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R. M. Argent

R. A. Vertessy

L. J. Minty

B. J. Stewart

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A National Water Resources Data and Prediction System for Australia

R M Argent[ab], **R A Vertessy**[b], **L. J. Minty**[b], **B.J. Stewart**[b]

[a] *Department of Civil and Environmental Engineering, The University of Melbourne, Australia*

[b] *Water Division, Bureau of Meteorology, Australia (R.Argent@bom.gov.au)*

Abstract: Australian water resources have a turbulent history of management, arising from a combination of jurisdictional and physical system characteristics. The position of state boundaries along rivers and across landscapes, and the imposition of state-based management regimes, have resulted in the water resources of large river basins being assessed and managed in significantly different ways. In addition to this, Australian water resources exhibit some of the world's highest variability in flows, leading to large uncertainties in prediction, and management, of the resource. This situation has been exacerbated in recent years as precipitation has diminished and become more variable, enhancing Australia's reputation as a land of 'droughts and flooding rains'. Under various future predictions of climate it is forecast that Australia's water resources will become more scarce and less reliable. In this situation the keys to improving future management of Australian water resources are to monitor the water resource, understand the interaction of water system components of demand and supply and the characteristics of the system, to predict the future state under a variety of conditions and management regimes, and to use system monitoring to improve such understanding and prediction. To achieve these ends the Government of Australia approved, in 2007, the development of an Australian Water Resources Information System (AWRIS). This system is designed as a national end-to-end system, taking data from long term and real-time monitoring networks, through a national data collection and collation centre, to web-based provision of water data, information, prediction and forecasting tools, and predictions. This paper describes the vision, and architecture, implementation and development issues of the AWRIS (http://www.bom.gav.au/water).

Keywords: AWRIS, Australian Water Resources Information System, Water Information, Data interoperability, Web Services

1. BACKGROUND

Water is a key area of concern for many societies and countries, particularly in the face of climatic change and increasing climatic variability. Australia is one country that is highly susceptible to these influences for, although having an overall low population density, much of land is arid, with a highly urbanised society and a significant dependence upon irrigated agriculture.

In Australia, water resources are largely managed or overseen at a state level, with various levels of management also occurring at local, catchment, region, system and basin scales. As a result, it is difficult to obtain a whole and consistent understanding of the nature of the resource, and even more difficult to make reliable forecasts of future water availability. There are over 200 agencies, authorities, corporations and organisations that manage part of the resource, and which therefore hold some of the pieces of the water resources puzzle. Effective and holistic water resources management to meet competing needs is thus impeded, as is water resource policy development and decision making on infrastructure investment.

Particular aspects of the Australian water resources system provide an impetus for improved understanding and management. For example, over the period since 1997 much of the country has been subject to a long term and widespread drought and although drought is not uncommon in particular regions or states, the coincidence and longevity this time has sustained water resources debate at a national level for a significant period. Additionally, significant surface and groundwater systems are positioned across multiple jurisdictional boundaries, increasing the difficulties in monitoring and understanding systems from a national perspective. This issue is further complicated by a strong reliance upon irrigated agriculture as a food source, which may at times be competing with other users in other jurisdictions for the diminishing resource.

In this climate and situation the importance of understanding the national water resource increased to the point where a series of coordinated actions were required at a national level. These activities include monitoring the water resource across the full spectrum of water processes, understanding the interaction of the system components in both space and time, investigating the characteristics of the natural and constructed water systems and the broad range of interactions occurring between the two, using such monitoring and investigation to assess the current state of the resource, and, finally, to provide forecasts of future states of the system. These needs have resulted in the establishment of a project to develop an Australian Water Resources Information System (AWRIS).

