Water Information
Research and
Development Alliance

ANNUAL REPORT 2008-09

Australian Government
Bureau of Meteorology

National Research
FLAGSHIPS
Water for a Healthy Country
CSIRO

Water Information
DATA › INFORMATION › INSIGHT

Contents

Water Information Research and Development Alliance

Through the *Water Act 2007*, the Australian Government has given the Bureau of Meteorology (the Bureau) responsibility for compiling and delivering comprehensive water information across Australia.

Water resources information is currently collected and reported by more than 200 organisations across Australia, using a variety of methods. The range of collection and reporting methods and arrangements for accessing water data has made it difficult to monitor the status and use of Australia's water resources and reliably forecast water availability. This has compromised the effectiveness of water resources management and planning.

Improved accessibility, integration and use of national water resources information will result in better informed policy and infrastructure decisions and better evaluation of water sector reforms. This will also lead to greater confidence in how Australia manages this vital resource. These outcomes require substantial innovation and this can only be achieved through a world-class water information research and development program.

The Water Information Research and Development Alliance (the Alliance) will transform the way Australia manages its water resources by delivering value-added water information products and tools based on a comprehensive and robust nationwide water information system.

The Alliance brings together the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) nation-leading expertise in water and information sciences with the Bureau's new operational responsibilities in water information. Through the Water for a Healthy Country Research Flagship around 40 leading CSIRO researchers are focusing on topics including data interoperability, hydrologic modelling, water accounting and water resource assessment and water availability predictions.

The Alliance is guided by the *Science Plan*, which outlines the scope of research and the *Implementation Strategy*, which guides investment priorities, maps out at a high level how the research may unfold over the next five years, and identifies processes to facilitate the transition of research into the Bureau's water information policies, systems, products and services.

Governance

The Alliance was established in April 2008 under an *Umbrella Research Collaboration Agreement* and is governed by a management committee.

The management committee's key role is setting the strategic direction for the Alliance, approving the annual research program and budget and overseeing effective delivery of the research program.

The committee comprises two executive representatives each from the Bureau of Meteorology and the CSIRO, with the Director of Meteorology as Chair. The committee members are:

Bureau of Meteorology
Dr Greg Ayers,
*Director of Meteorology
(from June 2009)*
Dr Neville Smith,
*Acting Director of Meteorology
(to June 2009)*
Dr Rob Vertessy,
Deputy Director Water

CSIRO
Dr Andrew Johnson,
Group Executive Environment
Dr Tom Hatton,
*Director Water for a Healthy Country
National Research Flagship*

The committee meets at least quarterly. Over the last year meetings were held on 11 August 2008, 30 October 2008, 17 November 2008, 9 February 2009, 1 May 2009 and 19 June 2009.

Message from the Chair

The Water Information Research and Development Alliance was launched by the Minister for Climate Change and Water the Hon. Penny Wong on 4 September 2008.

Our partnership offers the necessary mix of research expertise and operational experience to deliver high quality water information products and services. The Alliance also offers a rare opportunity to truly develop and deliver a collaborative program where Bureau and CSIRO teams undertake their activities in an integrated and focussed manner.

The Alliance is off to an excellent start. Research began in April 2008 with a number of 'bridging' projects. These projects helped define the scope of research to support the Bureau's water information functions. The Alliance's science plan was completed in May 2008.

As a pair of 'fresh eyes' (having recently been appointed as Director of Meteorology), I was struck by the ambitious and exciting science underway.

While there are many scientific and technical challenges ahead, our researchers have proven they are up to the task. Perhaps the greatest challenge of all is in meeting the ambitious plans and timelines for the Bureau to provide Australia with high quality water resource assessment, accounting and forecasting information services.

Robust science will provide the means and credibility to build user confidence in the Bureau's water information outputs. The program is demonstrably gathering momentum with the Water Data Transfer Format as the first of many research outputs to be adopted by the Bureau and water data providers across Australia.

I would like to extend my sincere gratitude to the leadership and guidance of Ian Prosser (interim Alliance Director) and his CSIRO colleagues Ross Ackland and Stuart Minchin in the formulation of the initial research portfolio. The Alliance Director, Warwick McDonald has developed the implementation strategy and operating procedures to put our partnership on a strong footing. Finally, I would like to acknowledge the contribution of Neville Smith who established and skilfully chaired the Management Committee until June 2009. Our sincere thanks are also due to Bruce Stewart who helped establish the Alliance and provided guidance on implementation as the Water Division's Research and Development Manager.

The management committee is looking forward to an exciting and productive year ahead.

G. P. Ayers

Dr Greg Ayers
Director of Meteorology

Greg Ayers
Director of
Meteorology

'The nation as a whole will benefit through the development of new tools and techniques in water reporting and assessment.' —Minister Penny Wong, *September 2008*

Dr Tom Hatton, Dr Rob Vertessy and Minister Penny Wong
PHOTO: MARK GRAHAM

Alliance Director's report

Excellent progress has been made across the Alliance's portfolio in our start up year, in terms of both research and collaboration. Our productivity is high, with a healthy balance between technical outputs and peer reviewed journal and conference papers.

Our research portfolio is designed to support the key functions and responsibilities of the Bureau of Meteorology.

Water information systems projects are defining water data transfer standards to support the Bureau's data ingestion and delivery requirements; developing workflow solutions that link hydrological data, models and reporting systems; and creating toolsets for best practice information management.

Substantial progress has already been made in the development of the interim Water Data Transfer Format with uptake by a number of industry and agencies data providers. CSIRO research and Bureau operational teams have worked in very close collaboration to achieve this outcome.

Foundation data products projects will provide fundamental data and methods to operationally generate rainfall, evapotranspiration and digital elevation model data sets that will be part of the Australian Hydrological Geospatial Fabric (Geofabric) which is being used to spatially enable Australia's water information.

With support from our partners Defence Imagery and Geospatial Organisation, Geoscience Australia and Australian National University a digital surface model and digital elevation model for the continent are now available to all government agencies (local, state and federal).

Water resource assessment and accounting research is developing methods and prototype systems for comprehensive national water assessments and water accounts. A prototype water balance system of models has been completed and is ready for testing by the Bureau. A draft uncertainty framework to support water accounts has been completed and will be tested in the pilot account accounts.

Water forecasting has the greatest potential to add economic and social value to Australia. Our projects are focusing on enhanced flood and continuous streamflow forecasting, and using statistically-based seasonal forecasting methods.

Statistical techniques using a range of indices that describe climate patterns, including El Niño-Southern Oscillation, have been demonstrated to improve prediction of seasonal streamflow forecast.

As a result of the outstanding achievements in each of these areas to date, the year ahead will see at least five research products implemented by the Bureau: the digital elevation model (which will be added to the Geofabric), the first of our continental precipitation data products, our prototype seasonal forecasting system using statistical methods, Version 1.0 of the water data transfer format (which will be embedded within the Australian Water Resources Information System (AWRIS)), and workflow automation for water resource assessment information products.

Finally, some well deserved thanks are due to the people who are at the heart of this program's success over the past year. To the research teams—what a fantastic start to this important program. Your efforts are already having an impact, well done! To the Bureau operational teams—thank you for your guidance and support to get the research program focused. Your continued involvement is vital.

Building on the solid foundations laid down over the past year, the year ahead is set to be just as successful—I'm looking forward to it!

