Water for a Healthy Country Research Flagship, CSIRO

The Water for a Healthy Country National Research Flagship is addressing one of Australia's most pressing natural resource issues, the sustainable management of our water resources. The Flagship – a research partnership between the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australian and State Governments, private and public industry and other research providers – is well on the way to achieving its long-term goal:

to provide Australia with solutions for water resource management, creating economic gains of $3 billion per annum by 2030, while protecting or restoring our major water ecosystems.

We are achieving this goal by delivering science and technology that:

- increases the benefits of a national expenditure of more than $7 billion per annum on *water infrastructure*;
- improving the *allocation efficiencies* of the 25,000 gigalitres of water (worth more than $100 billion) consumed each year;
- improving the *use efficiency* of the 25,000 gigalitres of water consumed each year; and
- improving the environmental outcomes of land and water management across Australia.

In this chapter, we briefly discuss Australia's management of water resources and how this both drives and impacts on our research. We will introduce the Flagship – who we are and what we aspire to achieve – as well as demonstrate our successes so far. Our research and its impact is presented more comprehensively in the following chapters, however we present a snapshot of our research here providing insight into our activities and our organisational culture. Overall we aim to provide, through this and the following chapters, a concise summary of our research and research partnerships, and build understanding of our operating environment, our capability and the impact of the Flagship nationally and internationally.

1. The CSIRO National Research Flagship Program

CSIRO – the organisation behind the Water for a Healthy Country Flagship – is Australia's national science agency and one of the largest and most diverse research agencies in the world. It's mission is to deliver great science and innovative solutions to Australian business and industry, Australian and State governments and their agencies, the Australian community and the international community including developing nations. CSIRO employs approximately 6500 people to conduct, and assist, scientific research at 52 sites across Australia. CSIRO's primary roles are to:

- undertake scientific research;
- assist Australian industry and to further the interests of the Australian community;
- encourage or facilitate the application and use of the results of its own or any other scientific research; and
- contribute to national and international objectives and responsibilities of the Commonwealth Government.

The National Research Flagships, launched in 2004 with strong endorsement from the Australian Government, were introduced to better meet the needs of government and industry and to better utilise the capability and develop the full potential of Australia's largest research and development institution. The flagships built on domains where CSIRO already had a strong research base (such as water, energy, health, mining) but deliberately moved beyond discipline "silos" (for example, water science is more than just *hydrology*) and small-scale, single researcher or "CSIRO-only" projects. The focus of the research is as much on meeting external or societal needs as on creating impact on the scientific literature.

The flagship programs are large-scale multidisciplinary research partnerships that harness world-class expertise to tackle national priorities. Flagships form the best multidisciplinary teams with our partners from business and the research community, both locally and internationally. They have a clear focus on the delivery and adoption of research outputs to maximise impact for Australia. This new paradigm for research delivery recognises that:

- Major national challenges require research and development that draws upon *multidisciplinary* capability (i.e., one cannot redress the water challenge with hydrology alone).
- Major national challenges require *large-scale, focussed* research and development efforts to have effect.
- Achieving significant impact usually means bringing together the best teams not only across CSIRO, but from across the National Innovation System (*research partnerships*).
- Science planning must be explicitly and intentionally *aimed at achieving significant impact* on a major national challenge.

2. Australia's water challenges

Water for a Healthy Country was established to address the sustainable management of Australia's water resources. Achieving Australia's 'water potential' is a long-term proposition. The Flagship must deliver value into a complex policy and management environment; informing water resource management decisions, reducing the uncertainty associated with these decisions, and providing enabling technologies that will allow Australians to realise the full benefits from current and future public and private investment in water.

Australia is going through its most ambitious and challenging period of water reform, concurrent with an unprecedented and prolonged drought. Water utilities are under pressure to be both competitive and socially responsible. The condition of many of our rivers, wetlands, estuaries and coastal environments reflect acute or chronic impacts of development. Conversely, there are opportunities for sustainable development of water systems in Northern Australia, however, our knowledge of how these systems function is rudimentary.

The scarcity of water in Australia stems from the variability of its water supply and the historical response to this has been to increase storage. As demand increases, as climate changes, and with most of the key water storage sites already in use, Australians must now develop strategies that reduce demand, increase efficiency, re-use wastewater, and allow and facilitate water to be traded between uses (consumptive and non-consumptive).

