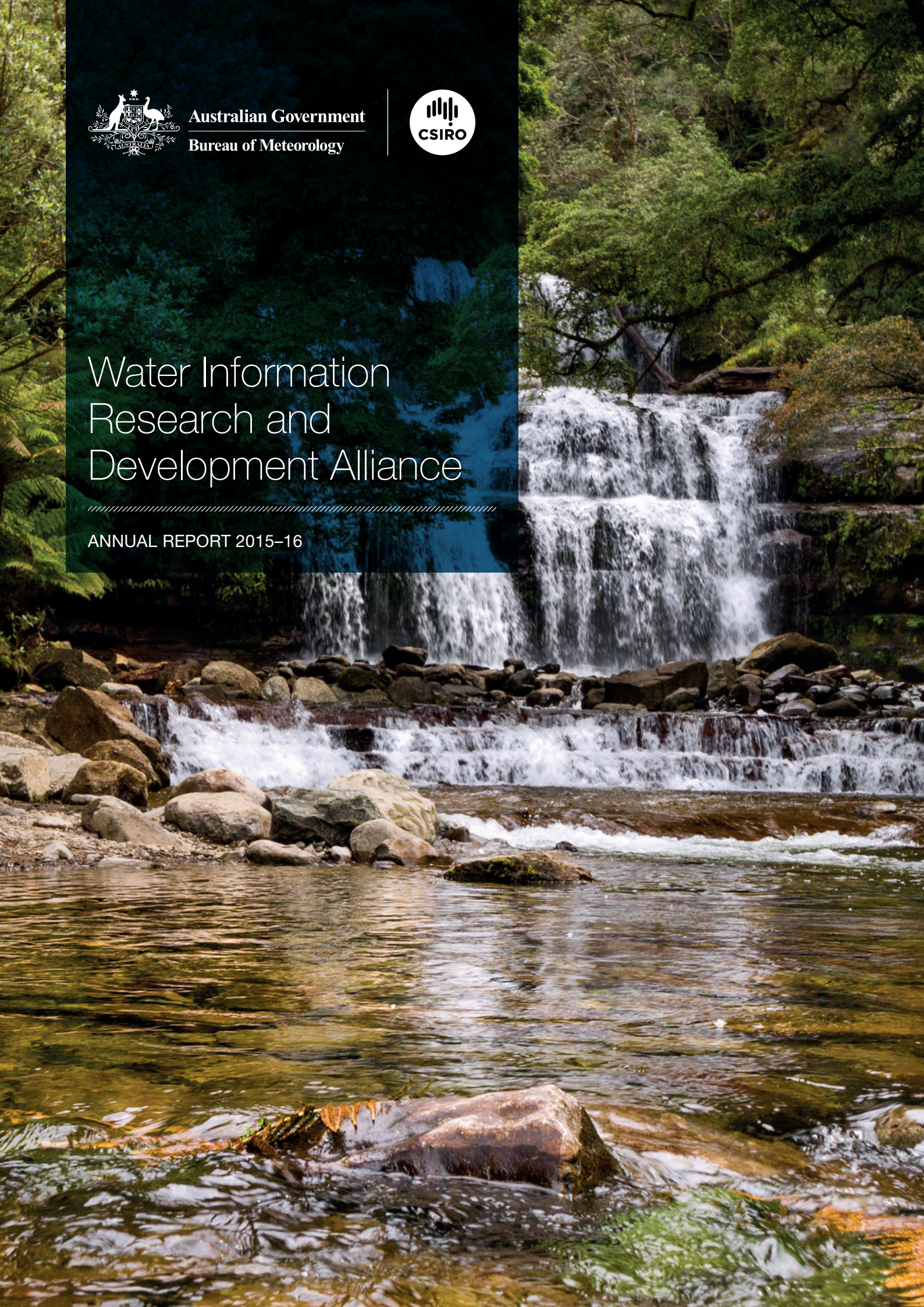

Australian Government
Bureau of Meteorology

CSIRO

Water Information Research and Development Alliance

ANNUAL REPORT 2015–16

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

CONTENTS

EXECUTIVE SUMMARY

With a focus on 'development to operations' this year, our research has produced new international standards, online data services, better flow-forecasting technologies and improved national water balance products.

This year WIRADA has targeted the operational transition of our research. All project outputs, such as international standards and software packages, reflect both the highest-quality science and user-readiness.

2015–16 WIRADA ACHIEVEMENTS

WATER RESOURCES MODELLING

As record rainfall deficiencies continue for many areas in Australia, the need for consistent, continental-scale water balance assessment products has never been clearer. We require water balance analysis to produce reliable estimates of the generation and movement of water across Australia, to support effective water resource policy and planning.

This year, WIRADA has:

- improved the Australian Water Resource Assessment model;
- created a continental dataset of groundwater recharge estimates to benchmark water balance model outputs; and
- developed a method for river flow model calibration that dynamically weights flow observations, to better utilise good data and rely less on poor data.

Australia now has a model that can consistently account for all key aspects of water resources, for all areas in Australia. The publicly accessible model outputs are being increasingly adopted by natural resource management agencies.

FLOW FORECASTING

The Bureau continues to expand our suite of flow forecasting services based upon our research. This year WIRADA has delivered improvements in forecast quality across timescales ranging from days to seasons.

At the daily-to-weekly scale, we improved forecast accuracy and reliability, to produce better forecasts, more frequently, for more sites. Our research delivered post-processors that increase rainfall forecast accuracy and better reflect the probabilities of different rainfall values, resulting in better flow forecasts. We also supported the future expansion of flow forecasting services by testing the techniques that we have developed for perennial streams on ephemeral streams.

Over the monthly-to-seasonal forecast timescales, we developed techniques to generate flow forecasts up to seven days earlier without significant loss of overall skill, enabling the Bureau capability to deliver forecasts to users a few days ahead of the current schedule. We also extended our ability to forecast beyond three months ahead, especially for dry catchments, and developed methods to provide forecasts broken down to monthly flow volumes in the three months ahead. These advances help the Bureau deliver better, more detailed and extended forecasts for more sites across Australia.

DATA AND INFORMATION SERVICES

Managing water resources, undertaking water assessment and delivering flow forecasts require water data to be shared, compared and used across sectors and systems. Our research this year has developed open data services to provide access to data for all users. We have also contributed unique Australian needs and insights into a set of international standards for the exchange of water information, time series observations and groundwater data.