2. THE AUSTRALIAN WATER RESOURCES INFORMATION SYSTEM

The concept of a national system for coordinating and managing water data and information has existed in Australia, in various guises, since the 1980's. At that time, and following a significant national level drought in 1982/83, the federal government invested significant resources to expand the national surface water monitoring scheme. With the considerable advances in information science and technology over the intervening decades, the concept re-emerged in the 00's in the form of a national network for water observations, akin to surface hydrology monitoring and management systems in countries such as Korea and USA. In 2007, development of this observation network (O'Hagan et al., 2007) informed planning for the AWRIS.

2.1 The Concept of the AWRIS

In its simplest form the AWRIS will be a data system for housing all of Australia's critical water data. It will be supported by systems for effective gathering and ingestion of data from multiple sources, in multiple forms, and the spatial and temporal relationships between these data will be represented in ways that provide effective support for querying and analysis to meet a broad set of data and information needs. The system will be constructed to provide robust and reliable, nationwide information on water availability, water quality and water usage, and will be the authoritative repository for water data and reporting in Australia.

A key role for AWRIS will be transformation of data into information, and the system will therefore deliver not only data and information, but also reports and tools to enhance the decision-making capabilities of users engaged in:

- Policy development;
- Planning;
- Operations;
- Public enquiry, and
- Research.

AWRIS is conceived as having three core components (Figure 1) - a central or 'enabling' framework for harvesting and organising water data, an external face providing public access to water data, tools and information, and an internal face providing analysis and reporting tools for delivery of key regular national water reports, such as Australian Water Resource assessments (AWRs) and National Water Accounts (NWAs).

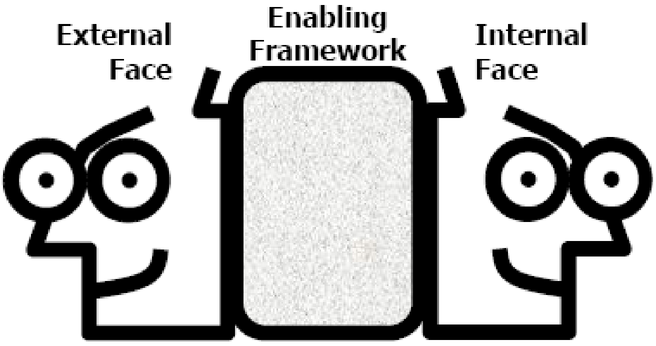

Figure 1. AWRIS Core Components – a central enabling framework delivering services to external and internal clients

As implied by the name, AWRIS will be an information system, providing end-to-end processing and delivery of data (Figure 2). The workflow starts with harvesting and checking data from primary collecting agencies, proceeds through an organising step that imposes a strong geo-spatial relationship formulation upon the data (in the form of a 'geofabric'), on to an analysis and interpretation component, to final internal and external delivery of customised reports. User needs may require all these steps or possibly only a few, such as in the provision of primary data to end users.

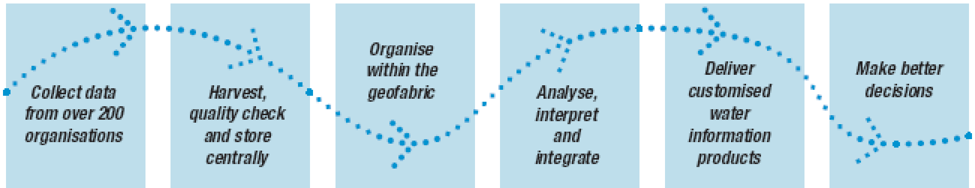

Figure 2. The AWRIS data harvesting, organisation, analysis, reporting and delivery pathway

The operation of AWRIS will occur through, and be enhanced by, data exchange standards and agreements, common data models and terminology, and appropriate systems infrastructure and architecture.

2.2 Legislation

Establishment of a system like the AWRIS can take place in a number of ways, such as through federated agreements and alliances, or through enablement via central legislation. In this case, AWRIS development is initially supported through a two-year (2008/09) grant under the Raising National Water Standards program of the National Water Commission. This 'phase 1' activity is further supported over a 10-year horizon through the national water plan.