Warwick McDonald
Alliance Director

Warwick McDonald
Alliance Director

collect · discover · ingest · assemble

Water resources and aquatic ecosystems

Climate and water monitoring and data collection

Data ingest and storage
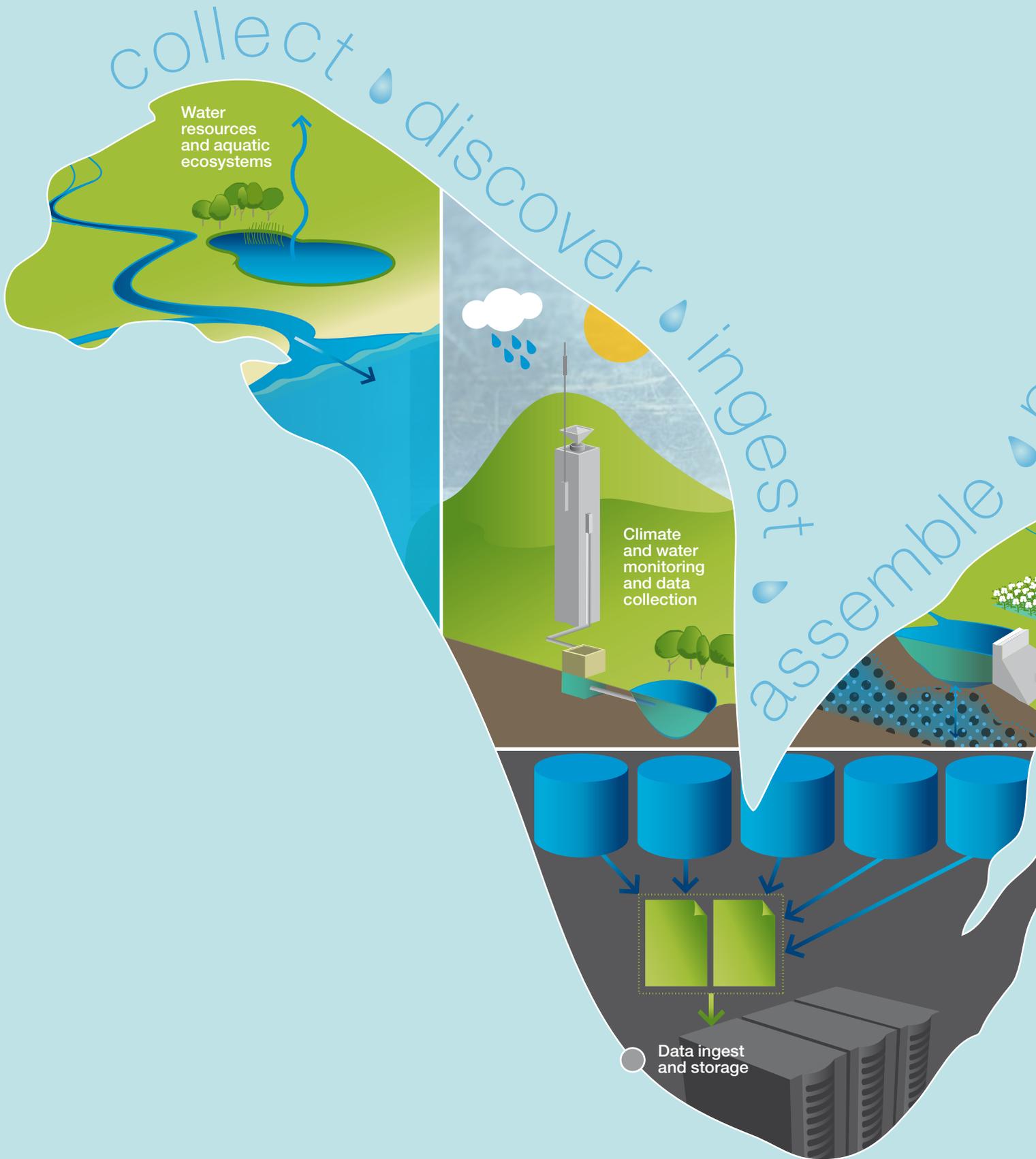
PROJECTS	Water Data Transfer Standards	Geofabric Design	Precipitation and Actual Evapo-transpiration products	Water Resources Assessment and Accounting

polish • augment • share • analyse • predict • report

Water balance analysis

Flood forecasting and warning

Water availability forecasts

Water information

Rainfall (mm)

800mm
600mm
400mm
300mm
200m
100
50

One-second
Continental DEM

Hydrologists
Workbench

Water forecasting and
Prediction – short term

Water forecasting and
Prediction – seasonal to
long term

5

Water Data Transfer Standards

Defining water data transfer standards and procedures
to meet the Bureau of Meteorology's data ingestion requirements.

BUREAU SPONSOR: Tony Boston

COLLABORATORS: Consortium of Universities for the Advancement of Hydrologic Science, Inc.
Open Geospatial Consortium
World Meteorological Organization

PROJECT LEADER: Simon Cox

Challenge

Water observations data such as river flow and groundwater level, are key elements of a water resources information system. At present these data are collected by many organisations in different formats using a range of methods. Standardising the format of the water observations data will make water information data more accessible and more useful, and will allow for the development of a state-of-the-art water resource assessment and accounting system. This will streamline the management of Australia's water resources data.

Solution

To meet the Bureau's immediate need of collecting and processing water information from more than 200 organisations, the project team is defining and developing the Water Data Transfer Format (WDTF). This standard will allow water data providers including government agencies, water suppliers, catchment management agencies and municipal councils to efficiently deliver water observation data to the Bureau in a format that is easily loaded into the Australian Water Resources Information System (AWRIS), and is consistent with information submitted by other providers.

The Bureau is promoting WDTF as a format for data exchange between organisations. WDTF will give water managers, decision making agencies and researchers easier access to water data, which in the past has had to be assembled and converted from numerous formats before it could be used.

The project team is also working with the international hydrological community to develop a water data transfer standard (WaterML2.0) that will be used worldwide. WaterML2.0 will include features from WDTF.

Achievements

The project team has delivered WDTF to the Bureau of Meteorology. WDTF was developed using Extensible Markup Language (XML), a standard notation for web-based data transfer. Its data model is based on the Open Geospatial Consortium's (OGC) observation and measurements standard. This makes WDTF compatible with standards for related environmental data and web data delivery.

The project team has also delivered a prototype vocabulary service to the Bureau of Meteorology. Water observation data uses many terms and definitions (vocabularies) that differ across jurisdictions and organisations. To streamline data collection and reporting the team is developing common vocabularies for water information. These vocabularies will underpin WDTF and feed into WaterML2.0.

Hydrology Domain Working Group

A highlight of the Alliance's first year was formation of the OGC Hydrology Domain Working Group. The OGC is an international organisation that is developing standards for spatial information. The Hydrology Domain Working Group is unique within OGC as it is a joint working group with the World Meteorological Organization.

The group provides a forum for the harmonisation and development of standards and best practices associated with hydrological data sets. The project team will be playing a significant role including co-chair and technical development. It is planned that a WaterML2.0 specification developed within the Water Data Transfer Standards project will be submitted to OGC for feedback and input into the specification.

Other participants in the working group include: San Diego Supercomputer Centre, University of Texas, Infrastructure for Spatial Information in Europe (INSPIRE), Consortium of Universities for the Advancement of Hydrologic Science, Inc., Global Runoff Data Centre (GRDC), Water Information System for Europe (WISE), US Geological Survey and Natural Resources Canada.

Next steps

In 2009/10 the project team will hand over day-to-day maintenance of WDTF to the Bureau of Meteorology and will continue to refine the standard based on feedback from the Bureau and Australian water agencies. This refinement will include support for groundwater data and water trading requirements. The project team will also develop automated generation of user documentation for WDTF so that it is updated quickly and easily so that users have updated documentation as the standard develops.