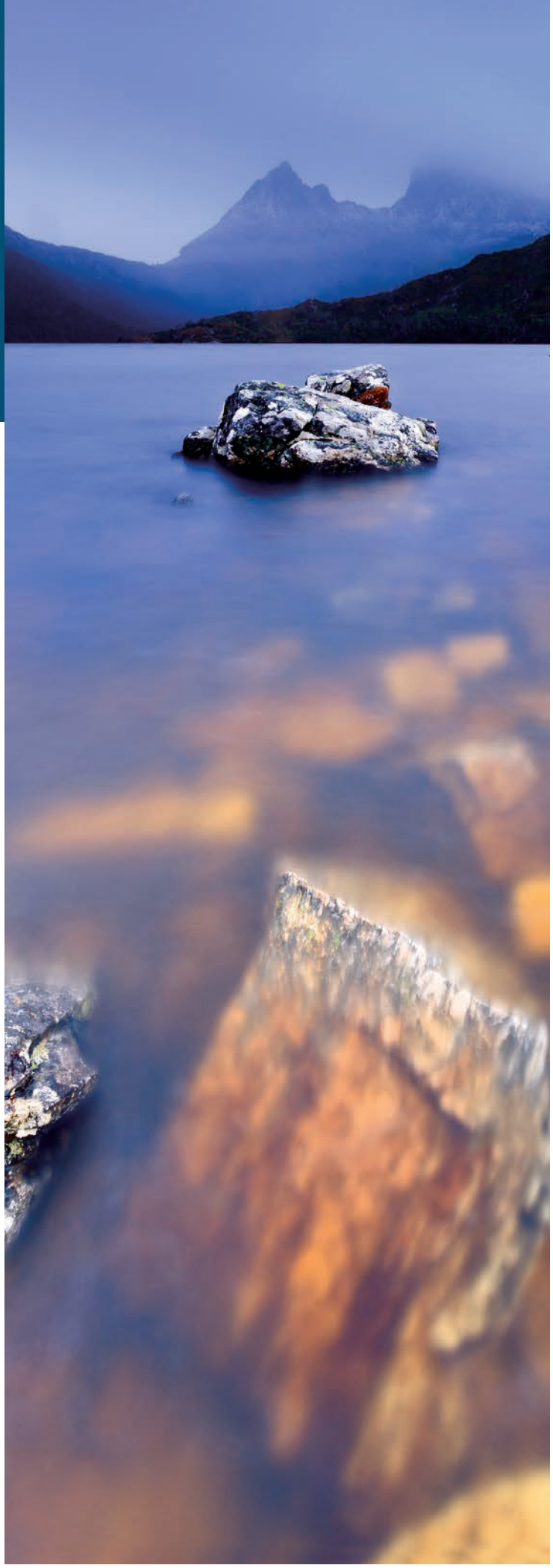
WIRADA MANAGEMENT

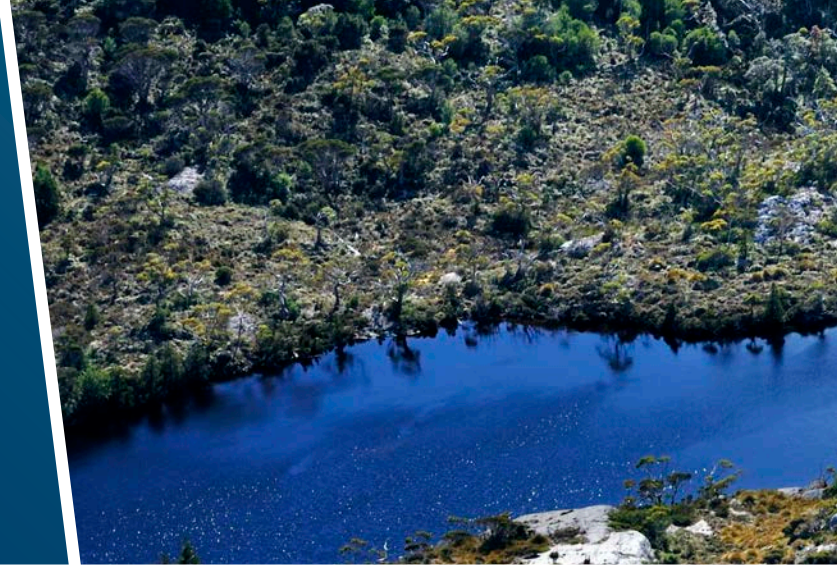
The WIRADA website now reflects the goals and achievements of WIRADA over the past eight years.

All-in-all we have had a very successful year, and I thank all our teams for their focus and commitment to delivering from development to operations this year.

To further build on this success, the WIRADA research collaboration agreement has been extended by the Management Committee for a further year to 30 June 2017, due to the joint understanding that the outcomes from WIRADA over the past eight years reflect the highest quality science and user-readiness.

Dr Robert Argent
WIRADA Director





WIRADA
ACHIEVEMENTS 2008–16

More than $65 million invested over 8 years to advance national water information science

One 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 8 years—representing over 250 person-years

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

27 research projects to deliver the science behind the Bureau's Water information program

Daily streamflow forecasts for the next 7 days issued at more than 100 sites across 50 catchments[3]

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

Australia's first national seasonal streamflow forecast service running at more than 140 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 20 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 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

WATER DATA
AND INFORMATION SERVICES

BUREAU SPONSOR	Tony Boston
COLLABORATORS	US Geological Survey; Open Geospatial Consortium; Geological Survey of Canada; European Commission Directorate General – Joint Research Centre; Federation University Australia; Polish Geological Institute; Bureau de Recherches Géologiques et Minières; University of Salzburg; International Groundwater Resources Assessment Centre; Geological Surveys of Germany; British Geological Survey
PROJECT LEADER	Peter Taylor

Objective: to provide standards, tools and data services that support the delivery and exchange of environmental intelligence about our water resources

CHALLENGE

Sharing, comparing and using water data is essential to water resources management. Water data are collected and managed by many agencies using a multitude of data systems with unique structures, definitions and access means. The Bureau receives more than 15 000 water data files every day from across Australia. Automatic tools that integrate the data into a coherent national dataset—regardless of how it was collected and managed—are needed to support effective water data and information services.

SOLUTION

Automated, machine-based data transfer through the internet requires common languages—or data exchange standards— for data sharing and understanding. Development of standards draws together international experts in computer science, geospatial information systems and hydrology to capture and harmonise international definitions for groundwater concepts and terminology.

