Australian Government
Bureau of Meteorology

CSIRO

# Water Information Research and Development Alliance

ANNUAL REPORT 2016–17

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www.bom.gov.au/water
www.csiro.au/en/Research/LWF/Areas/Water-resources

# **EXECUTIVE** SUMMARY

## ABOUT WIRADA

The Water Information Research and Development Alliance (WIRADA) is a research partnership between the Bureau of Meteorology and CSIRO. It delivers the innovation required to develop national water information products and tools. WIRADA brings together CSIRO's expertise in water and information sciences and the Bureau's operational role in hydrological analysis and prediction..

## 2016–17 WIRADA ACHIEVEMENTS

This year WIRADA has undertaken targeted research projects to improve the use, performance and accuracy of operational products

### WATER RESOURCES MODELLING

Australia has gone from one of the wettest years on record to an exceptionally dry winter for large areas of southern Australia. Record rainfall deficiencies are apparent in many areas. Expanding the use and reliability of the Bureau's water modelling capability is critical for us to understand what such changes mean for the movement of water across Australia.

Towards this, WIRADA has tested and updated the Australian Water Resource Assessment model so it can:

- explicitly model hydrological processes for a wider range of areas, such as urban zones, large lakes and irrigated agriculture; and
- operate at a finer spatial scale, on a 0.01° ( ~1 km) grid.

These advances will let users apply the model with greater confidence to questions at catchment and local scales.

### FLOW FORECASTING

Reliable streamflow forecasts need good estimates of expected rainfall. This year our research has focused on how to make best use of rainfall forecasts from the new generation of climate and numerical weather models that run on the Bureau's new supercomputer.

Particular effort has gone into adapting existing models and tools that process seasonal and monthly precipitation forecasts, and streamflow forecasts. The results demonstrate that the Bureau can use data from the new climate and weather models to improve the accuracy and range of Bureau streamflow forecasts.

WIRADA science has led to new software, systems, and toolkits that directly support:

- seasonal forecasts at more than 180 sites across Australia; and
- daily streamflow forecasts for the next seven days at more than 200 sites.

**'This year we have undertaken targeted research projects to improve the use, performance and accuracy of operational products."**

# WIRADA ACHIEVEMENTS
2008–17

More than $68 million invested over 9 years to advance national water information science

1 arc-second (~30 m) resolution Digital Elevation Model developed for Australia to understand our landscape and water resources

200 of Australia's top water scientists working together over 9 years—representing over 250 person-years

New hydrological models that produce daily estimates of soil moisture, runoff, precipitation, evapotranspiration and deep drainage at resolutions of 25 km$^2$ and 1 km$^2$ across Australia[2]

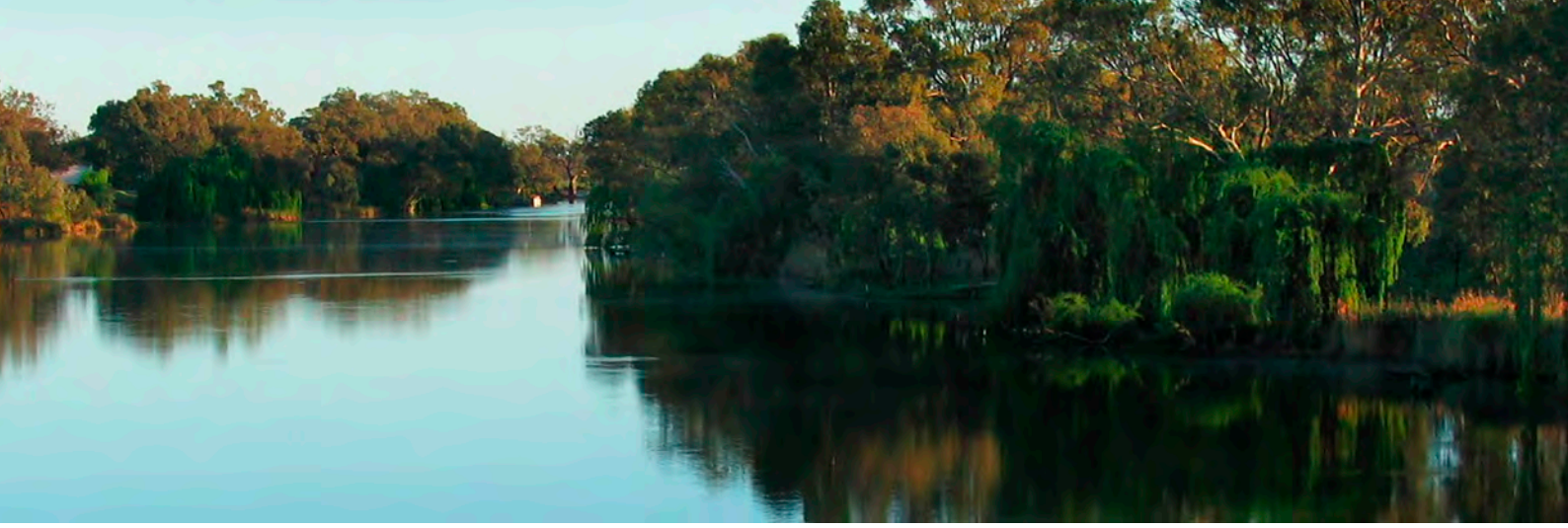
More than 30 research projects to deliver the science behind the Bureau's Water standards program