The team will continue to be a leading partner in the development of WaterML2.0 and to promote international water data standards through the OGC Hydrology Domain Working Group. Over the next 12 months they will develop an XML Schema, primarily covering water observation time-series data, backed by a data model in the Unified Modelling Language (UML). The schema will be put to the OGC for endorsement.

The project team will also continue to develop common vocabularies for water information, looking particularly at extending web-based solutions for hosting vocabulary services to cover vocabulary versioning and governance arrangements.

FIGURE 1

WaterML2.0 design methodology
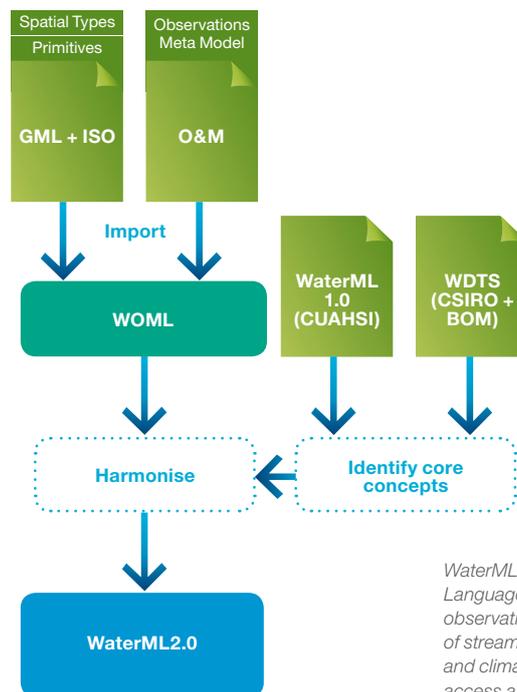
ACRONYMS

CUAHSI Consortium of Universities for the Advancement of Hydrologic Science, Inc.

GML Geography Mark-up Language

O&M Observations and Measurements

WDTS Water Data Transfer Standard

WOML Water Observations Mark-up Language

ISO International Organization for Standardization

WaterML Water Mark-up Language

WaterML2.0 is an eXtensible Markup Language (XML) schema for time series observations, at specified locations, of streamflow, water quality, groundwater and climate to enable data discovery, access and transfer.

WaterML1.0 from CUAHSI and WDTS from CSIRO are being used to identify the critical concepts for capturing water information. Water Observations Markup Language (WOML) is existing work that CSIRO has used in the area of developing an OGC-based information standard, which uses information models from GML, ISO and O&M. Combining this with the concepts from WDTS and WaterML1.0 through a processes of harmonization we will develop WaterML2.0.

Australian Hydrological Geospatial Fabric Design

Developing methods and tools for managing multi-scale, multi-version geospatial data sets.

BUREAU SPONSOR: Tony Boston

COLLABORATORS: PSMA Australia
Office of Spatial Data Management
Infrastructure for Spatial Information in Europe (INSPIRE)

PROJECT LEADER: Rob Atkinson

Challenge

The water community uses a variety of water information systems. These systems are typically developed to support specific business processes within customised operating environments and cannot be easily linked. This lack of consistency in information systems presents many technical challenges for users and developers of hydrological applications. The key challenge is to achieve continuity and consistency by creating standards and tools that work together to allow access, retrieval and publishing of water information data as systems and applications evolve over time.

Solution

The project team is developing a framework for managing access to, and storage and retrieval of, a growing knowledge base of hydrological and geospatial data. This framework, the Australian Hydrological Geospatial Fabric (Geofabric), will be a single, national geospatial database, which the Bureau will use to undertake water-related reporting and analysis. It will contain authoritative versions of hydrological features including catchment boundaries, streams, aquifers, floodplains, storages and wetlands. The Geofabric will store foundation data sets, including the one-second continental digital elevation model data sets being developed through the Alliance.

Achievements

The project team has developed a conceptual model of the Geofabric. The model is platform independent and is written in the industry-standard Unified Modelling Language (UML). By separating conceptual and data product aspects this innovative model has captured the essential elements of the Geofabric design in a way that can be used by all interested parties including data managers and software developers creating data access services, analysis functions or client applications such as AWRIS.

The team has also developed a methodology and tools for management of the Geofabric. Some of these tools directly automate the steps involved in:

— mapping an existing database implementation to a conceptual model

— creating a new database implementation view from a conceptual model

— transforming a UML model to a database schema

— generating data migration Standard Query Language (SQL) script

— generating SQL views to recreate an existing implementation or new database from the entire conceptual model.

This automation increases the consistency and efficiency of database documentation, management and development, particularly when new data types or revised data sets are added.

FIGURE 2
Geofabric conceptual architecture

BUILD FOUNDATION DATA · STORE, MAINTAIN AND RETRIEVE DATA · SUPPLY VIEWS ON THE DATA
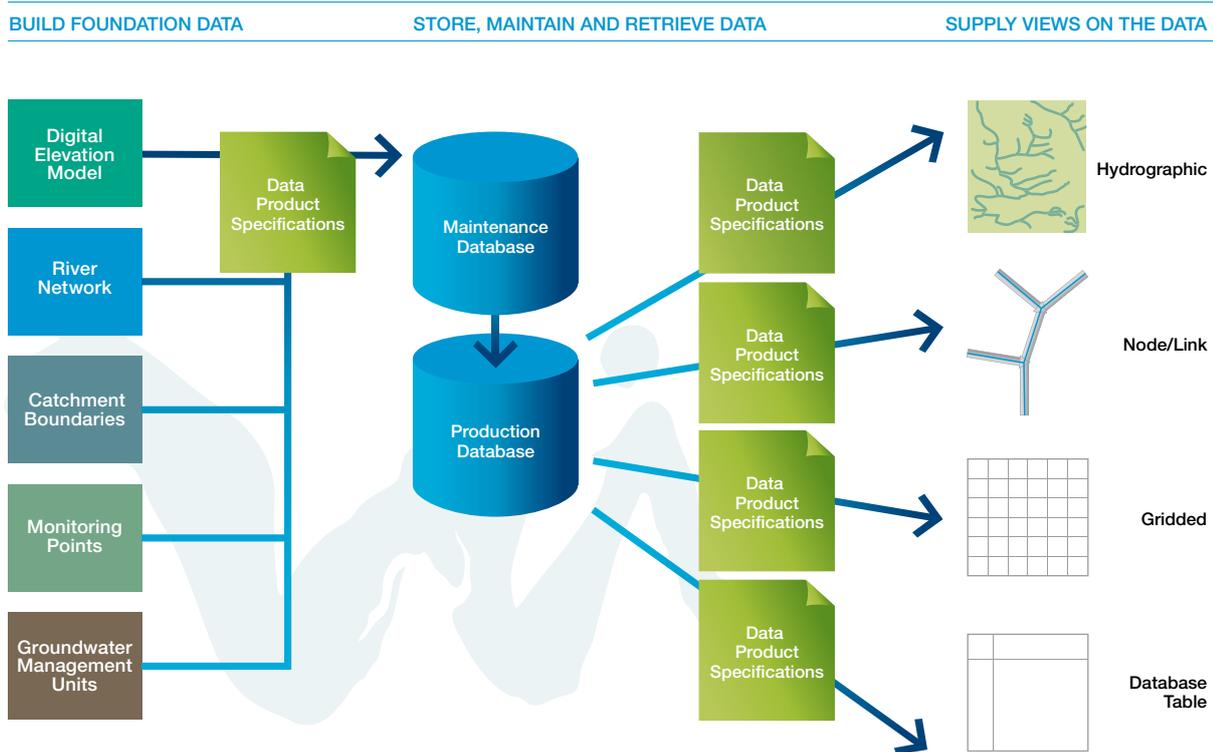
The AHGF is designed such that a suite of data products at different spatial and temporal resolutions, and using different representations of features where appropriate, can be produced from a single maintenance environment. This is required to support the many disparate needs of the Bureau. Key to this design are formal data product specifications that describe each required product as well as input data sets. Underpinning the AHGF is a formal, modular conceptual model which allows for direct mapping between the input data sets and the many products.