'National and international uptake of common data exchange standards supports us to share water information and work together regardless of software systems'

2015–16 ACHIEVEMENTS

- We contributed to a new international standard (GWML2.0) for exchanging groundwater data. We ensured the standard met Australian needs and was compatible with existing systems, such as the National Groundwater Information System.
- We led development of TimeseriesML1.0—a new generic exchange standard for use in multiple domains. This was approved as an Open Geospatial Consortium (OGC) standard and we are working with the World Meteorological Organization (WMO) to use it in the WMO global data exchange system.

OUTCOME

Through international collaboration, WIRADA has improved how data users around the world exchange hydrological information. GWML2.0 is the fourth international water data transfer standard to use WIRADA research, and we are working on a fifth:

- **WaterML2.0 – Part 1 (Timeseries)** allows users to share or discover successive or sequential hydrometeorological observations and measurements.
- **WaterML2.0 – Part 2 (Ratings, Gaugings and Sections)** used for rating tables, gauging observations and river sections.
- **TimeseriesML1.0** extends WaterML2.0 – Part 1 for generic time-series data exchange.

- **GWML2.0** is used for groundwater features (e.g. aquifers, wells) and observations.
- **HY Features:** a proposed standard conceptual model for hydrological features, including basins, rivers and networks.

Water data standards have been actively supported by commercial vendors of hydrological software systems, and are now in use across Australia. They have been adopted by key public organisations, including the US Geological Survey and the Open Geospatial Consortium, and are endorsed by the United States National Strategy for Civil Earth Observations, the Federal Geographic Data Committee, and for cross-domain exchange within the European Unions' INSPIRE initiative. The WMO is also assessing them for endorsement, further adding to the international impact of WIRADA research.

OUR DATA EXCHANGE STANDARDS ARE ADOPTED INTERNATIONALLY:

WATERML2.0 (PART 1.0 AND 2.0), TIMESERIESML1.0, AND GWML2.0

OUR WATER DATA STANDARDS ARE USED ACROSS

AUSTRALIAN STATES AND TERRITORIES

BUREAU RECEIVES OVER **15000** DATA FILES EACH DAY

Linked Data and Web Services

Nationally-collated datasets need to deliver information to people in the forms they require. We are developing standard web services that open access for developers to interact with existing weather, climate and water data services—allowing users to repurpose and add value to Bureau products.

The Bureau is also working towards structuring information as Linked Data, allowing it to be read automatically by computers and connected with data from different sources in new ways, thereby supporting development of new applications and tools using Bureau data.

In 2015–16, we:

- developed a prototype Linked Data service providing access to Bureau observations from selected sites in the Australian Capital Territory and New South Wales in multiple forms—this service is available to the public (http://lab.environment.data.gov.au/weather) and will enhance access for software developers to Bureau observations data; and
- provided an in-depth review and set of recommendations on the use of Web Application Programming Interfaces (API) for environmental data, which will give the Bureau a basis to move forward with a Web API strategy for publishing the wide range of environmental data that we hold.

HYDROLOGICAL MODELLING
TO ASSESS WATER RESOURCES

BUREAU SPONSOR	Ian Prosser
COLLABORATORS	Monash University; The University of Melbourne; The University of New South Wales; The University of Newcastle; New South Wales – DPI Water; New South Wales Office of Environment and Heritage; WaterNSW
PROJECT LEADER	Jai Vaze

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

CHALLENGE

Data on Australia's water resources varies in extent, quantity and quality. However, effective water resource policy and planning requires comprehensive and consistent information on water generation, distribution, storage, availability and use.

To produce these, and to track changes over time, we require conceptually consistent models, tools and systems that use the data we have, and which simulate the dominant landscape, river and groundwater processes from catchment to continent scales.

SOLUTION

The Australian Water Resources Assessment (AWRA) modelling system was developed and tested to provide continental-to-regional scale water balance estimates. It combines field and satellite data with detailed hydrological modelling, and calculates water flows and stores on a daily time scale at a spatial resolution of 5 km. The system's landscape (AWRA-L) and river (AWRA-R) model components have been developed and validated against a range of observations.

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

2015–16 ACHIEVEMENTS

This year we improved the research model and supported uptake of the Bureau's operational AWRA modelling system outputs by the water and agriculture sectors. Key achievements include:

- a reliable continental dataset of groundwater recharge estimates to benchmark AWRA-L, based on assessing existing recharge estimates and developing a quality-assured dataset that is consistent with observed soil, land use and climatic conditions—tests showed that AWRA reliably simulates recharge estimates across different conditions in Australia;
- a new calibration methodology to dynamically weigh stream gauge data within AWRA-R, so users can account for the quality and period of data available and use expert judgement to place emphasis on locations with better data or strategic importance; and
- workshops and case studies to demonstrate the AWRA modelling system and build confidence amongst State and Australian government agencies in its outputs—our soil moisture estimates are now used by the Australian Bureau of Agricultural and Resource Economics and Sciences in its Weekly Australian Climate, Water and Agriculture update and the Australian Crop, and Agricultural Commodities reports.

OUTCOME

Australia now has a model that can consistently account for important aspects of water resources for all areas in Australia.

Science advances through WIRADA allowed us to develop:

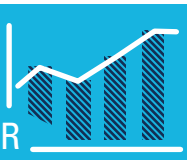
- a fully coupled national landscape and river system model; and
- techniques that can use all available data sources to provide regionally and continentally consistent estimates of the nation's water balance.

WIRADA research underpins the Bureau's operational water balance model, producing daily landscape water balances across Australia. Interactive outputs from the AWRA-L model are publicly available through the Australian Landscape Water Balance website.

The Bureau also uses AWRA-L and AWRA-R model outputs to deliver National Water Accounts, Water Resource Assessments and Water in Australia reports. These Bureau products provide basin, regional and national water perspectives and help us understand the present state of water resources across the continent and its variation over the last century.