Daily streamflow forecasts for the next 7 days issued at more than 200 sites across Australia[3]

5 international data exchange standards developed to help users share, analyse and compare water information[1]

Australia's first national seasonal streamflow forecast service running at more than 180 sites, issued every month[4]

1 www.bom.gov.au/water/standards/aboutStds.shtml
2 www.bom.gov.au/water/landscape
3 www.bom.gov.au/water/7daystreamflow
4 www.bom.gov.au/water/ssf/index.shtml



Improved rainfall forecasts at scales required for streamflow forecasts and accurate estimates of evapotranspiration across the continent

Over 25 million data files transferred to the Bureau using WDTF since 2009

Spatial model to map relationships between more than 3 million unique hydrological features across Australia—such as storages, monitoring points, streams and catchments[5]

20 operational water information products developed, tested or supported with WIRADA science

SolidGround: tools to create and manage information models in a consistent way

Over 100 international science journal papers published, 350 conference presentations given, 200 reports written

Water Data Transfer Format (WDTF), to automate sharing of Australia's water information, adopted by industry and lead water agencies

World-class science in partnership with nearly 50 national and international research collaborators

5 www.bom.gov.au/water/geofabric/index.shtml

# HYDROLOGICAL MODELLING
## TO ASSESS WATER RESOURCES

| | |
|---|---|
| BUREAU SPONSOR | Robert Argent |
| COLLABORATORS | Monash University; The University of Melbourne; The University of New South Wales; The University of Newcastle; New South Wales Department of Primary Industries—Water; New South Wales Office of Environment and Heritage; WaterNSW |
| PROJECT LEADER | Jai Vaze |

**Objective: an integrated modelling system to estimate water flows and stores across Australia and to provide seamless water balance data for the past and present.**

## CHALLENGE

The Australian Water Resources Assessment (AWRA) model simulates how water moves across Australia. It has two spatial response units that model hydrological processes based on whether an area has shallow- or deep-rooted vegetation. The model runs daily at a 5 km scale (0.05° grid) across Australia.

Feedback from users, such as water supply operators and planners, demand for:

- better model estimates for landscapes that are not currently explicitly modelled, in particular, urban areas, large lakes, dams and irrigated farmland; and
- model outputs at a finer resolution that can be applied at a scale that many decision-makers need.

## SOLUTION

We need to extend the Australian Water Resources Assessment model to represent additional landscape types and to generate more detailed outputs. Our approach was to:

- add new response units into the model to better capture key landscape dynamics relevant to the water balance; and
- update and refine the existing spatial datasets used as inputs to the model.

## 2016–17 ACHIEVEMENTS

We used the Murrumbidgee River basin as a case study area to develop and test new model structures and updated spatial input layers. We demonstrated a new version of the Australian Water Resources Assessment model that has:

- five response units that can represent key landscapes in Australia including: shallow- and deep-rooted vegetation, impervious areas, large water bodies and irrigated agriculture; and
- up-to-date spatial datasets capable of supporting spatial grid resolutions of either 0.05° (~5 km) or 0.01° (~1 km).