Next steps

From 2009/10 the Sustainable Water Information Models project will further develop the water information management principles, methods and tools generated in this project and apply them to support the design of the Geofabric and AWRIS. This will involve finalising and testing the design of a modular, evolvable information model for the Geofabric and using information-model driven architectures to manage AWRIS metadata catalogues.

By developing common underlying metadata models for AWRIS and the Geofabric, future integration of these tools and systems will be easier.

The core components of this model will be proposed to the OGC Hydrology Domain Working Group as a candidate model for the features of WaterML2.0.

Hydrologists Workbench

Developing a platform-independent tool for linking hydrological models and large data sets across multiple platforms in a repeatable, auditable and transparent way.

BUREAU SPONSOR: Louise Minty

COLLABORATORS: Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.
University of Muenster

PROJECT LEADER: Michael Kearney

Challenge

Developing a water account or undertaking a water resource assessment involves many activities using a variety of tools and data sets. It involves large data volumes and often includes activities that are highly repetitive and labour intensive. To produce regular national water accounts and assessments, the Bureau needs tools to automate many of these activities so they can be performed easily, efficiently and in a repeatable, transparent manner.

Solution

The Hydrologists Workbench (HWB) is a productivity tool that uses scientific workflows technologies to link the activities involved in water resource assessments and the development of water accounts. It provides a way to describe, link and execute processes involving a range of models, geographic information system (GIS) packages and other tools.

The HWB will be a desktop application that allows users to discover and integrate hydrological models, common work processes and hydrological data (including data held in AWRIS and the Geofabric) into a workflow. It will automate repetitive tasks, not only reducing the time taken to perform them but also providing consistency and repeatability. The HWB will also allow workflows to be saved and re-run at a later date, making the process of developing water resource assessments and water accounts transparent and auditable.

HWB will be fully compliant with the standards and protocols being developed by the Geofabric and Water Data Transfer Standards projects.

Achievements

The project team has evaluated a number of workflow technology platforms for functionality and suitability for hydrological applications. They have also developed a relational database of information typical of water resources assessment for future exploitation by the HWB.

Using GeoNetwork the team has developed and tested a metadata catalogue application to make the Murray-Darling Basin Sustainable Yield data sets more accessible.

Next steps

The HWB's capabilities and features will be extended. Priority water resource assessment applications for development will be determined and released quarterly from September 2009.

Work is also underway on integrating the HWB with other workbenches and tool sets. Focus is on the ARCGIS Server and similar products currently used by the Bureau, and tools in the eWater tool kit.

Rainfall for 250 catchments in two minutes

The project team has demonstrated that a hydrological workflow can be automated, dramatically improving productivity without loss of quality control. For example, the process to calculate the average annual catchment rainfall runoff for all catchments in the Murray-Darling Basin takes several days and involves four to five people using a number of stand-alone software tools. The HWB system calculated average annual rainfall for 250 catchments (40,000 grid cells, 106 years of daily data) in around two minutes on a desktop computer. The workflow also included production of a classified map of the results.

FIGURE 3
Hydrologists workbench
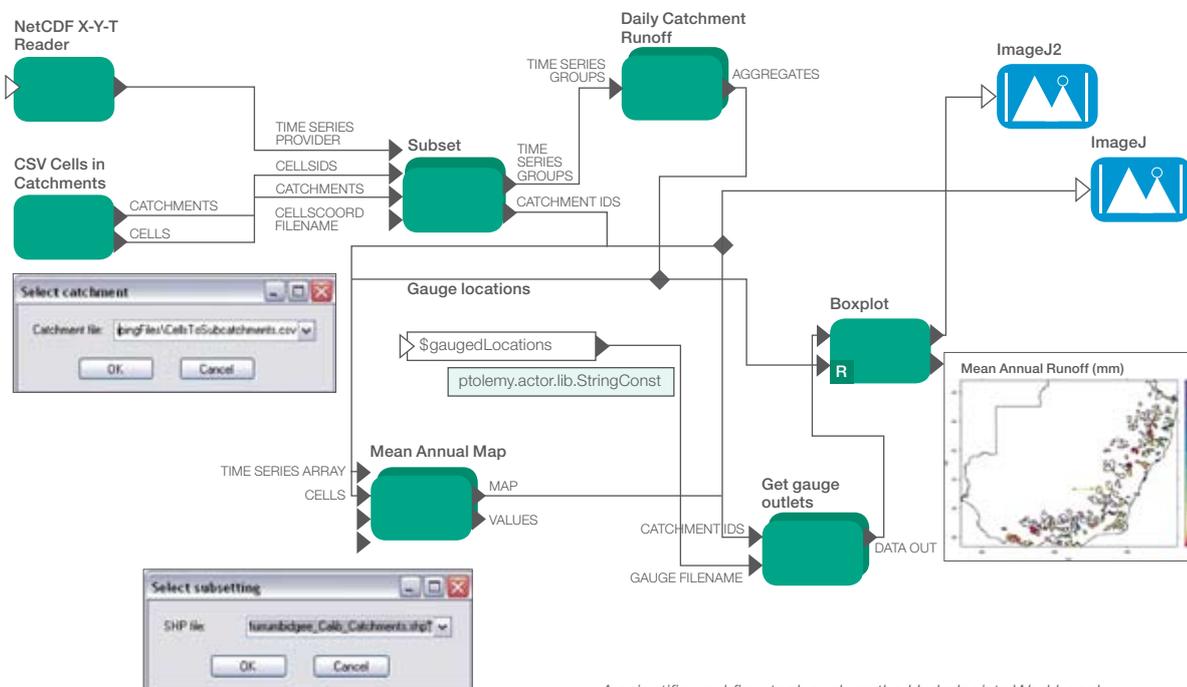
A scientific workflow tool, such as the Hydrologists Workbench, provides the user a graphical interface with which to compose and execute workflows. The complete workflow consists of components (data, models, visualisation functions) linked together such that the outputs of one task can becomes the input to one or more subsequent tasks. This example asks the user to select a catchment which is then used to subset a NetCDF format file of rainfall data. This subset is analysed to produce daily runoff and a spatial visualisation which is produced using the R statistical package.

One-second Continental Digital Elevation Model

Preparing a one-second (30m) resolution digital elevation model for the nation for use in hydrological applications.

BUREAU SPONSOR: Tony Boston

COLLABORATORS: Geoscience Australia
Defence Imagery and Geospatial Organisation
Australian National University

PROJECT LEADER: John Gallant

Challenge

The Bureau needs high resolution elevation (topographic) data for the Australian continent to support water forecasting, assessment and accounting. In the past this was only possible at a nine-second (250 m) grid resolution. Now, the United States National Aeronautics and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) data is available through the Australian Defence Imagery and Geospatial Organisation. While this data has significantly greater resolution—one-second or 30 m—it contains sensor errors and gaps that must be removed and filled before the data set can be used for hydrological modelling.

Solution

The project team is developing new techniques for 'cleaning up' the SRTM data and deriving the best possible hydrologically-sound digital elevation model (DEM). This will result in a new and improved terrain data set for the Geofabric.