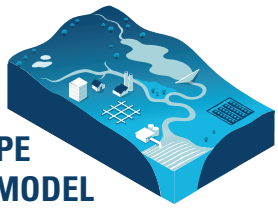
CONTINENT-WIDE ESTIMATES OF KEY WATER BALANCE TERMS AT A SPATIAL RESOLUTION OF **5 KM**

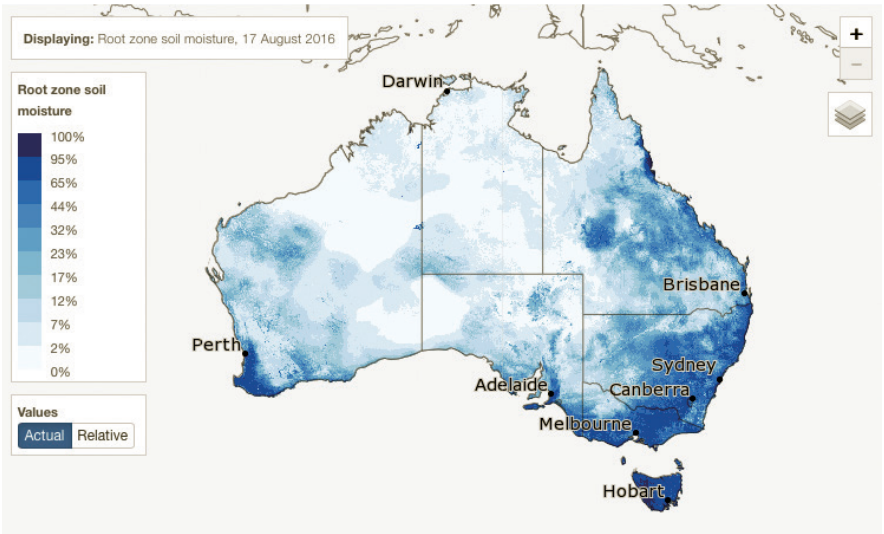
OUR MODEL OUTPUTS ARE TESTED AGAINST OBSERVATIONS FROM OVER



600 CATCHMENTS ACROSS AUSTRALIA

AWRA IS A FULLY COUPLED, **NATIONAL LANDSCAPE AND RIVER SYSTEM MODEL**





Root zone soil moisture estimates for 17 August 2016. The Bureau's operational Australian Water Resources Assessment Landscape model (AWRA-L v5.0) is a daily, grid-based, distributed water balance model. It simulates the flow of water through the landscape—from rainfall entering each grid cell through the vegetation and soil to water leaving the grid cell through evapotranspiration, runoff or deep drainage to the groundwater.

FLOOD AND SHORT-TERM STREAMFLOW FORECASTING

BUREAU SPONSOR	Dasarath Jayasuriya
COLLABORATORS	The Collaboration for Australian Weather and Climate Research; 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 manage floods and optimise river and water resource operations. To assist water managers, the Bureau provides a seven-day streamflow forecast service for catchments across Australia.

The current service is deterministic: a rainfall runoff model forecasts the most likely future streamflow, based upon the best estimates of observed and forecast rainfall, model parameters and catchment conditions.

However, forecast accuracy and reliability need to be improved in problem catchments across Australia, such as intermittent streams. Also, existing methods and tools need to be adapted to take advantage of 'ensemble' outputs from new, high-resolution numerical weather prediction models. This will support the development of a planned ensemble streamflow forecast service.

'In 2015 the Bureau released its new 7-day streamflow forecasts service which implements a number of data and modelling tools developed under WIRADA'

SOLUTION

Science advances through WIRADA have allowed the Bureau to:

- produce streamflow forecasts out to seven days; and
- automate these forecasts to enable daily updating.

In the last year, we have improved the accuracy and reliability of forecast services. Our research has also supported expansion of the existing deterministic service and the planned transition to ensemble forecast services.

2015–16 ACHIEVEMENTS

- We extended rainfall post-processing methods to handle ensemble numerical weather prediction forecasts and incorporate new parameter estimation techniques. The Bureau will adopt these in its new ensemble seven-day streamflow forecasting approach.
- The staged error modelling approach (ERRIS), initially applied to perennial streams, was evaluated on a range of intermittent streams. This will enable the Bureau to generate robust ensemble streamflow forecasts across the range of conditions experienced in Australia.
- We also updated the Short-term Water Information Forecasting Tools (SWIFT) software to improve computational efficiency and include new methods, such as ERRIS. This software facilitates the adoption of research outcomes by the Bureau, supporting improvements in operational forecasts.

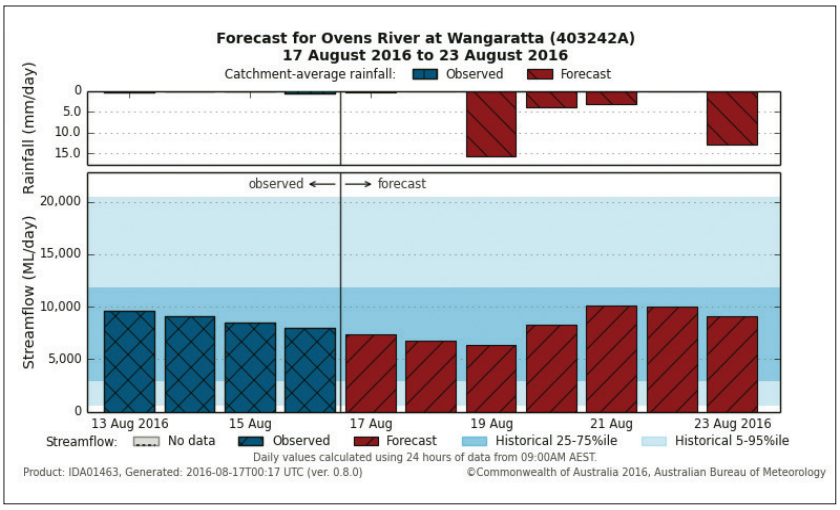
OUTCOME

In 2015, the Bureau released its seven-day streamflow forecast service to the public, covering 103 locations in 50 catchments around Australia.

The service uses deterministic modelling approach and relies on software, systems and toolkits developed under WIRADA—including hydrological forecasting and error reduction. It combines real-time observations from a national network of rain and river gauges with computer models to simulate rainfall, runoff and streamflow.

These forecasts advise water managers, primary producers and others on likely river flow for each of the next seven days. More accurate forecasts lead to economic benefits through better management to meet production and environmental water needs.

A more advanced service is being tested that will provide hourly ensemble forecasts out to seven days to help dam and river operators plan water releases around expected rainfall. This will make use of more recent WIRADA research, including rainfall post-processing methods, and will provide probabilistic forecasts that give the likelihood of any of a range of streamflows occurring.



Seven day forecast for Ovens River, 17 August 2016. Blue bars represent observed catchment rainfall (upper) and gauged streamflow (lower panel) before the forecast was issued. The red bars represent the total forecast rainfall (upper panel) and streamflow (lower panel) for each the next seven days. The light blue shading in the background is the 5th–95th percentile and dark blue shading is the 25th–75th percentiles of average historical flows at the current time of the year. The Bureau's 7-day streamflow forecast service has 103 locations in 50 catchments around Australia.