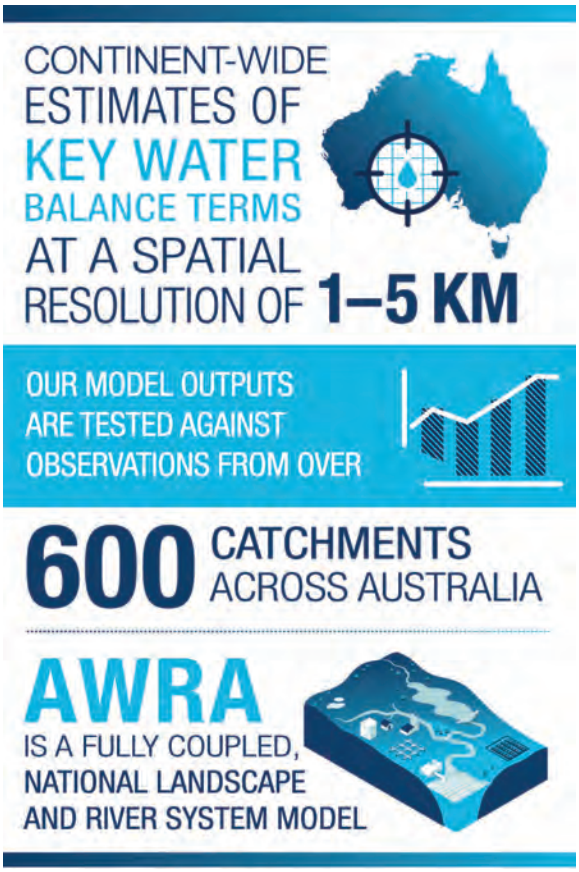
**'The Australian Water Resources Assessment modelling system gives estimates of water fluxes and stores to help us understand how water moves across the Australian landscape.'**

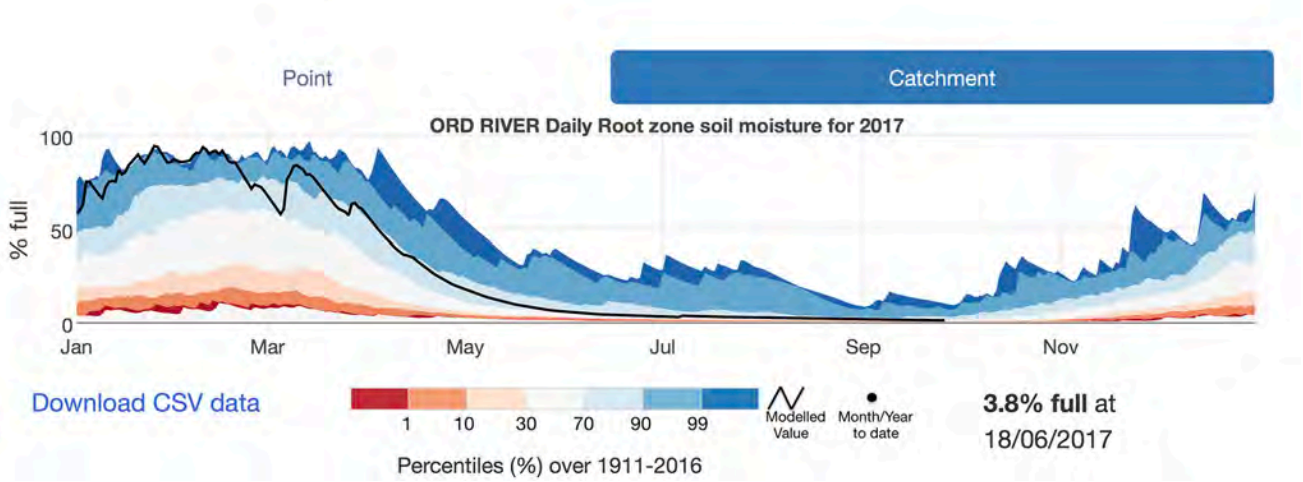
## OUTCOME

The Australian Water Resources Assessment model can now explicitly represent hydrological processes in impervious areas, lakes and irrigated agriculture. This adds to the existing capability to model areas with shallow- and deep-rooted vegetation.

The model is also capable of simulating hydrological processes at either a 5 km or 1 km spatial grid resolution, providing improved water balance estimates suitable for catchment and local-scale applications.

Australia now has a model that can consistently account for important aspects of its water resources, including runoff and river flow, soil water storage, groundwater recharge and vegetation water use.




Root zone soil moisture estimates for the Ord River catchment on 18 June 2017. The Bureau's operational Australian Landscape Water Balance model simulates the flow of water through the landscape in each grid cell—entering as rainfall, passing through the vegetation and soil, and leaving through evapotranspiration, runoff or deep drainage to the groundwater.