Achievements

The project team has delivered two versions of the one-second continental DEM. Version 1 is a cleaned digital surface model (DSM) which has had the sensor anomalies removed and signal voids (gaps) filled for the Australian continent. Version 2 is a bare-earth DEM that has had the vegetation elevation signal removed. Built features, such as urban areas, will be removed in Version 3.

These data products will be part of the Bureau's Geofabric. They are available to local, state and federal government agencies (and their approved consultants) through Geoscience Australia.

Next steps

Version 3 of the DEM will incorporate river network mapping to improve the positional accuracy of drainage features within the product—this is sometimes referred to as hydrological enforcement. The team will also develop methods and tools that use the DEM geometry to transfer information from one hydrological network (e.g. GEODATA TOPO 250K) to more detailed versions.

Developing a national data asset

The one-second DEM for Australia is a foundation data product for understanding how the geometry of Australia's land surface influences the volume and distribution of water resources. When completed, this data product will provide a significant improvement in our national capacity to represent hydrological processes. The development of the one-second DEM is the result of an effective partnership between the Bureau, CSIRO, the Defence Imagery and Geospatial Organisation, Geoscience Australia and the Australian National University. All play a part in the sourcing, analysis, presentation and delivery of the DEM.

FIGURE 4
Shuttle Radar Topography Mission (STRM) cleanup

| Original SRTM | Stripes and voids removed | Vegetation removed |
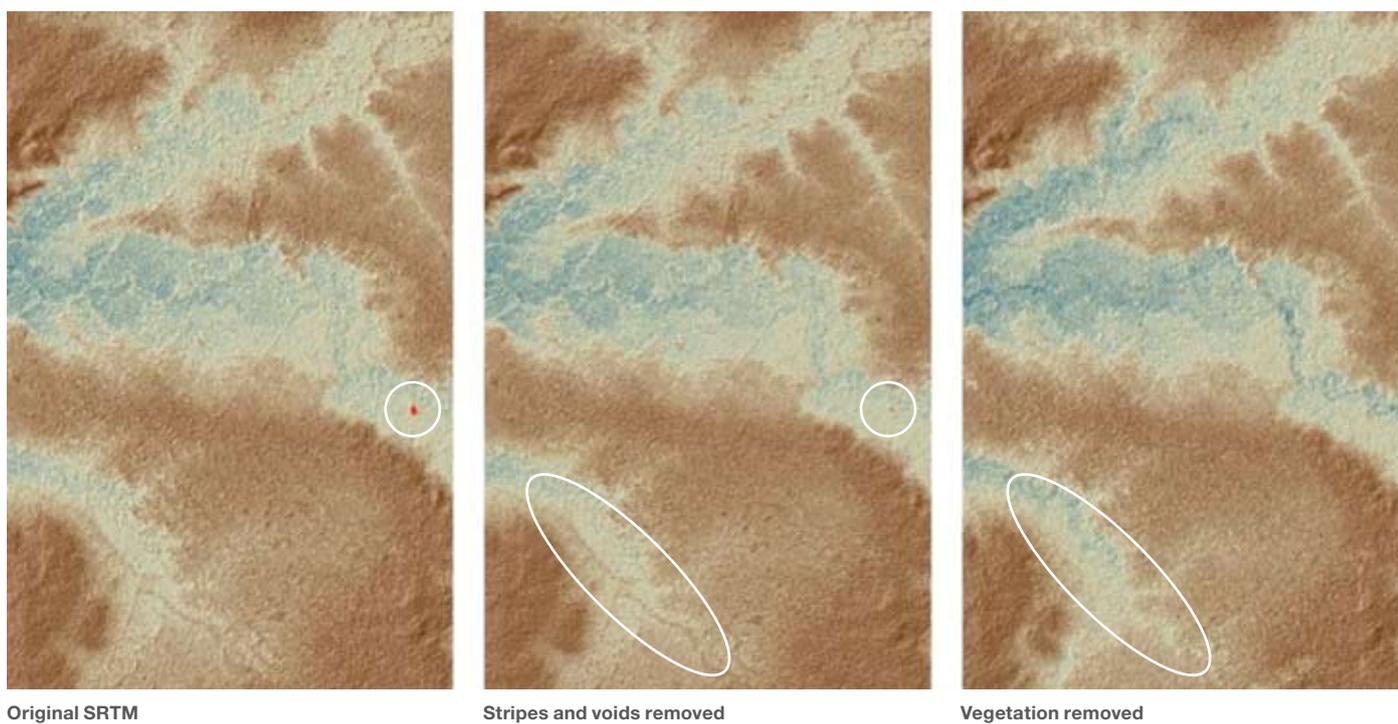
The area around Chichila, southern Queensland

Shuttle Radar Topography Mission (SRTM) sensor errors and gaps must be removed and filled before the data set can be used for hydrological modelling.

Sensor striping in the data set (lower left) and voids (red spot circled) were removed in cleaned digital surface model (DSM – Version 1). The vegetation signal including trees along roads and around (refer oval) water features were removed in the bare-earth digital elevation model (DEM – Version 2)

Precipitation and Actual Evapotranspiration

Developing natioanl data sets of daily precipitation and evapotranspiration with improved accuracy and spatial representation.

BUREAU SPONSOR: Louise Minty

COLLABORATORS: Centre for Australian Weather and Climate Research

PROJECT LEADER: Luigi Renzullo and Edward King

Challenge

Precipitation and evapotranspiration are two of the most important elements of the terrestrial water balance. At present there is no precipitation data set at a resolution in time and space with the accuracy required to adequately meet the Bureau's hydrologic assessment and forecasting needs. There is no agreement on the most suitable methods of computing actual evapotranspiration for hydrological modelling. The Bureau needs precipitation data products suitable for water accounting, assessment and reporting application and improved methods for routinely estimating actual evapotranspiration.

Solution

The project team is developing new methods and tools to produce precipitation and actual evapotranspiration data products to underpin hydrological assessment and forecasting across Australia. They are critically assessing existing methods and developing new techniques to produce gridded (~5 km, ≤daily) precipitation and evapotranspiration data products. With these products the Bureau will be better able to undertake hydrological monitoring and modelling. The data sets will allow improved water management and reporting.

Achievements

Precipitation

The project team has developed a strategy for blending near real-time rain gauge and satellite-based precipitation data for Australia. The strategy includes establishing near and post real-time feeds of satellite-based precipitation estimates, and developing a routine to generate accumulations of satellite estimates that are consistent with daily rain gauge measurements.

The team has also evaluated methods for:

— processing daily radar and gauge precipitation data for use in semi-distributed rainfall-runoff modelling in Australia

— statistical downscaling of numerical weather prediction (NWP) precipitation forecasts

— improving the statistical approach to merge Tropical Rainfall Measuring Mission (TRMM) rainfall estimates and rain gauge data.