Australia’s water challenges are not unique, although few developed nations have faced the same level of shortages as Australia in the last decade. While the world's population tripled in the 20th century, the use of renewable water resources grew six-fold. While agriculture accounts for 70 to 80 percent of total water use at present, generating food and fibre, by 2050, its share will have declined to about 60 or 70 percent, as a result of competing water demands, such as urban expansion and industrial development. The overall pressures on water are increasing globally and Australia is part of an active global research community as we adapt, respond and share the learning from these challenges.

Recognizing the unprecedented pressures on water resources, Australia has committed to ambitious and world leading water reforms. The blueprint for the reforms is the *National Water Initiative*, agreed to in 2004 by the Council of Australian Governments. The Australian Water Act 2007 further cements the reforms by creating a Commonwealth Environmental Water Holder; a national water information role for the Bureau of Meteorology; and new processes for managing water in the Murray-Darling Basin.

The overall objective of the National Water Initiative (NWI) is to achieve a nationally compatible market, regulatory and planning based system of managing surface and groundwater resources for rural and urban use that optimises economic, social and environmental outcomes. The NWI commits all Australian governments to:

- prepare water plans with provision for the environment;
- deal with over-allocated or stressed water systems;
- introduce registers of water rights and standards for water accounting;
- expand the trade in water;
- improve pricing for water storage and delivery; and
- meet and manage urban water demands.

The Australian Government is investing $12.9 billion in water reforms over the next ten years under the *Water for the Future* strategy. It includes major investments in regional Australia for improving irrigation water use efficiency, modernising irrigation infrastructure, and buying and saving water for the environment. In urban environments it includes support for diversifying water supplies beyond traditional rainfall fed supplies, and encouraging reductions in energy and water use. Investment under the strategy aims to:

- facilitate the operation of efficient water markets to enable water to be put to high value use and enable adaptation to climate variability and change;
- price water to support trade, fully recovery costs, and efficiently deliver services;
- return over allocated systems to sustainable levels of use, and identify and deliver environmental outcomes for water systems;
- provide increased security of supply to both consumptive and environmental uses of water;
- provide planning frameworks for assigning and managing risks to water resources;
- increase the efficiency of water use for both irrigation and urban uses; and
- provide strategies to adapt water supply and use to climate change and increasing demand.

Water for a Healthy Country is strategically positioned to provide research, information and technology to underpin Australia's water reforms. The Australian Water Act 2007, the *National Water Initiative* intergovernmental agreement and the *Water for the Future* national investment strategy, combined with various state water legislation and strategies, provide clear pathways for Flagship research to impact on national water reforms. The Flagship has a key role in development of national guidelines for water quality and explicit objectives for protecting key environmental assets – including the Living Murray Initiative, the [Great Barrier] Reef Water Quality and Protection Plan and the Murray-Darling Basin Plan – which facilitates path to impact for Flagship research. Alignment of the Flagship's research portfolio with these significant policy and management initiatives has enhanced impact.

The emergence of a deepening national water crisis over the period 2005 to present (see Figures 1 to 4 below depicting decline in runoff, the emerging gap between supply and demand, and consequent water restrictions) caused by drought, has dramatically influenced the operating environment for Water for a Healthy Country.

Australian and state governments as well as water utilities and private industry, have brought unprecedented needs, expectations and resources to CSIRO. This included direct requests from the Prime Minister, and State Premiers through the Council of Australian Governments for help. Such demand is in response to the strategic positioning of Water for a Healthy Country, including early successes in focussing capacity onto key issues (the sustainability of the Murray-Darling Basin and urban water security), and CSIRO's enduring legacy of high quality water research.

The increased demand on Water for a Healthy Country has had three profound consequences for the Flagship, now and for the foreseeable future:

- It has reinforced CSIRO's role in the National Innovation System – that we stand ready to deliver solutions to Australia's major national challenges, and that we are responsive.
- It has necessarily changed the balance of our portfolio toward more applied research in order to meet the policy and management timetables of government and water utilities.
- It has placed great pressure on particular areas of science capability, especially river modelling, hydrology, climatology, systems modelling and analysis and groundwater science. Ultimately, our delivery in most areas of application has been limited by capacity and not financial resources.