SEASONAL STREAMFLOW FORECASTS

BUREAU SPONSOR	Dasarath Jayasuriya
COLLABORATORS	The Collaboration for Australian Weather and Climate Research; US National Oceanic and Atmospheric Administration; European Centre for Medium-Range Weather Forecasts
PROJECT LEADER	Q.J. Wang

Objective: to increase streamflow forecast accuracy, timeliness and lead time for water managers.

CHALLENGE

Timely and accurate seasonal streamflow forecasts provide vital information for effective water management.

The Bureau's operational seasonal streamflow forecasts cover major water storages and river systems across Australia. Forecasts are issued by the seventh working day of each month, and provide the likelihood of a range of total volumes of water flowing in the next three months.

The service has been well received, with users requesting improvements that include:

- forecasts of monthly volumes, in addition to three-monthly totals;
- more timely publication of forecasts; and
- extension of forecast lead-time beyond three months.

SOLUTION

Previous scientific advances through WIRADA allowed the Bureau to develop services that forecast streamflow out to three months ahead. The service uses WIRADA-produced methods and tools to quantify and convey forecast uncertainty, and to verify forecast accuracy.

In the last year we improved, maintained and extended existing seasonal forecast services. We focused on adapting current models and tools to use outputs from the Bureau's new high-resolution climate model; extending forecasts beyond three months, especially for dry catchments; forecasting monthly volumes in the three months ahead; and enabling forecasts to be produced in a more timely manner. The latter work provides more flexibility to increase the number of forecast locations, while also providing forecasts to stakeholders as early as possible.

2015–16 ACHIEVEMENTS

- We developed techniques that enable forecasts to be generated at least seven days earlier than before, without significant loss of overall skill, allowing earlier release of forecasts to the public.
- We showed that our Bayesian joint probability methods can generate skilful and reliable forecasts of monthly streamflow volumes for the coming three months, with more skilful forecasts at shorter lead-times. When the monthly forecasts are accumulated, they are similarly skilful to the existing three-month volume forecasts.
- We developed the 'ensemble link functions' method to calibrate climate model outputs before they are used in streamflow forecasting. This approach also caters for the ensemble generation configuration that will be used in future Bureau seasonal forecasts.
- We revised the Forecast Guided Stochastic Scenarios model to enable it to produce reliable forecasts in the very challenging extremely dry catchments, where flows often cease for some time during the year. This will allow the Bureau to provide forecast services further into drier regions of Australia.

OUTCOME

The Bureau's seasonal streamflow forecasts are available for more than 140 locations across Australia. They are used by river managers and water storage operators to plan water supplies, transfers and environmental flows. They are also used as an input when determining water allocations each season, and to inform planning and strategic decision-making.

One- and three-month streamflow forecasts based on a dynamic modelling approach have been evaluated for 300 locations and released for 100 locations, with sites in every State and Territory. The dynamic approach uses hydrological models to simulate changes in streamflow and catchment state in response to inputs from the Bureau's seasonal climate prediction model.

The Bureau aims to release a merged forecast based on statistical and dynamic models in 2018. This will allow the Bureau to further increase the number of forecast locations and improve forecast quality.

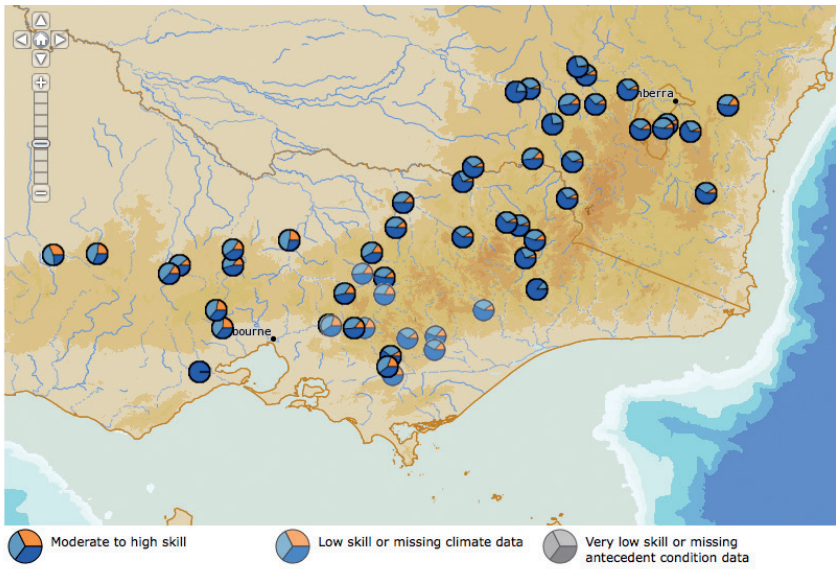
WE HAVE EXTENDED
SKILFUL STREAMFLOW FORECASTS
TO THREE MONTHS AHEAD

OUR RESEARCH WILL LEAD TO

MORE TIMELY AND ACCURATE FORECASTS

MORE THAN **140** OPERATIONAL SEASONAL STREAMFLOW FORECAST LOCATIONS ACROSS AUSTRALIA

August to October 2016 seasonal streamflow forecast for southeastern Australia, indicating that high streamflows are more likely.



IMPROVED WATER INFORMATION THROUGH THE WATER INFORMATION RESEARCH AND DEVELOPMENT ALLIANCE

At the inception of the Improving Water Information Programme, I reasoned that breakthrough research and development was necessary before an appropriate service suite could evolve. It seemed logical to me to look to CSIRO for help, as they had the largest and most talented cohort of applied hydrology researchers. But there were also important niche skills at Geoscience Australia and within several Australian universities that needed to be tapped into. The Water Information Research and Development Alliance (WIRADA) provided a framework for these institutions to work cooperatively to surmount a number of massive problems besetting water information. WIRADA helped to bring together CSIRO's leading expertise in water and information sciences and the Bureau's operational role in hydrological analysis and prediction to deliver value-added water information products and tools.

Australia's water data, sourced from over 180 institutions, were a jumble. Our researchers responded by building the Water Data Transfer Standard, enabling all data suppliers to provide their information to the Bureau in a standard form. Likewise, there was no standardised digital 'water map' for Australia, defining catchment boundaries, river course and reservoir positions, the location of hydrologic monitoring points and so on. Our researchers responded by building the Australian Hydrologic Geospatial Fabric. Now we could see how hydrologic systems were connected.