FIGURE 5
Precipitation and actual evapotranspiration

Rain gauge locations   Radar Map   Blended daily rainfall products   Precipitation (mm per day)
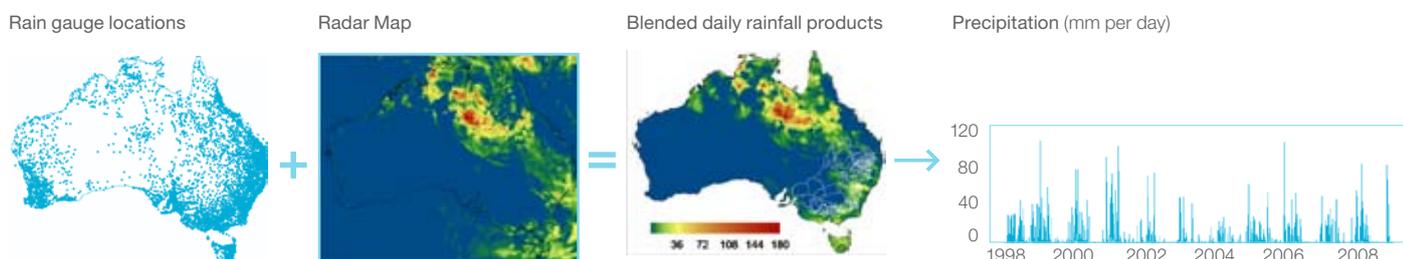
Rainfall gauging data and satellite radar data sources will be blended to produce daily rainfall estimates across the Australian continent. Rainfall time series data can be extracted for specific locations or regions such as the Murray-Darling.

Actual evapotranspiration

The project team has formulated the benchmarking methodology for assessing actual evapotranspiration methods.

The team has identified six candidate methods:

— Normalised Difference Temperature Index (NDTI) model which uses a resistance energy balance approach

— the Penman-Monteith algorithm adapted for global use with Moderate Resolution Imaging Spectroradiometer (MODIS) data

— MODIS-scaled potential evapotranspiration algorithm demonstrated for the Murray-Darling Basin

— the micrometeorology-based method used in the Australian Water Availability Project (AWAP)

— Penman-Monteith approach to estimate surface conductance and calibrated by streamflow measurements

— latent heat flux estimates derived from the CSIRO Atmosphere Biosphere Land Exchange (CABLE) land surface model that is under development for use in the Australian Community Climate Earth System Simulator (ACCESS).

Next steps

The project team will use observation data from rain gauges to correct precipitation estimates obtained from satellites, and generate a blended gauge-corrected satellite-based precipitation product. This product will be refined by incorporating precipitation estimates from NWP models.

The team will also assemble six candidate actual evapotranspiration test data sets. Using the benchmarking techniques formulated over the Alliance's first year these data sets will be compared to determine what they have in common and where they differ. They will be tested against independent data sets, such as catchment-scale streamflow measurements and direct field measurements of latent heat fluxes, to assess how well they perform. Discussions are ongoing with other potential providers of actual evapotranspiration data sets in both the commercial and university sectors with a view to broadening the inter-comparison, and it is planned to compare the candidate surfaces with the lower spatial resolution fields produced by NWP re-analyses such as ERA-40. A prototype operational system to routinely prepare actual evapotranspiration will be developed based on the outcomes of the evaluation.

Water Resources Assessment and Accounting

Developing prototype systems to help generate comprehensive national water resources assessments and water accounts.

BUREAU SPONSOR: Louise Minty

COLLABORATORS: eWater CRC
Geoscience Australia

PROJECT LEADER: Albert van Dijk

Challenge

State-of-the-art water resource assessments and water use accounting require comprehensive information on the generation, distribution and use of water resources across the whole of Australia. This information needs to have local detail, accuracy and currency, and it needs to be produced on demand in a robust and transparent manner. At present, this data is not available for all areas and water measurements, and what is available has to be collected from a variety of sources.

Solution

The project team is developing the world's first integrated system for detailed water balance analysis at continental to sub-catchment scale. A prototype system for Australian water resources assessment will couple modelling with observations and provide entirely new insights into trends, drivers and interactions in Australia's water systems. This system will draw on a wide range of on-ground and remote sensing data, and provide unprecedented accuracy and coverage.

The project team is assessing the performance of the variety of existing models that describe parts of the water cycle, and integrating the best methods within a flexible modelling system. The project team is also developing innovative methods to deal with incomplete data and uncertainty in measuring and estimating the water balance, and statistical methods to summarise and interpret the large volumes of water data being generated.

Achievements

A prototype water balance system of models has been completed and is ready for testing by the Bureau. A draft uncertainty framework to support water accounts has been completed and will be tested in the pilot account. To get to this point the project team has completed:

— state-of-knowledge reports on groundwater, surface water, landscape modelling, water use estimation and modelling infrastructure

— an optimum complexity catchment model to resolve the water balance that integrates gauging, terrain and satellite data

— statistical trend analysis techniques for hydroclimatic data

— a consultation draft of an uncertainty framework for application to the first national water accounts

— specifications of information and communication technology requirements of the water resources assessment system, including data integration and access integration of model components and infrastructure.

Next steps

Over the coming year the project team will develop:

— surface water model components by comparing alternative modelling approaches and structures to set benchmarks, and investigating the incorporation of new modelling techniques into existing modelling approaches

Observed water balance changes across Australia

Thirty years of remote sensing data has enabled scientists to understand Australia's water resources availability in a historical context.

The project team have been building a water balance observation and prediction capability that collects, collates and interprets water information.

The combination of remote sensing observation, long term on-ground records, and models to integrate the data, has resulted in information that is both reliable and comprehensive and can be interpreted with confidence.

The analysis has revealed a unique insight into the country's water balance with the data showing that the impact of the drought on our current water resources is broadly consistent with the historical trend and climate change predictions.
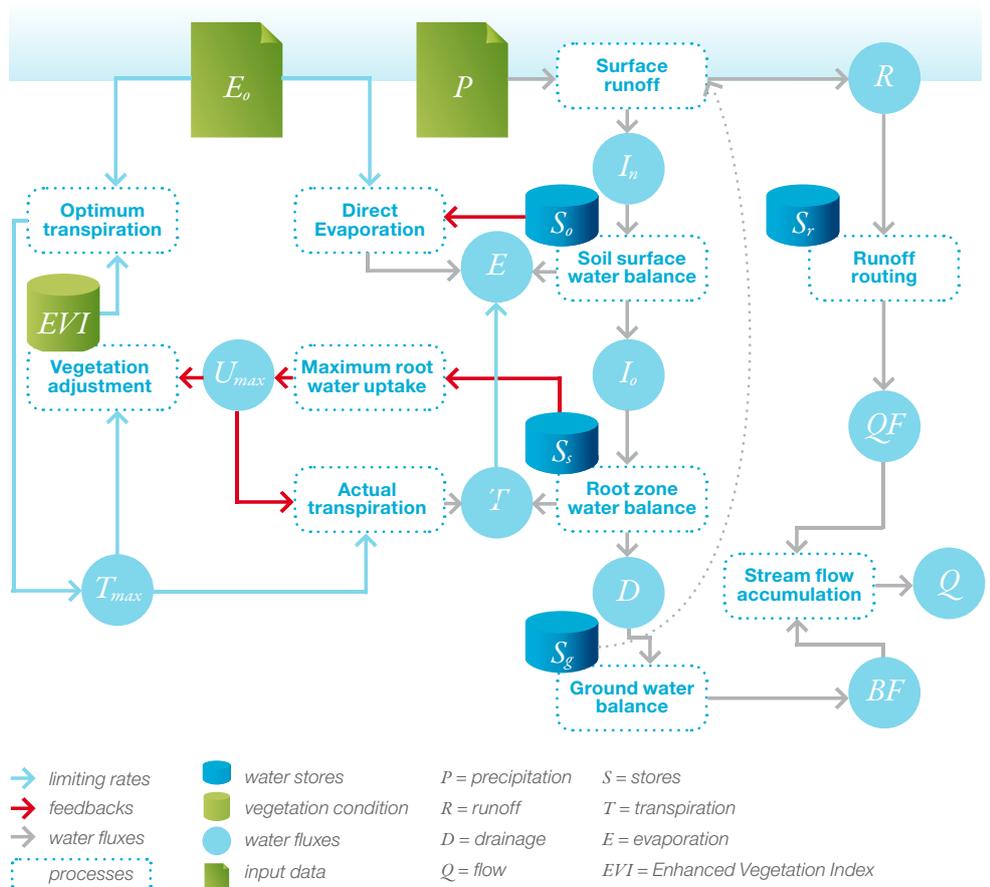
Future application of this information will give earlier warning of emerging water trends and support adaptive, efficient and sustainable water resource management.