Historical streamflows 1950-2008 with projected streamflows from 2009 *(figure 9)*
(Gigalitres per year)

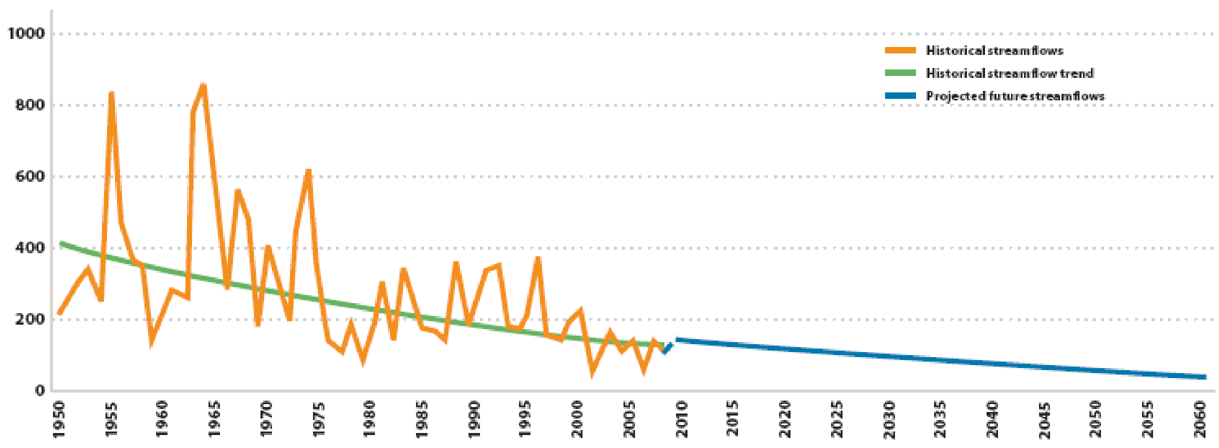


Figure 1. Historical and projected streamflows into surface water supplies for the Perth Integrated Water Scheme (from Water Forever 2009). On the basis of this historical record, and CSIRO projections of climate change, planning estimates from this source have been de-rated.

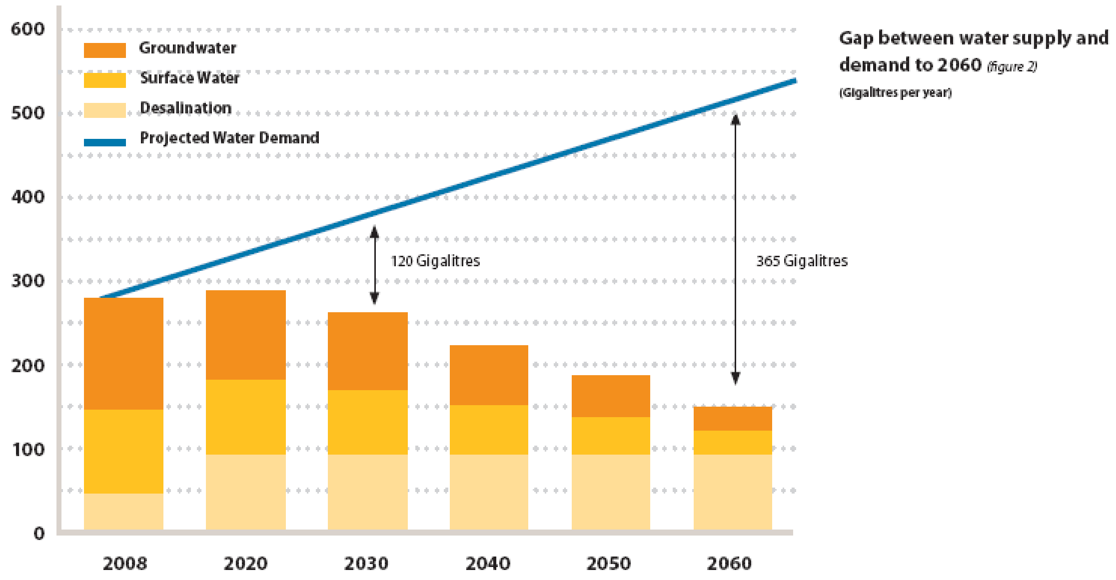


Figure 2. The gap between supply and projected demand for the Perth Integrated Water Scheme (from Water Forever 2009).