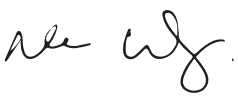
We had no way to look back through time and see where all the water went. How much rainfall became runoff, replenished soil moisture or seeped to groundwater? We couldn't say until our researchers built the Australian Water Resources Assessment model. This made it possible to compile national water accounts. Another serious deficiency in the water sector was that we had no ability to predict future inflows into our reservoirs. This got us in to trouble during the Millennium Drought so a new predictive capability was vital to harden our nation's water security. Our researchers responded by building the Seasonal Streamflow Forecasting System that provides streamflow forecasts for more than 140 locations across Australia for the next three months, updated monthly. There were many other breakthroughs too but these examples highlight how seminal research and development was to the Improving Water Information Programme.

The research conducted under WIRADA has been of an exceptional standard, described extensively in leading international journals and praised by the international research community. Equally impressive has been the implementation of the research products into operational services by the Bureau, enabling day-to-day use of valuable services for end users in the water sector. So much research and development fails to make a difference. Not so in WIRADA. This program of effort has been more efficient and productive than any other I have known during my long career in applied hydrologic research.

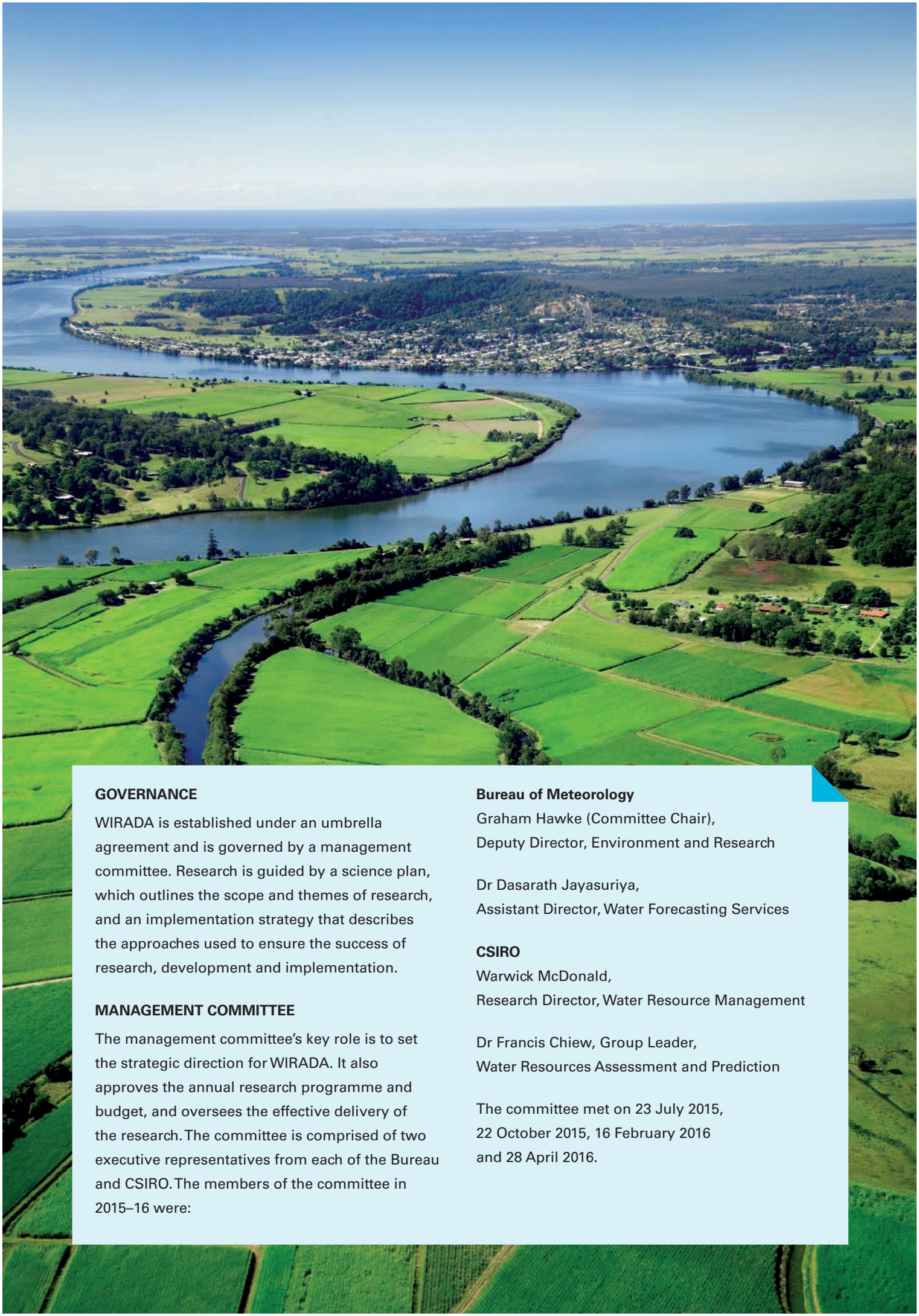
To my mind, the five key success factors for the WIRADA program have been:

- the union of Australia's very best researchers with an operational agency;
- competent governance provided by very senior officials at CSIRO and the Bureau;
- crystal-clear articulation of end user needs;
- diligent project planning and project management overseen by the talented managers that served as WIRADA Directors; and
- a commitment to, and excellence in, transitioning research products into operations.

I congratulate everyone involved in WIRADA for an outstanding contribution to the nation.



Dr Rob Vertessy FTSE
Former Director of Meteorology



GOVERNANCE

WIRADA is established under an umbrella agreement and is governed by a management committee. Research is guided by a science plan, which outlines the scope and themes of research, and an implementation strategy that describes the approaches used to ensure the success of research, development and implementation.

MANAGEMENT COMMITTEE

The management committee's key role is to set the strategic direction for WIRADA. It also approves the annual research programme and budget, and oversees the effective delivery of the research. The committee is comprised of two executive representatives from each of the Bureau and CSIRO. The members of the committee in 2015–16 were:

Bureau of Meteorology
Graham Hawke (Committee Chair),
Deputy Director, Environment and Research

Dr Dasarath Jayasuriya,
Assistant Director, Water Forecasting Services

CSIRO
Warwick McDonald,
Research Director, Water Resource Management

Dr Francis Chiew, Group Leader,
Water Resources Assessment and Prediction

The committee met on 23 July 2015, 22 October 2015, 16 February 2016 and 28 April 2016.

MESSAGE
FROM THE CHAIR

The success of the Bureau's Water Information Programme relies on innovative science delivered from the Water Information Research and Development Alliance.