# FLOOD AND SHORT-TERM STREAMFLOW FORECASTING

| | |
|---|---|
| BUREAU SPONSOR | Dasarath Jayasuriya |
| COLLABORATORS | The University of Melbourne; United States Department of Agriculture—Agricultural Research Service |
| PROJECT LEADER | David Robertson |

**Objective: to expand coverage of seven-day streamflow forecast services and establish methods for an ensemble forecast service**

## CHALLENGE

Reliable streamflow forecasts with lead times from a few hours to seven days are critical to inform flood management and optimise river operations. To assist water managers, the Bureau now has a seven-day streamflow forecast service for catchments across Australia.

Recent research needed to be refined to improve forecast accuracy and reliability for many catchments across Australia.

The Bureau is also building an ensemble streamflow forecast service, requiring the adaptation of existing methods and tools to process the new rainfall forecasts outputs. We must also learn how to make better use of rain gauge observations for hydrological forecasting applications.

## SOLUTION

To face the technical and scientific challenges posed, we focused on:

- transferring recent WIRADA research into the Bureau's operational seven-day streamflow forecasting system; and
- testing and refining existing science and associated software.

## 2017–18 ACHIEVEMENTS

- We developed and tested new parameter estimation methods to better use the new ensemble precipitation forecasts. These produce robust rainfall forecasts that can be used at a catchment scale for streamflow forecasts.
- We have improved techniques to deal with errors in stream flow forecasting that allow us to now reliably apply our models to intermittent streams. This new approach allows the Bureau to give more reliable streamflow forecasts for a much wider range of locations.
- We extended the ensemble spatial data infilling and interpolating model to generate real-time estimates of catchment rainfall. The use of up-to-date rainfall observations improves our modelling of catchment runoff and forecasts of likely streamflow.

### What are ensemble forecasts?

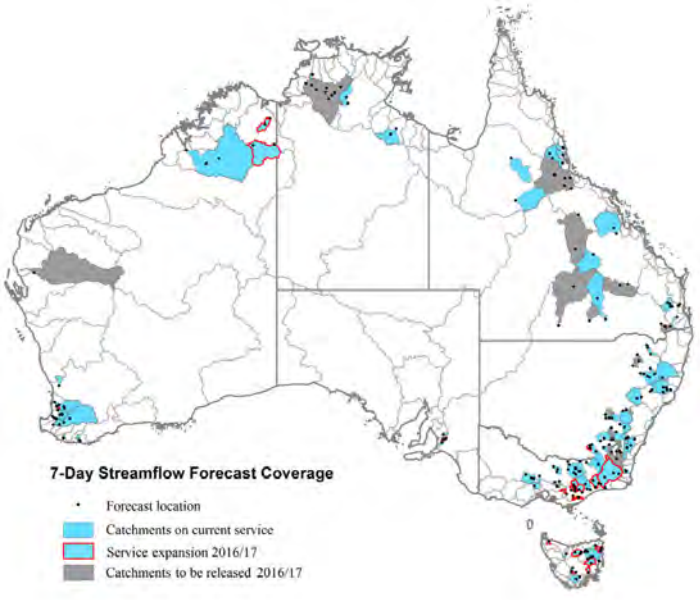
Ensemble forecasts provide a set (an ensemble) of many forecasts for the same period and location. They can be generated either from many models or from one model with many parameter sets. Ensembles give an indication of the range of possible future states; for example, for precipitation in a catchment or flows in a stream. Such information allows for more reliable forecasts and better knowledge of forecast uncertainty for decision-makers.

## OUTCOME

The Bureau's seven-day streamflow forecast service now covers over 200 locations in more than 100 catchments around Australia. The service relies on software, systems, and toolkits developed under WIRADA. It combines real-time observations from a national network of rain and river gauges with computer models to simulate rainfall, runoff and river flow.

We are testing a more advanced service that will provide hourly ensemble forecasts out to seven days. This service will use recent research in rainfall post-processing methods to give probabilistic forecasts. Knowing the likelihood of a range of streamflows occurring will help dam and river operators plan water releases.

The Bureau's national seven-day streamflow forecasts guide water managers, primary producers and other users on how much water is likely to flow in a river for each of the next seven days—this allows for informed decisions based on the latest science. Forecasts that are more accurate bring economic benefits arising from water releases that optimise the use of the nation's water—through improved environmental flow management and more efficient operation of rivers and storages.