This capability will assist the Bureau to conduct regular national water resource assessments.

— groundwater model components that estimate diffuse recharge and integrate groundwater and surface water assessment

— methods to estimate water use by intercepting activities (such as farm dams and forestry), drawn from rivers and in urban water systems

— products that map different land cover classes and their properties, to support hydrological estimation and aggregation in water accounts

— an uncertainty framework for water accounts, including data reconciliation, uncertainty estimation and reporting of uncertainty

— the information and communication technology infrastructure and components that will enable the system's deployment into the Bureau's environment.

The Bureau will assess the uncertainty framework and the prototype system as part of the pilot water account and water resource assessments due at the end of 2009.

FIGURE 6

Resolving the water balance

→ limiting rates	▮ water stores	P = precipitation	S = stores
→ feedbacks	▮ vegetation condition	R = runoff	T = transpiration
→ water fluxes	● water fluxes	D = drainage	E = evaporation
⋯ processes	▮ input data	Q = flow	EVI = Enhanced Vegetation Index

Schematic of the prototype Australian water resources assessment modelling system. Boxes indicate described processes. The left side shows the model component that simulates the ecohydrological processes and evapotranspiration, the right side shows the model component that simulates catchment hydrology.

Short-term Water Forecasting

Enhancing existing flood forecasting systems by increasing the lead time and accuracy of forecasts, and extending to continuous flow forecasting.

BUREAU SPONSOR: Dasarath Jayasuriya

COLLABORATORS: Centre for Australian Weather and Climate Research
University of Melbourne

PROJECT LEADER: QJ Wang

Challenge

Reliable water forecasts are critical for the management of extreme events and for optimising river and water resources management. These forecasts need lead times ranging from weeks down to hours to be of value. While the current hydrological model used by the Bureau for flood forecasting is event-based, a model that continuously simulates streamflow and accounts for soil moisture variability would allow for more accurate forecasts with extended lead times. For this reason, the Bureau's forecasting and warning services are expanding to include continuous flow forecasting.

Solution

The project team is developing methods and tools to enhance the Bureau's operational flood forecasting and generate continuous short-term streamflow forecasts across Australia. The team is developing new techniques to forecast water flow at particular river sites for periods from hours to weeks. The team is also developing software that will improve the integration of hydrological data and models needed for streamflow forecasts.

Achievements

The project team developed a streamflow simulation application that links a rainfall-runoff model with catchment-routing and channel-routing models. These models are used to convert rainfall into runoff, convey runoff from the landscape to the river channel, and convey streamflow through the river network to the channel outlet respectively.

As the first step in developing an uncertainty framework, the project team completed a review of methods for quantifying uncertainty. Forecast uncertainty in hydrological predictions occurs due to data errors and model limitations. Quantifying uncertainty better informs decision making, resulting in improved risk assessments by agencies, policy makers and communities.

The project team also assessed:

— the Flood Early Warning System functionality as a possible replacement platform to put flood forecasting models into operation

— continuous soil moisture accounting and routing modelling to support short lead time streamflow forecasting

— land surface temperature data (from the MTSAT-1R satellite) and their potential role as observational constraints on surface energy balance estimation for Australia

— methods for quantifying uncertainty in short-term hydrological forecasting.

FIGURE 7

Probability distributed moisture model for water forecasting
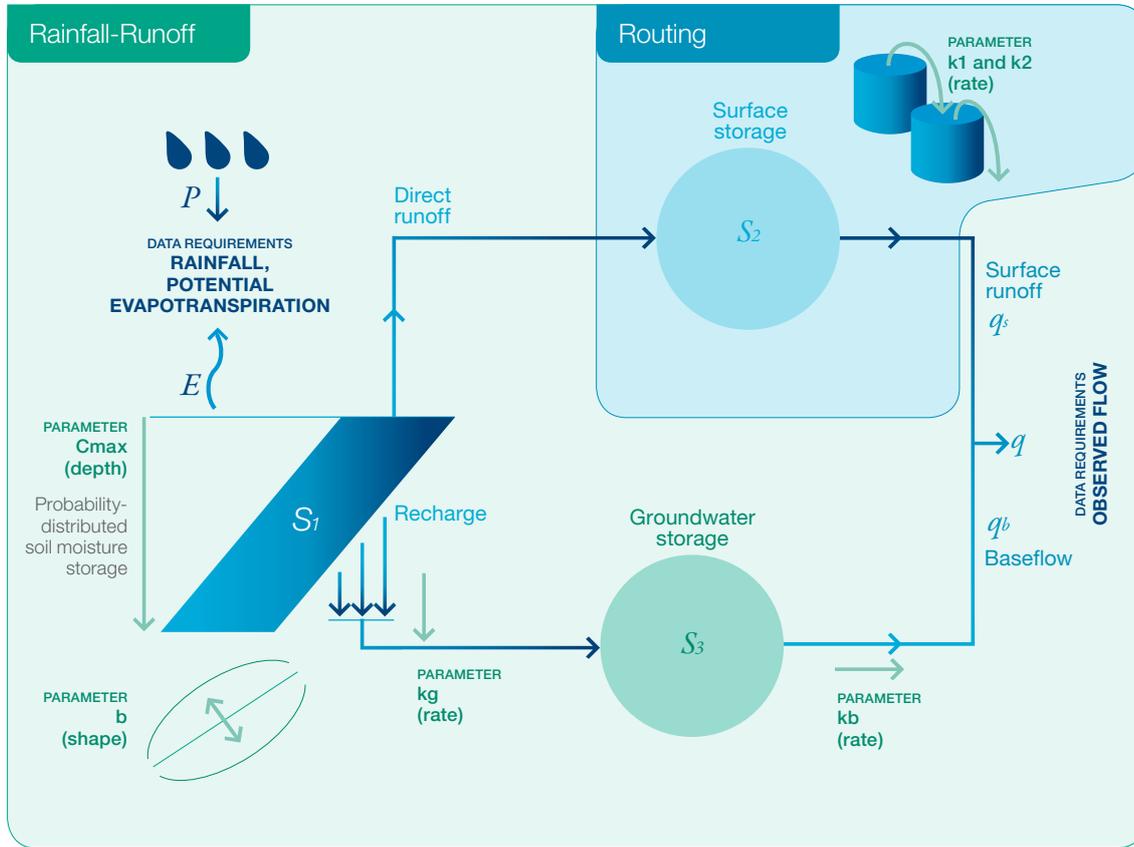
The Probability Distributed Moisture (PDM) model captures the important processes for streamflow generation, namely the conversion of rainfall into evaporation, the fast response of runoff excess, and the slower response from groundwater recharge. The model has a few key parameters (shown in green) that are adjusted to give a good fit of the model output to the observed streamflow.

Next steps

The project team will:

— develop new methods for improving current sub-catchment network-based hydrological modelling to provide better flood and continuous flow forecasts

— evaluate flow forecasting performance, by collecting baseline information and comparing it to the output of the extended model

— develop practical methods for quantifying forecast uncertainty

— integrate numerical weather prediction into flood forecasting models for improved streamflow forecasting

— examine physically-based spatially-distributed hydrological models to see if their use can improve forecasts.

