Climate Resilience Analysis Framework: Testing the resilience of natural and engineered water resource systems

This research gives water resource managers practical steps and tools to assess climate impacts on their systems and guide climate change adaptation.

Leader: Associate Professor Seth Westra (The University of Adelaide)

Team: Bree Bennett (The University of Adelaide); Lu Zhang, Nick Potter (CSIRO)

Project partners:

Climate projections often include high levels of uncertainty, making it a challenge for water resource managers to plan for the short-term future and for capital-intensive assets with 50 to 100+ year lifespans. The *Climate Resilience Analysis Framework and Tools* (CRAFT) project has given decision-makers the framework and tools they need to plan well for climate change adaptations and to confidently develop resilient systems in the face of this uncertainty.

KEY FINDINGS

The CRAFT project:

- developed a 5-step framework to 'stress test' complex water resource management systems and their resilience to climate change
- created innovative statistical open source software – foreSIGHT – which supports the framework
- applied both tools to a case study water resource management system to create a plan for its future.

IMPACT

The climate resilience analysis framework is a freely available, five-step process that helps users to:

- test the resilience of an existing water resource management system
- design new systems or augment existing ones for climate adaptation
- develop and assess system management options.

It differs from most climate change planning tools by taking a systems approach that places emphasis on how the system functions and responds to emerging climate stressors, before exploring opportunities to strengthen system resilience across a range of possible scenarios. This makes it easier to identify the best course of action for each system under different climate scenarios.

The framework also strongly focuses on communication between modellers and decision makers in a way that traditional approaches do not, by involving decision makers and system operators from the start. This provides unique opportunities to help prepare systems for unforeseen 'black swan' events, develop adaptive pathway approaches to investing in system improvements, and to identify new solutions to improve overall system resilience.

The framework has been specifically designed to:

- recognise that systems are inherently complex and that links with climate are often non-trivial
- emphasise the importance of system understanding by numerically 'stress testing' systems against a range of hypothetical and projected climate states
- provide a basis for iterative dialogue between decisions makers, system modelers and climate experts about model uncertainty and the implications of different design and operation options
- allow exploration of the implications of deep uncertainty by combining climate projections (via top-down approaches) with hypothetical climate scenarios (via bottom-up approaches) that cover a wide range of possible climatic changes
- enable rapid update of impact assessments under new lines of evidence (e.g. if new climate model projections become available)
- provide a basis for adaptive planning (including supporting the development of adaptive pathways).

WHO CAN USE THE FRAMEWORK?

The framework is freely available and relevant for anyone interested in understanding how weather and climate affect a given system, and/or what options are needed to maximise system resilience.

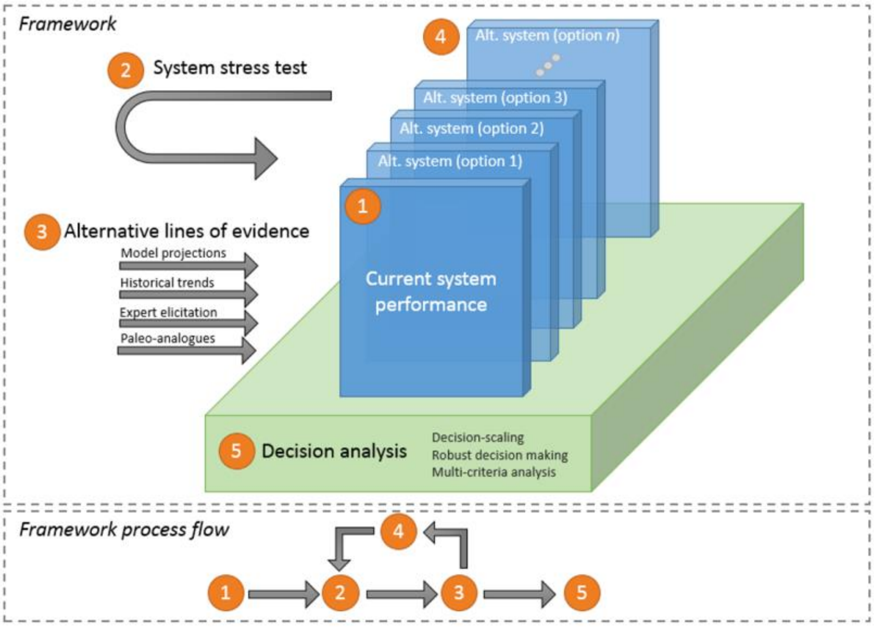
Resource managers, planners and decision-makers who use the framework will be helping to protect the communities they serve as they navigate climate change. More resilient systems will be better able to provide the services we rely on every day and make the best use of our financial resources when adapting to a changing climate.