Seven-day streamflow forecast coverage. Black dots represent forecast locations in each catchment. Blue catchments are in the current service, red-outlined catchments are part of the next service expansion. Grey catchments will be included this year.

# SEASONAL STREAMFLOW FORECASTS

| | |
|---|---|
| BUREAU SPONSOR | Dasarath Jayasuriya |
| COLLABORATORS | United States National Oceanic and Atmospheric Administration; European Centre for Medium-Range Weather Forecasts |
| PROJECT LEADERS | Q.J. Wang and David Robertson |

**Objective: to expand coverage of seven-day streamflow forecast services and establish methods for an ensemble forecast service**

## CHALLENGE

Timely and accurate streamflow forecasts are vital to inform good water management decisions.

The Bureau currently operates seasonal streamflow forecast services that cover major water storages and river systems across Australia. Forecasts are issued each month, and give the likelihood of the total volume of water flow for the next three months.

The Bureau has a new dynamic streamflow forecast system developed under WIRADA that processes predictions from dynamic climate models. As new higher resolution climate models became available, the streamflow forecast system needed to be adapted.

## SOLUTION

The Bureau's dynamic seasonal streamflow forecast system uses several models, systems and toolkits developed under WIRADA. We are working to further develop and adapt these methods to make use of next generation climate forecasts.

Our solution was to adapt existing approaches and develop new methods to:

- process the new dynamic seasonal precipitation forecasts at daily time steps (intervals);
- extend the existing probabilistic functions; and
- improve the dynamic streamflow forecasts.

## 2016–18 ACHIEVEMENTS

- We developed a new method to process precipitation forecasts at daily time steps. The method produces streamflow forecasts with minimal bias, and can reduce forecast errors.
- A method to calibrate ensemble climate precipitation forecasts was adapted to process monthly forecasts. The method can take into account both the accuracy of the new climate forecasts and their ensemble spread.
- We adapted the existing hydrological error model to reduce errors and quantify uncertainty in monthly streamflow forecasts. The model can produce streamflow forecasts with minimal bias, and reliable uncertainty estimates for individual months and for three-monthly accumulations.

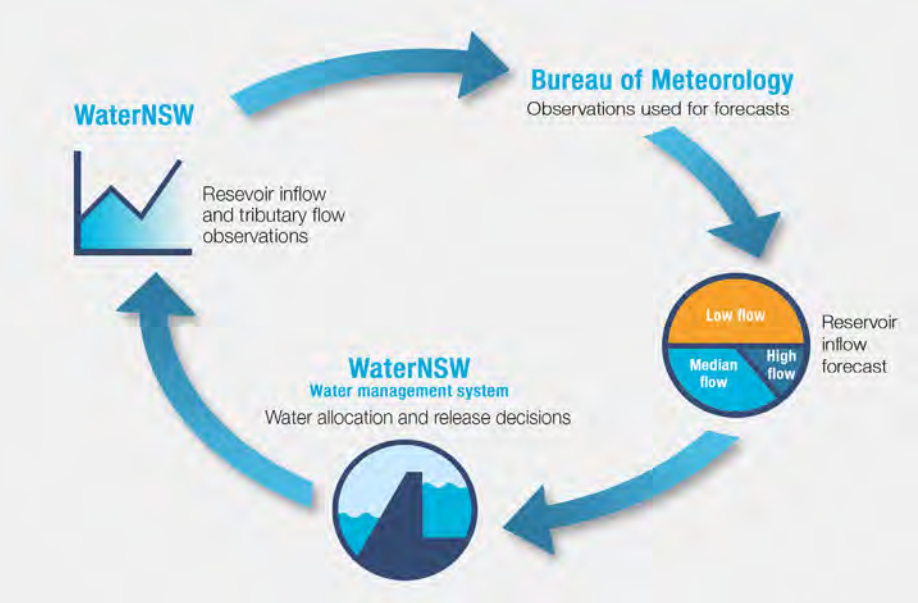
## OUTCOME

The Bureau's seasonal streamflow forecasts developed under WIRADA are used by river managers and storage operators to plan water supplies, transfers and environmental flows. They are also used as an input to determine water allocations each season, and to inform planning and strategic decisions.

Research this year will let the Bureau take advantage of advances in climate forecasts. It will also enable streamflow forecasts that split the initial three-month forecast volume into monthly volumes. These outputs can be linked more directly to decision-support systems of water agencies in Australia.