The primary associated legislation for AWRIS is the Water Act, 2007, and in particular Part 7, dealing with water information (Government of Australia, 2007; http://www.comlaw.gov.au). Under this the Bureau of Meteorology (the 'Bureau') takes a central role, being charged with:

- collecting, holding, managing, interpreting and disseminating Australia's water information;

- providing regular reports on the status of Australia's water resources and patterns of usage of those resources;
- compiling and maintaining water accounts for Australia, including a set of water accounts to be known as the National Water Account;
- providing regular forecasts on the future availability of Australia's water resources;
- undertaking and commissioning investigations to enhance understanding of Australia's water resources;
- issuing National Water Information Standards;
- giving advice on matters relating to water information, and
- any other matter, relating to water information, specified in the regulations

These activities significantly expand the Bureau's role in water information, from traditional areas of climate monitoring and flood forecasting. AWRIS is being built and will be owned by the Bureau, consistent with this expanded role.

2.3 Providers of Water Information

A key aspect of the Water Act 2007 is that it *requires* 'persons' to provide water information to the Bureau. In this context, 'persons' refers to over 200 agencies, authorities and other bodies collecting and holding relevant water data. An indication of the breadth of this endeavour, and possibly the complexity of the data harvesting and collation task, is found in the list of persons in Regulations under the Act. These include leading (eg water) and other (eg agriculture or environment) national and state water agencies, hydroelectricity organisations, owners and operators of major storages, rural and urban water utilities, catchment management authorities, and collectors of rainfall and/or stream height data (e.g. councils). In a country such as Australia, with three-tiered government, this spread of authority and control is not surprising when dealing with a commodity as important as water.

2.4 Data Categories Being Supplied

The complexity of obtaining data from a range of agencies, with different skills, capabilities and data systems, is compounded when considering the information to be provided. These data, listed in Table 1, are required so that comprehensive analyses can be undertaken, in line with the legislative needs for national water resource assessments and accounts.

Table 1. Types of water information to be provided to the Bureau

Category number	Description of category information
1	Surface water resource information
2	Groundwater resource information
3	Information on major and minor water storages
4	Meteorological information
5	Water use information
6	Information about rights, allocations and trades in relation to water
7	Information about urban water management
8	Information about water restrictions
9	Water quality information
10	Descriptive and reference information about water information in other categories

3. CONCEPTUAL WORKFLOW FOR THE AWRIS

As indicated in Figure 2, a reasonably straightforward process is defined for operation of the AWRIS. These are expanded in Figure 3, along with an indication of feedbacks that will need to operate, and which will naturally complicate the process.

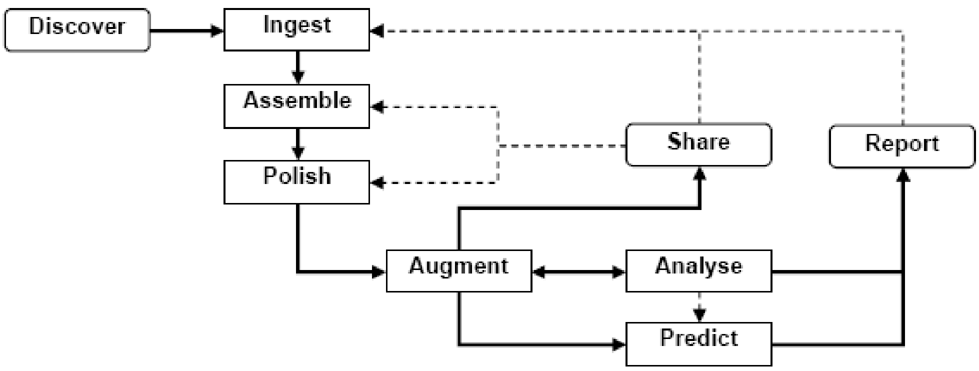

Figure 3. Data processing through the AWRIS, where solid lines show primary flows, and dashed lines represent feedback mechanisms