The framework can be used in any project around the world that:

- focuses on long-term planning
- is large enough to warrant a detailed quantitative analysis of system resilience
- has complex relationships between weather and climate drivers and the overall system function.

The framework was designed to be used for natural and engineered systems across the water resources, municipal, agricultural, energy, mining, industrial, transport and environmental sectors. The framework can be used for municipal water supply planning, irrigation system design, environmental flow management or energy systems planning, where the network relies on one or more climate-dependent sources (e.g. water, solar and wind). It can also be used in the agricultural sector to help determine the most resilient crop or cultivar for a region as the climate changes.

THE FIVE FRAMEWORK STEPS



Step 1: Define the problem and system performance measures

The first step involves defining the problem(s) you are attempting to solve in order to achieve sustainable system management.

Step 2: Stress test the system

This step will help you gain a quantitative understanding of the system and its sensitivities to climate variation.

Step 3: Climate projections and other lines of evidence

Step 3 involves developing system performance maps that include other lines of evidence such as global climate change models (GCMs) to identify parts of the solution space that are more or less likely. This has important implications on which decision-making tools are decided on in Step 5 and whether they need to account for 'deep uncertainty'.

Step 4: System management options

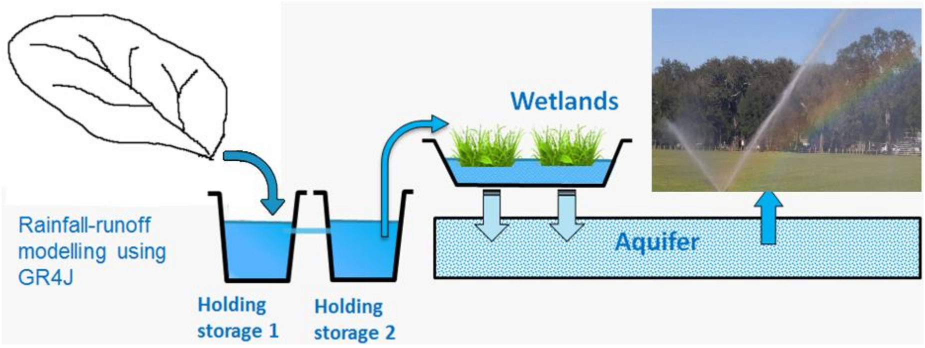
In this step you'll visualise system performance as maps, incorporating other lines of evidence for all considered system management options.

Step 5: Decision analysis

The outcome of the framework is to arrive at a preferred option to improve system resilience. The final decision analysis evaluates the various system management options in light of the analysis in steps 2 to 4. It considers the feasibility, cost, benefit and the potential political will to implement of each option. There may also be a need to balance economic benefits with environmental and social values. Final recommendations may include: 'do nothing'; implement alternative system management options; or identify key trigger points at which action is required as part of an adaptive pathways approach.

CASE STUDY: PARAFIELD STORMWATER CAPTURE AND MANAGED AQUIFER RECHARGE SCHEME

The project applied the climate resilience analysis framework to the managed aquifer recharge (MAR) scheme in the City of Salisbury. The MAR scheme captures stormwater from a 16 km^2 residential and industrial catchment, which passes through two storage basins and wetlands for cleaning and sediment reduction. Four wells inject and extract water from the aquifer for reuse in industrial and irrigation applications. A system model including a rainfall runoff model was coded in R, with volumetric reliability chosen as the performance measure.



Schematic of the Parafield Managed Aquifer Recharge system.

System stress tests were conducted using the foreSIGHT software. Initial tests were conducted to determine which of a range of climate variables produced the most change in system performance. These tests indicated that system resilience is most sensitive to changes in mean annual rainfall, potential evaporation (especially through influencing demand), mean number of wet days (rainfall intermittency) and rainfall seasonality. The stress test showed that future climate conditions would lead to a deterioration in performance, with volumetric reliability expected to decrease from 72% under current climate conditions to as low as 22% under the worst-case future climate projections by 2085 based on the climate model projections.

Multiple climate variables including changes to total annual rainfall, potential evapotranspiration, intermittency and seasonality were all found to contribute to a decrease in system performance, suggesting that a multi-pronged solution may be needed.