One- and three-month forecasts based on the new dynamic modelling approach are being evaluated for 100 locations.

The Bureau aims to release an improved forecast based on statistical and dynamic models in 2018. This service will increase the number of forecast locations and improve forecast quality


A schematic from a joint case study with WaterNSW, highlighting the value that the seasonal streamflow forecast service can provide for water management agencies

# PERFORMANCE REPORT

## BUDGET, FINANCE AND RESOURCES

The 2016–17 investment of $3.6 million was allocated to:

- water resource assessment modelling (24 per cent);
- streamflow forecasting (73 per cent); and
- management and communication (3 per cent).

The end-of-year financial position for WIRADA was an under-expenditure of $206 000.

## DELIVERY AND PRODUCTIVITY

WIRADA had 41 deliverables across ten projects scheduled for completion in 2016–17. At year's end, 39 deliverables had been submitted; the remaining two were delivered by 31 August.

Over 2016–17 WIRADA:

- published 12 journal papers;
- submitted six journal papers;
- presented 16 conference papers, and
- produced 18 technical reports.

Total WIRADA output since 2008 is summarised in the table below.

| PERIOD | JOURNAL PUBLISH | JOURNAL SUBMITTED | BOOKS | CONFERENCE PAPERS[1] | PUBLISHED REPORTS | INTERNAL REPORTS | TOTAL |
|---|---|---|---|---|---|---|---|
| 2008–09 | 17 | | 1 | 45 | 41 | 21 | 125 |
| 2009–10 | 13 | | 0 | 32 | 26 | 41 | 112 |
| 2010–11 | 11 | | 0 | 91 | 16 | 4 | 122 |
| 2011–12 | 22 | | 1 | 79 | 7 | 7 | 116 |
| 2012–13 | 11 | | 0 | 30 | 10 | 1 | 52 |
| 2013–14 | 15 | | 5 | 50 | 14 | 10 | 94 |
| 2014–15 | 15 | | 0 | 27 | 10 | 11 | 63 |
| 2015–16 | 9 | | 1 | 47 | 13 | 3 | 82 |
| 2016–17 | 12 | 6 | 0 | 16 | 18 | 0 | 52 |
| Total | 125 | 6 | 8 | 417 | 155 | 98 | |

1 includes abstracts*
2 The decrease in total outputs for the 2013–16 phase of WIRADA reflects a reduced investment by the partners

# WIRADA REPORT CARD
2016–17

To maximise impact, streamline delivery and evolve research, the WIRADA portfolio has three core strategies:

- targeted research;
- quality relationships and collaboration; and
- quality delivery and impact.

| OBJECTIVES | ACHIEVEMENTS |
|---|---|
| **1: DEFINE RESEARCH DIRECTION**<br>Design a coordinated research portfolio that delivers knowledge, information and tools to vastly improve water data integration, water resource assessments, national water accounts, flood forecasts and water availability outlooks. | **ACHEIVED:** New project agreements for 2017–18 developed and approved by Management Committee<br>The Bureau accepted 97.5 per cent of WIRADA deliverables. |
| **2: ALIGN RESEARCH FOR IMPACT**<br>Determine the priority between research investments and develop path to impact. | **ACHEIVED:** Research transition plans embedded in all individual project plans for 2016–17. |
| **3: DEVELOP RELATIONSHIPS**<br>Define and develop relationships to enhance delivery of the WIRADA program and establish the necessary governance arrangements. | **ACHEIVED:** Joint project governance arrangements operated for all research projects. Dedicated project activities to transfer research to Bureau operations and information technology systems exist. |
| **4: HARNESS COLLABORATION**<br>Harness and value-add from relevant research investment. | **PARTIALLY ACHEIVED:** All projects have strong collaboration with state and national research partners. |
| **5: MANAGE SCIENCE QUALITY**<br>Ensure sound science quality management practices maintained. | **ACHEIVED:** All WIRADA deliverables achieved and 97.5 per cent accepted for the year.<br>Twelve journal papers published. |
| **6: CHAMPION, EVALUATE AND FEEDBACK**<br>Champion the research outcomes, assess impact and adapt the WIRADA research program. | **ACHEIVED:** Sixteen papers presented at leading national and international conferences.<br>2016–17 Annual Report drafted for approval.<br>2017–18 investment approved in July 2017. |

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