In Figure 3, data from multiple sources, and in multiple formats, is ingested into the central data system, having possibly been 'discovered' via web services methods (e.g. Horak et al., 2008). These data are then assembled and polished into a consistent geo-spatial and temporal framework through use of appropriate data models and quality control checks. Data augmentation can then be undertaken by inferring additional water balance components. These data are then made available to users, and are also analysed and used in predictions to provide a variety of internal and external water resources reports. In terms of feedbacks, the needs and outputs of analysis will likely inform both the augmentation and prediction processes. For example, a water balance analysis may require prediction at places in the system, or possibly provide model output that can further augment the data pool. The gaps, errors and glitches identified in data and information by users through sharing and reporting will provide a valuable response mechanism that will inform not only the assembly and polishing processes, but also feed back through the ingestion step to the original data providers. This latter point raises a key problem identified by jurisdictional representatives of the data providers, and also in architectural discussions, of the 'point of truth' for the data. As ever with data management and publishing by multiple sources with a range of capabilities, there is a requirement for clear procedures and mechanisms by which data updating (eg fixing errors or changing quality codes) is undertaken.

4. ANALYSIS, SHARING, PREDICTION AND REPORTING REQUIREMENTS

Whilst the complexity of the data ingestion and assembly tasks is significant, the current business needs for the data held in AWRIS are reasonably clear. These reflect the first four points noted from the Water Act (Section 2.2), and can be described as:

- Make all data available publicly, with the exception of data deemed 'not to be in the public interest', or data which 'expressly identifies a persons water use' (Government of Australia, 2007).
- Support the undertaking of water balances (e.g. Zhang et al., 2005; Welsh et al., 2006) at various scales and complexities of systems, the dominant components of which may include storages, incoming and outgoing volumes, groundwater stores and level changes, reuse and recycling of water, diversions and extractions.
- Support production of water accounts (e.g. Turner et al., 2007; Kirby et al., 2008) for various systems, and the National Water Account.

- Support production of water resource assessments for various reporting units, such as catchments, basins, states and systems.

It is useful at this point to return to the concepts described previously, whereby the AWRIS includes not only the central framework for data management but also the analysis tools and reporting systems underpinning the internal and external faces. The development of these has significant implications for the system architecture and geo-spatial and temporal data systems.

5. ARCHITECTURE, DATA SYSTEMS AND INFORMATION DELIVERY

Development of the AWRIS by the Bureau began early in 2008, with attention focussed across the spectrum of data ingestion, assembly, sharing and reporting, supported by a strong focus on stakeholder engagement. Given the nature of the newly legislated data delivery requirement for 'persons' holding water data, this latter point is essential.

AWRIS development activity is being driven by a 2-year Phase 1 project plan, with the purposes of delivering 'useful functionality' in the short term, and a 'reliable and relevant system' for the long term. Development is occurring in four key areas – data, architecture, 'geofabric' and products.

5.1 Data Interoperability and Management

The first data harvest under the new legislation is currently timed to occur in September 2008. This includes only a portion of the total data pool, and only a sub-set of the data providers, as the Regulation stipulate that different 'persons' need to deliver data at different times and frequencies, with frequencies range from daily (or possibly finer for data sourced automatically via e.g. web services), to annually for types such as irrigation system allocations.

With such a varied data stream, understanding of the data types and flows is important. The AWRIS team is thus undertaking a data inventory to determine the data types held, although this is difficult due to the sheer range of authorities and responsibilities. It is recognised that 'discovery' will be an ongoing process through the first year and beyond – not only with respect to data held, but also the formats used.

Some of the larger data collection organisations, with larger data holdings, are well set up in terms of data management, using robust commercial data systems. We are currently undertaking a first pilot data harvest with these groups to identify problems and issues that may arise down the track, and to create solutions to serve future needs.