Our research partnership with CSIRO has allowed the Bureau to overcome many practical challenges to develop and deliver a range of national water information products and services demanded by industries and communities. A suite of information products developed with WIRADA science is now used across Australia for:

- flood mitigation;
- water supply forecasting;
- river management and environmental flows;
- water sharing plans;
- policy advice; and
- investment and rural financing.

Now in the eighth year of our partnership, our focus has been to ensure that we have translated research investment into products and services for those that manage our vital water resources.

In 2015–16, WIRADA research continued to be released to the public through new and updated water information services supported by world class research.

To share and celebrate our recent research we held a special WIRADA-themed session in December at the international Hydrology and Water Resources Symposium in Hobart. The Bureau also launched its new seven-day national streamflow forecast service and unveiled an interactive website providing public access to national high-definition datasets of key water balance terms. These products represent a culmination of eight years of research into forecasting methods and the Australian Water Resources Assessment Model.

I am pleased to report on WIRADA's achievements for 2015–16 and reflect on the successes over the last eight years. I also thank the research teams for their effort to complete vital research during this year, and to thank all who have contributed to the success of this eight-year partnership. I am delighted the successful partnership has been extended into a ninth year.

Graham Hawke Deputy Director,
Environment and Research

It is with enormous pride that I reflect on the achievements of WIRADA—the eight-year partnership between CSIRO and the Bureau of Meteorology—that was developed to provide high-value, high impact water information products and services for the nation.

Together, we have delivered excellent science and water information services that have enabled us to extend our reach and impact internationally, through streamflow forecasting, continental water balance modelling, water data exchange and interoperability standards, both now and into the future.

WIRADA's success is located in its shared vision and teamwork. Its outputs and outcomes represent 250 person-years in research effort that involved more than 200 scientists and operational staff.

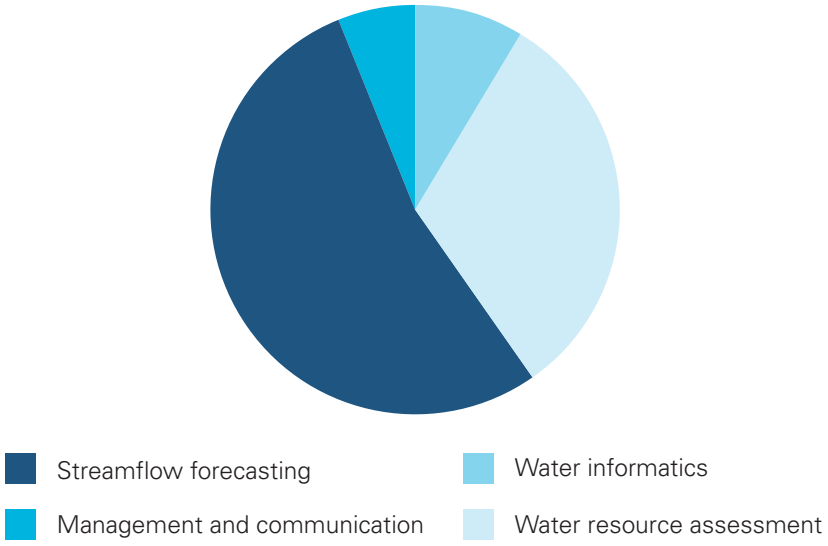
I congratulate both the CSIRO and Bureau teams on their achievements during this year, which culminated in the successful delivery of an unprecedented information platform that directly supports sustainable water management in Australia. Everyone involved should be extraordinarily proud of this remarkable achievement.

Warwick McDonald
Research Director,
Water Resource Management, CSIRO

PERFORMANCE REPORT

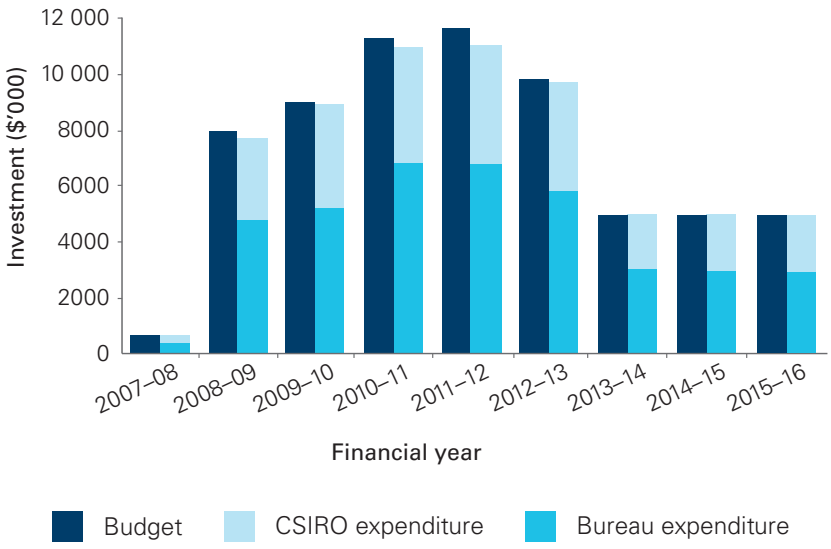
FINANCE AND RESOURCES

The 2015–16 investment of $5 million was allocated to water informatics (9 per cent); water resource assessment modelling (32 per cent); streamflow forecasting (54 per cent); and management and communication (6 per cent). The end-of-year financial position for WIRADA was an under-expenditure of $91,000.



WIRADA BUDGET PERFORMANCE

The WIRADA budget plan for 2015–16 proposed 16.00 full-time equivalents to be allocated to the four research projects. Total expended effort for the programme was 15.50 full-time equivalents. In addition, the Bureau of Meteorology contributed 3.25 full-time equivalents in kind.



DELIVERY AND PRODUCTIVITY

WIRADA had 55 deliverables across five projects scheduled for completion in 2015–16. One deliverable was stopped, based upon changes agreed with the project sponsor. At year's end all 54 deliverables had been submitted and 52 (96 per cent) accepted. All remaining deliverables were due for completion in July 2016.