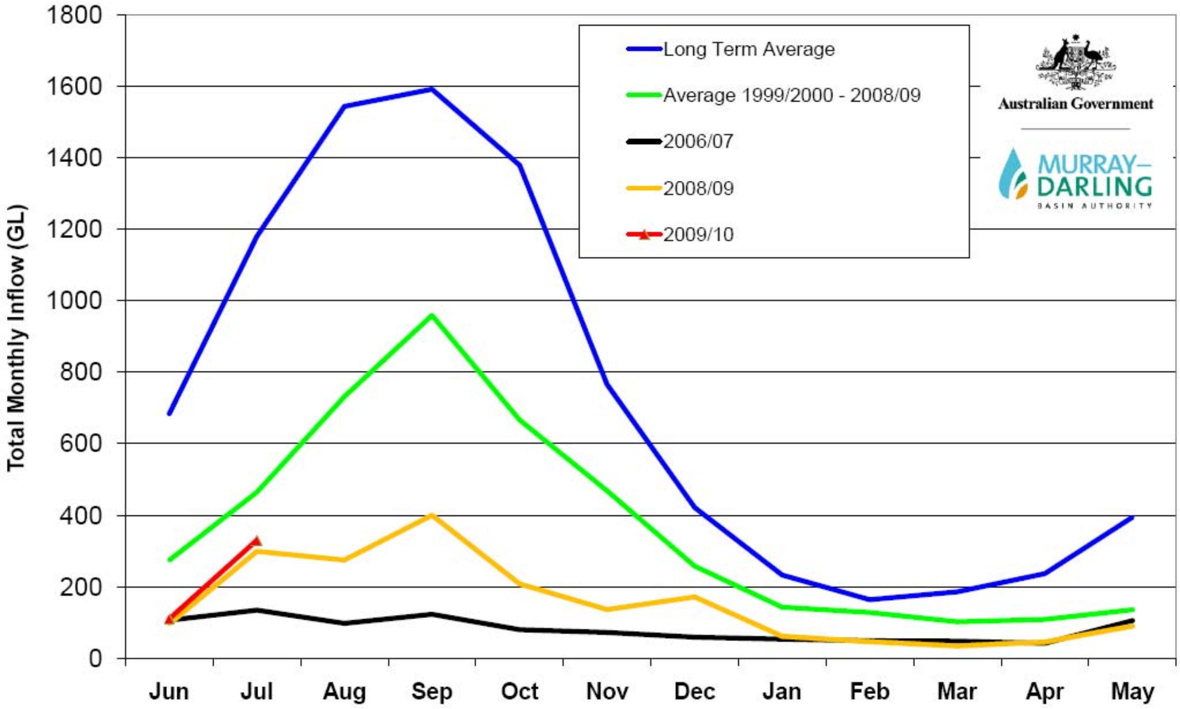


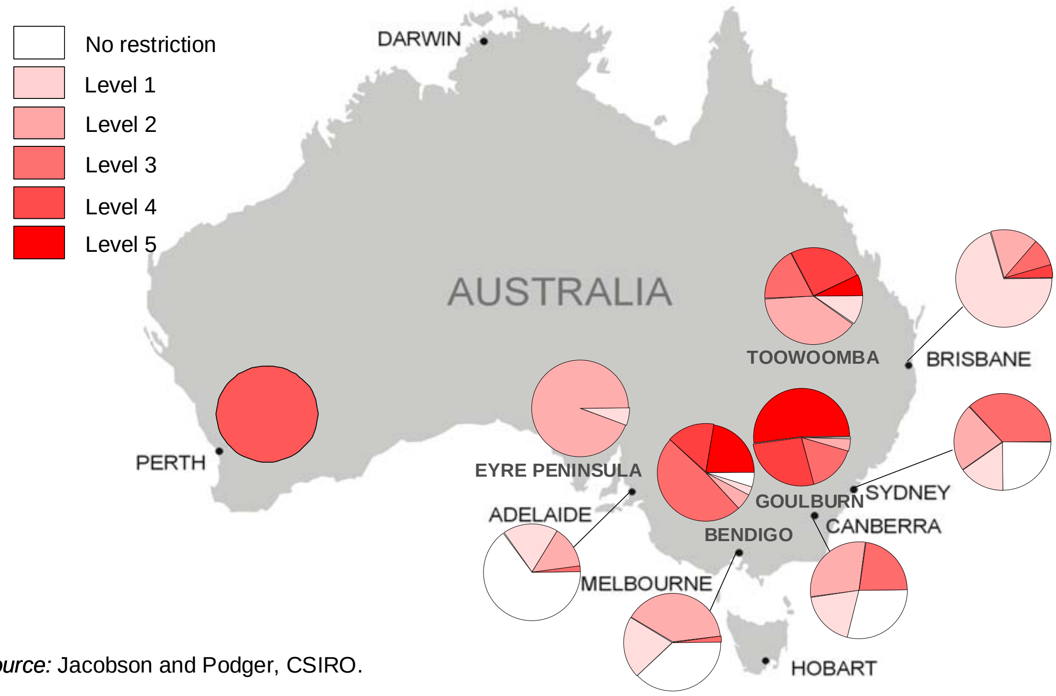
Figure 3. Monthly inflows in to the Murray-Darling Basin, home of 60% of Australia's agricultural production, and the water supply for 2 million Australians. The magnitude of the 1999-2008 drought was unprecedented. Flagship research indicates that this region will dry into the future.