5.2 Solution Architecture

In a system such as AWRIS the architectural needs are many and varied. In the initial phase, focus is on development of a solution architecture that can support the highest priority and most immediate requirements, whilst providing a platform for future development beyond Phase 1. Principles of operation in this area therefore include the adoption of an agile and evolutionary approach built around components and embodying some of the fundamentals of service oriented architectures, such as loose coupling, autonomy, statelessness and reuse. A number of requirements identification activities have been undertaken to inform architectural design in the period leading up to 2008, and early activity is continuing in this area, focussing particularly upon both functional and non-functional requirements of internal users.

5.3 Geofabric

Undertaking water balances and other water resource analyses across different spatial and reporting units (eg catchment, system, basin, state) requires a consistent approach to the spatial relationships between data. Support for this in AWRIS will be done through a 'geofabric' - a concept that is easy to grasp but hard to define. Through the developmental phases of the AWRIS the geofabric has been described variously as:

- a sophisticated three-dimensional representation of all landscape elements and their interrelationships that impact on the water cycle. It explicitly describes the spatial relationships and functional connectivity between geophysical landscape elements from a water balance perspective
- a baseline suite of common data sets that allow shared understanding of definition, naming and characterisation of landscape elements
- a specialised Geographic Information System that describes spatial relationships between important hydrologic features.
- a single, consistent, national geospatial framework for hydrological features, spatially coincident and topographically enforced to a 1" national digital elevation model

Thus, the geofabric not only encompasses fundamental geospatial data, but also i) the description of features, ii) the hydrological data associated with those features, and iii) the relationships between and amongst the features and their data from a hydrological perspective. As an example, a feature such as a monitoring point may be part of a surface runoff system, a groundwater system, and an engineered water supply system. It will thus have a different hydrological 'meaning' and information role depending upon the system of interest. The geofabric will support these multiple identities and roles for such monitoring points. Initial activities in defining and designing the geofabric have focussed upon conceptual and abstract design (eg geometry v network v feature based approaches), the utility of existing hydrological data models and tools (eg ArcHydro), and development of protocols for testing and comparing alternate models within the geofabric.

5.4 Products

One of the advantages in constructing a national water information system is that many users can readily identify and articulate their needs for such a system. Thus the opportunity exists from very early in the project to meet some of these needs, particularly in the area of data exploration and delivery. Early developments in the area of 'products' are therefore focussing upon provision of services by which users can explore, become familiar with, and obtain data of interest in a variety of raw and derived formats and forms. A data exploration system and 'dashboard' of data reporting tools are being developed to this end. An example of a derived product, in the form of a national dam level reporting system, is also being developed as a both a functional report and a testing ground for other products.

6. FUTURE PROGRAM

This paper has provided a brief introduction to the vision of the AWRIS, some of the issues in architecture, development and implementation, and an overview of current activities. There is a risk in considering the design, development, implementation and operation of such a broad system that the complexity of the data harvesting, processing, analysis and reporting will outweigh the elegance of the concept. To overcome this, we have chosen a multi-faceted approach, built around the principles of 'adopt, adapt, develop', and encompassing a range of strategies. Firstly, we have selected a team with a broad range of experience and contacts in the areas of spatial and temporal water information systems. Secondly, data management and reporting systems of this complexity have been built before and so we aim to understand and adopt technologies and solutions that are already well proven, or which are at the forefront of current operational thinking. For this, we will draw upon international linkages and solution developers and providers to inform our selection of methods and technologies. Thirdly, we have established a research alliance with Australia's leading researchers in water information. These will provide a pool of talent upon which we can draw in future to adapt the technologies and methods initially adopted, and to extend and develop these based upon longer term research investigation. Finally, we are taking a phased approach to development, accepting that will make mistakes as we go along, and that the things learned from these provide the ‘experience’ we draw upon in the long term.

ACKNOWLEDGEMENTS

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