To determine the potential for system augmentation to mitigate these changes, several hypothetical infrastructure scenarios (e.g. increase in number of injection wells, augmentation of holding storage) were assessed in the context of overall system resilience. This analysis revealed that increasing detention time, surface storage capacity and changing the number of injection wells led to a moderate improvement in performance.

However, because of the complex nature of future climate changes identified during the stress testing phase, it is likely that no single system augmentation option will be sufficient to address the considerable reduction in system performance in isolation. Any system augmentations should be considered in combination and potentially in conjunction with demand management and consideration of alternative water sources to maintain a suitable reliability of supply.

*fore*SIGHT software

Accompanying the climate resilience analysis framework is the *fore*SIGHT software, created with open-source R program, that guides users through the system specific analysis steps (e.g. system stress testing). *fore*SIGHT is the first of its kind and includes innovative ways to generate hypothetical climate scenarios; assess the magnitude of changes on given measures of a system's performance; and quickly update impact assessments when new climate model projections become available.

MORE INFORMATION

The following technical reports associated with the research program are available at www.goyderinstitute.org/publications/technical-reports/:

- Bennett, B., Zhang, L., Potter, N.J. and Westra, S. (2018) Climate Resilience Analysis Framework: Testing the resilience of natural and engineered systems. Goyder Institute for Water Research Technical Report Series No. 18/02, Adelaide, South Australia.
- Potter, N.J., Zhang, L., Bennett, B. and Westra, S. (2018) Case study for Climate Resilience Analysis Framework and Tools (CRAFT): Managed aquifer recharge at Parafield Airport. Goyder Institute for Water Research Technical Report Series No. 18/03, Adelaide, South Australia.

GOYDER INSTITUTE FOR WATER RESEARCH

Contact:

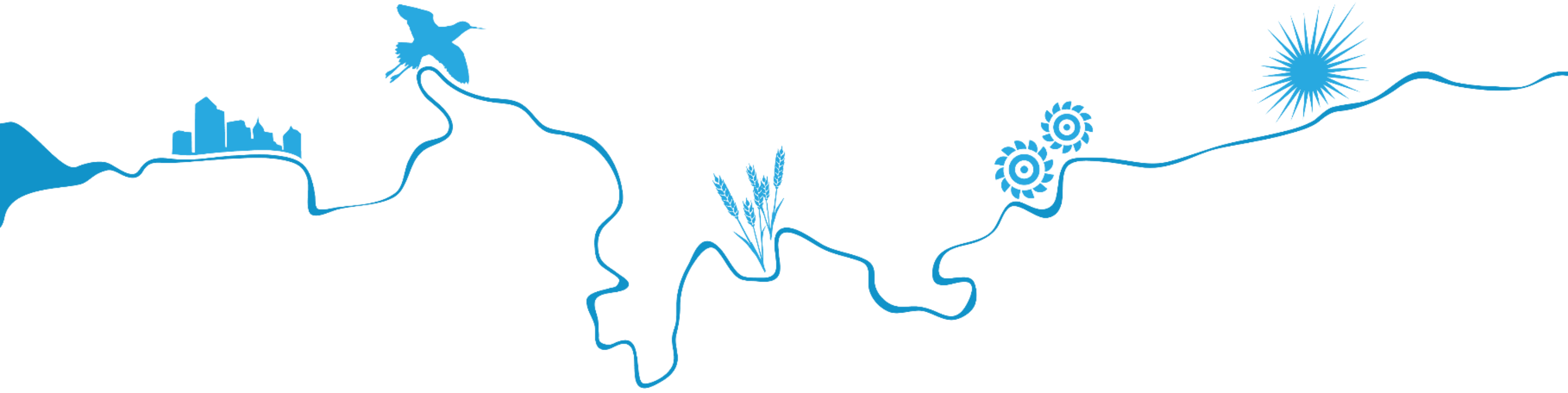
209A, Level 2, Darling Building, The University of Adelaide, North Terrace, Adelaide, SA 5005

+61 (08) 8313 5950

enquiries@goyderinstitute.org

@goyderinstitute

www.goyderinstitute.org



PARTNERS

Government of South Australia Department for Environment and Water

CSIRO

Flinders University Adelaide • Australia

The University of Adelaide

University of South Australia

ASSOCIATE PARTNERS

EPA South Australia

National Centre for Groundwater Research and Training

SARDI South Australian Research and Development Institute

SA Water