Over 2015–16 WIRADA produced:

- 9 journal papers published;
- 9 journal papers in press;
- 47 conference papers; and
- 16 technical reports

Total WIRADA output since 2008 is summarised in the table below. A full listing of WIRADA research outputs is available at www.bom.gov.au/water/about/waterResearch/wirada.shtml

PERIOD	JOURNAL PUBLISH	JOURNAL SUBMITTED	BOOKS	CONFERENCE PAPERS[1]	PUBLISHED REPORTS	INTERNAL REPORTS	TOTAL
0809	17		1	45	41	21	**125**
0910	13		0	32	26	41	**112**
1011	11		0	91	16	4	**122**
1112	22		1	79	7	7	**116**
1213	11		0	30	10	1	**52**
1314[2]	15		5	50	14	10	**94**
1415	15		0	27	10	11	**63**
1516	9	9	1	47	13	3	**82**
Total	**113**	**9**	**8**	**401**	**137**	**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
2015–16

STRATEGY	KEY PERFORMANCE MEASURE	ACHIEVEMENT
1. TARGETED RESEARCH	**Goal: Design an integrated and coordinated research portfolio that targets medium to longer tem end user needs.**	
1.1 Define research direction	**OBJECTIVE 1:** 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.	
	Confirmation by the Bureau that WIRADA outputs meet their and their users' needs.	**ACHIEVED:** 96 per cent of WIRADA deliverables have been accepted by the Bureau
	WIRADA project agreements refreshed and approved annually by the management committee.	**ACHIEVED:** New project agreements for 2016–17 developed and approved by Management Committee
	WIRADA communication plan aligned with Bureau's product adoption plans.	**ACHIEVED:** WIRADA communication activities are a subset of the Bureau's broader product adoption.
1.2 Align research for impact	**OBJECTIVE 2:** Determine the priority between research investments and develop path to impact.	
	WIRADA research transition plans developed for all projects.	**ACHIEVED:** Research transition plans embedded in all individual project plans for 2015–16.
	WIRADA communication plan developed, reviewed quarterly and progressively being implemented.	**ACHIEVED:** 2015–16 communication implementation plan approved in July 2015; implementation reviewed quarterly.

STRATEGY	KEY PERFORMANCE MEASURE	ACHIEVEMENT
2. QUALITY RELATIONSHIPS AND COLLABORATION	**Goal: Develop quality relationships and harness added value from related research investments particularly across the Water for a Healthy Country flagship portfolio, and build enduring partnerships with supporting initiatives.**	
2.1 Develop relationships	**OBJECTIVE 1:** Define and develop relationships to enhance delivery of the WIRADA programme and establish the necessary governance arrangements.	
	Processes for Bureau engagement in project design, development and delivery defined, agreed and implemented—i.e. project sponsor, business lead, implementation lead, Bureau research team members.	**ACHIEVED:** Roles defined and implemented through project planning templates and guidance, progress reporting and review, and deliverable submission and approval workflows.
	Bureau staff actively engaged in the research design and development. CSIRO researchers actively participating in R&D transition processes to operations.	**ACHIEVED:** Joint project governance arrangements operate for all research projects. Dedicated project activities exist to transfer research to Bureau operations and information technology systems
	Outcomes specified and monitored for collaboration with CAWCR, eWater, and GA.	**NOT APPLICABLE:** No formal collaborations in place in 2015–16.
	Outcomes specified and monitored for collaboration with international initiatives including CUAHSI, OGC and WMO.	**ACHIEVED:** WIRADA leadership in GroundwaterML2.0, WaterML2.0 part 2, and TimeseriesML international standards development
	No skills gaps or shortage of capabilities to meet demand.	**ACHIEVED:** All projects met skill and resource demands with most deliverables accepted during the year.

WIRADA REPORT CARD
2015–16

STRATEGY	KEY PERFORMANCE MEASURE	ACHIEVEMENT
2.2 Harness collaboration	**OBJECTIVE 2: Harness and value-add from relevant research investment.**	
	Action plans for research collaboration implemented with particular regard to eWater, CAWCR, GA, CUAHSI and relevant CSIRO Land and Water themes.	**ACHIEVED:** All projects make use of strong collaboration opportunities with state, national and international research partners.
	Jurisdictional and industry participation in WIRADA research projects and pathways for adoption specified (including training).	**ACHIEVED:** WIRADA science progress and products presented through WIRADA sessions at the 36th Hydrology and Water Resources Symposium in Hobart, Tasmania, 2015. Adoption of AWRA supported through series of briefings with commonwealth and state natural resource management agencies.
	WIRADA research project participation and leadership in communities of practice.	**ACHIEVED:** WIRADA research project members are active within research community groups including the OGC Hydro Domain Working Group, Hydrological Ensemble Prediction Experiment, and Australian Energy and Water Exchange initiative.

STRATEGY	KEY PERFORMANCE MEASURE	ACHIEVEMENT
3. QUALITY DELIVERY AND IMPACT	**Goal: Deliver quality science with real-world impact and positive peer recognition.**	
3.1 Manage science quality	**OBJECTIVE 1:** Ensure sound science quality management practices maintained.	
	More than 80 per cent of the WIRADA deliverables achieved and accepted to time and budget, with the delayed deliverables completed within 30 days.	**ACHIEVED:** 100 per cent of WIRADA deliverables achieved and 96 per cent accepted for the year, remaining deliverables are due for completion early in the following quarter.
	The majority of WIRADA research outputs embedded in, or influential on the implementation of Bureau operational systems.	**ACHIEVED:** Short-term water forecasts released to public; Seasonal streamflow forecasting service expanding; data outputs from AWRA-L model are now available to the public.
	WIRADA portfolio subject to periodic independent peer review and aligned with formal reviews of the Improving Water Information Programme and CSIRO Land and Water Flagship.	**NOT APPLICABLE:** No formal independent reviews held in 2015–16.
	Scientific publication productivity and citation index at or above the CSIRO benchmark (two journal papers per research scientist).	**NOT ACHIEVED:** WIRADA included 15.5 full time equivalents in 2015–16, while 9 journal papers were published.

WIRADA REPORT CARD
2015–16

STRATEGY	KEY PERFORMANCE MEASURE	ACHIEVEMENT
3.2 Champion, evaluate and feedback	**OBJECTIVE 2:** Champion the research outcomes, assess impact and adapt the WIRADA research programme.	
	WIRADA research outcomes reported in media coverage, participation in key jurisdictional and industry forums and contribution to international initiatives.	**ACHIEVED:** 47 conference papers at eight national and international conferences. Dedicated WIRADA sessions at the 36th Hydrology and Water Resources Symposium in Hobart, Tasmania, 2015.
	Research impact assessment undertaken and reported in the WIRADA Annual Research Report.	**ACHIEVED:** 2015–16 Annual Report drafted for approval by the Management Committee.
	A rolling implementation strategy and investment profile agreed by Bureau and CSIRO through the WIRADA management committee.	**ACHIEVED:** 2016–17 investment approved in July 2016.