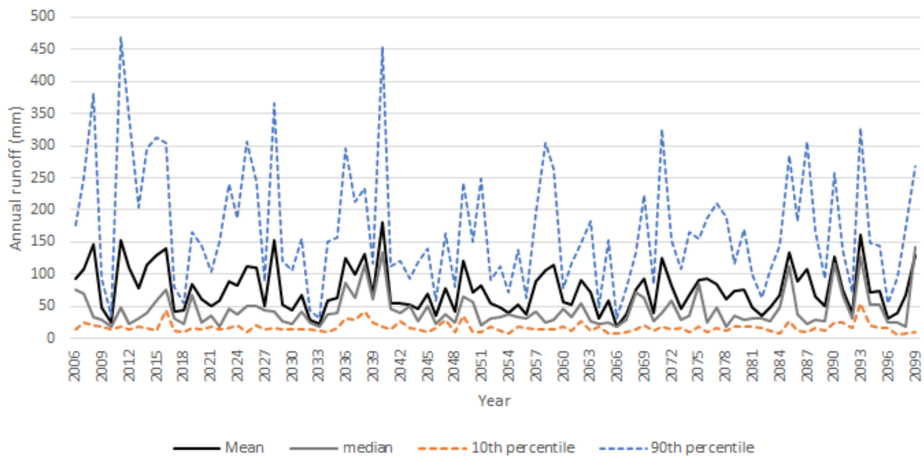


Figure 5 Percentage change in streamflow, compared with the 1976–2005 period, for four future time periods for the catchments. Analysis is for ensemble median of all 16 ensemble members (four GCMs and four bias correction/downscaling methods) from the NHP outputs.(see ESCI Key Concepts—National hydrological projections).

SEQ Wivenhoe RCP8.5



Derwent RCP8.5

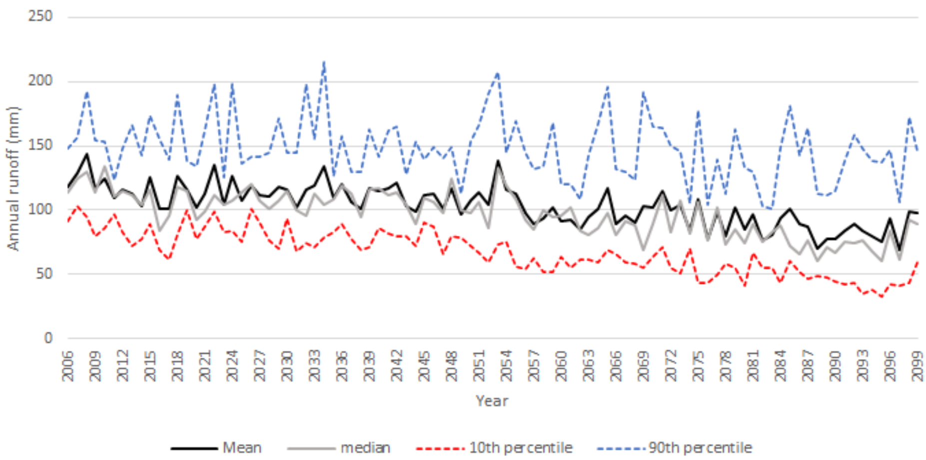


Figure 6 Projections for annual runoff (mm) for the Wivenhoe catchment, QLD (top) and Derwent catchment, TAS (bottom) based on the RCP8.5 scenario, showing the model ensemble mean, median, and 10th and 90th percentile of the range.

Compare and prioritise against other risks

Projected streamflow changes throughout this century will impact water availability for hydropower generation. The projected changes are catchment specific. Changes in streamflow present risks and opportunities to system security and will need to be assessed in conjunction with other changes and system-wide risks. For example, increasing dependence for electricity generation on variable renewable energy will require support from all sources, including hydropower.

Risk treatment

Regulated basins with large reservoir capacities are more resilient to water resource changes, less vulnerable to climate change and can act as a storage buffer in the face of climate variability. Pumped hydro systems may also be less susceptible to changes in water availability as they operate (approximately) as closed systems, compared to traditional hydropower.

Hydropower development, pumped or otherwise, should account for projected changes in water availability due to climate change. This case study demonstrates how rainfall and streamflow projections can be used to assess risk and support planning decisions.

Further Information

Maps and time-series for more catchments are available via the ESCI data website.

References

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