Seasonal Water Forecasting

Developing methods and systems for predicting streamflow over seasonal to decadal time scales.

BUREAU SPONSOR: Dasarath Jayasuriya

COLLABORATORS: Centre for Australian Weather and Climate Research

PROJECT LEADER: Enli Wang

Challenge

Australia has one of the most variable and driest climates on Earth, with most of its water resources fully allocated. New seasonal (from months to several seasons) and long-term (decades) water forecasting methods will provide information for understanding the effects of climate variation on flows and water demand. This will optimise water management while managing risks, and inform water trading and water futures markets. It will also inform the development of future policy on water supply and use.

Solution

The project team is developing new methods to provide reliable seasonal and long-term water forecasts to assist in understanding the impacts of climate variability and climate change on water availability, and managing Australia's water into the future.

Two approaches for forecasting streamflow at key points, and possibly forecasting runoff across the Australian continent, are being investigated. Probabilistic forecasting of multi-site inflows for major water resources systems in Australia is being developed using a Bayesian statistical approach. The team is also developing an approach based on dynamic hydrological modelling

using rainfall from historical analogue years downscaled from forecast outputs of the Bureau's Predictive Ocean Atmosphere Model for Australia (POAMA).

For long-term forecasts, the project team is developing methods and tools to construct hydrological scenarios using rainfall-runoff models driven by climate modelling results. The scenarios will be updated as climate change projections continue to be improved.

Achievements

During the reporting period the project team has:

— developed a Bayesian Joint Probability (BJP) modelling approach for predicting (with probabilities) seasonal streamflows at multiple sites

— made significant progress in the identification of best predictors for seasonal runoff forecast in Australia

— investigated a dynamic hydrological modelling approach for predictions of seasonal streamflows and identified areas of improvement: model parameterisation and updating

— reviewed techniques for downscaling climate predictions from POAMA to catchment scale

— assessed statistical downscaling methods for use in seasonal forecasting of streamflow.

Probabilistic predictions of seasonal streamflows at multiple sites

The Bureau has initiated a program to pilot and, if successful, put into operation the Bayesian Joint Probability (BJP) statistical modelling approach to provide a brand new, nationwide seasonal streamflow forecasting service. The aim is to begin experimental forecasts by the end of 2009 and official forecasts by mid-2010 for key sites throughout Australia. The BJP approach uses initial catchment conditions (such as antecedent streamflow and soil moisture) and indices that describe patterns of weather or climate (such as the El Niño-Southern Oscillation or Indian Ocean Dipole) to predict (with probabilities) future streamflows and inflows to water storages.

Next steps

The project team will refine and assess the BJP approach, and expects to implement a pilot system over the coming year.

The team is also using currently available methods to downscale POAMA outputs which will be tested against observed results. From this testing the team will be able to improve the method used to downscale POAMA forecasts, and use this output to drive hydrological modelling for seasonal forecasts of streamflow in a selected basin.

The team will also use a number of dynamic hydrological models to investigate the improvement in model predictions through conditional parameterisation and advanced model updating. The selected models will be used, together with weather data from historical analogue years and the downscaled POAMA outputs, to generate seasonal forecasts of streamflows and compare the forecast skills with those from the BJP forecasts.

FIGURE 8

Model use for probabilistic predictions
Ensemble prediction for Oct-Nov-Dec 1993 at Site 404214
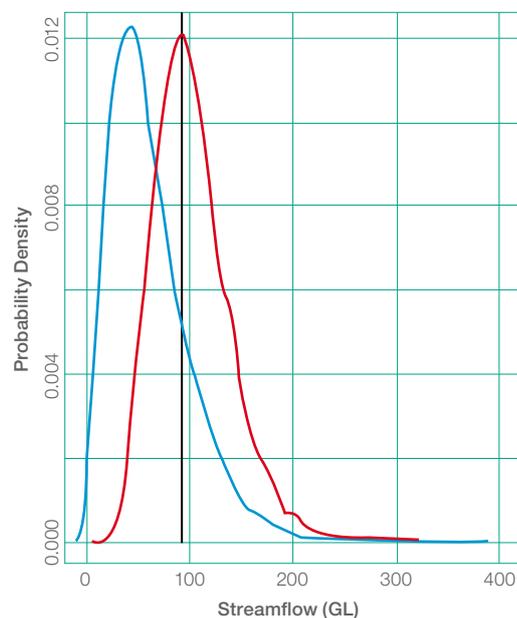
This graph shows the results of using the Bayesian Joint Probability (BJP) technique to hindcast (apply historically) streamflow in the Goulburn river catchment for October-December 1993 (Gauge 405214). The cross-validation predictive probability density (in red) is compared with actual value (in black) and the observed historical frequency distribution (in blue). This demonstrates that using initial catchment condition and future climate predictors as part of the prediction model leads to better accuracy than using only the past streamflow frequency to predict future streamflows

Performance Report

Finance and Resources

The 2008/09 $8m investment, was allocated to Water Information Systems, 30%; Foundation Data Products, 20%; Water Accounting and Assessment, 28%; Water Forecasting and Prediction, 17%; and Management, 5%.

The end of year financial position for the Alliance is an under expenditure of $0.287m.

The Alliance budget plan proposed 32.9 full time equivalents to undertake and manage the eight research projects. Some 31.9 full time equivalents were applied to the program to 30 June 2009.

Delivery and Productivity

The Alliance had 141 deliverables across eight projects scheduled for completion in 2008/09. By the end of financial year, 108 deliverables had been completed, with a further nine deliverables to be completed in July 2009. Formal variations deferred delivery of 14 deliverables to early 2009/10 – often rephased to align with the Bureau's work plans.

Over 2008/09 the Alliance produced:

Journal papers published	5
Journal paper in press	10
Technical reports	63
Conference papers	48
Web pages (often Wiki pages)	29
Continental data sets	2

A full listing of Alliance research outputs is available in a companion document to the Annual Report (www.csiro.au/partnerships/wirada).

PHOTO: WILLEM VAN AKEN © CSIRO

Glossary

ARCGIS Server	Organisations use ArcGIS Server to distribute maps and GIS capabilities via Web mapping applications and services to improve internal workflows, communicate vital issues and engage stakeholders.
Australian Hydrological Geospatial Fabric	A national geospatial database being developed by the Bureau to support water resource analysis and reporting.
Australian Water Resources Information System (AWRIS)	An online information tool (currently under development by the Bureau) that will be the authoritative repository for water data and reporting in Australia.
Bayesian statistics	Statistical approaches to parameter estimation that use prior distributions of parameters are known as Bayesian methods.
Downscaling	Downscaling applies statistical and empirical methods to derive higher spatial resolution information from relatively coarse-resolution data outputs, such as global climate models.
Evapotranspiration	The total water transferred to the atmosphere directly (evaporation) and from vegetation (transpiration).
Extensible Markup Language (XML)	A computer language used for web-based data transfer.
Geofabric	See Australian Hydrological Geospatial Fabric
GeoNetwork	GeoNetwork is a standards-based, free and open source catalogue application to manage spatially referenced resources through the web. It provides metadata editing and search functions as well as an embedded interactive web map viewer.
Numerical weather prediction	Weather forecasting that uses the current weather conditions as the basis for predictions.
Structured Query Language (SQL)	A computer language used for managing data in relational databases.
Unified Modelling Language (UML)	Unified Modelling Language is the industry-standard language for the specification, visualisation, construction, and documentation of the components of software systems. UML helps to simplify the process of software design, making a model for construction with a number of different views.