Box 1 – Australia's water systems: three key pressure points

Growing cities. The four major Australian cities (Perth, Melbourne, Sydney and South-east Queensland) with rapidly increasing populations face reductions in per capita consumption of between 40% and 50% by 2030 under existing supplies.

Sustainable irrigation. Australian irrigation industries produce close to 50% of total Australian agricultural production. Australia's irrigation industries add more than $12 billion to the national economy and provide jobs for 188,000 people. These industries face an uncertain future – increasing climate variability and change, trading between uses, and trading to urban and ecological water uses is reducing the water available for agriculture and creating stresses in addition to declining terms of trade.

Water for the environment. Government and industry are committing to ecological repair and improved ecological outcomes for many of Australia's rivers, wetlands, estuaries and near-shore coastal zones while also managing for economic (commodities and tourism) and social (cultural, recreation) outcomes. Designing methods to better manipulate water systems to deliver the desired surface water and groundwater quantity, timing and quality of flows will be a prerequisite for success.



Source: Jacobson and Podger, CSIRO.

Figure 4. Level of water restrictions across Australia's major metropolitan areas, 2002-2006. While the specific meaning of a given level varies from city to city, the highest restrictions generally ban or greatly limit outdoor water use. Since 2008, rains have brought some relief to Sydney and Brisbane.

3. Water for a Healthy Country – responding to the water challenges

The Australian government water reforms and implementation programs are based on sophisticated policy with ambitious objectives. There are high expectations in all levels of government and some sectors of the community of improved outcomes while using less water, requiring more efficient irrigated agriculture and better service delivery in urban water from less water use per capita. This requires substantial innovation in urban and agricultural water supply and use. To successfully implement these policies will continue to put very high demands on our knowledge of water systems, their future prospects, and the responses of communities and industries to water management.

Following are summaries of four of the major growth areas in water research in Australia, where significant investment is being made by government and industry in programs to provide the knowledge and innovation underpinning national water reforms. Water for a Healthy Country partnerships undertake programs in each of these areas and the Flagship themes, described in later chapters of this report, align with each of these growth areas. The following summaries provide a snapshot of the national (and international) research urgently needed to make the use of Australia's water resources significantly more effective.

Climate change, land use change and landscape water balance

There is agreement among the R&D community and within government agencies that water planning should no longer be based on historical hydrology, for either surface water or groundwater systems. Climate variability and future climate need to be considered, as do risks posed by bushfires, land use changes such as new plantations and farm dams, and the impacts of increased groundwater extraction on surface water. This requires reasonably accurate scenarios of future hydrology. We know that historical relationships between rainfall and runoff probably will not apply in future, as in many basins they have not applied to the conditions over the last few years. We need regional runoff predictions that are able to produce both the observed and future responses to climate and land cover change.

The R&D challenge lies in the large uncertainty around future climate and being able to distinguish climate change from Australia's very high intrinsic variability in rainfall and runoff. Runoff, recharge, floods, droughts, and ecosystem response all occur episodically toward the extremes of climate conditions. They all occur largely at the local scale, whereas climate is driven by larger scale global phenomena. Thus we need to able to predict climate extremes and variability, and we need to be able to downscale climate projections to the catchment and aquifer scale at which water is managed.

Water resource planning relies upon a good understanding of water balances at the landscape scale. While there is a good understanding of how hydrological processes operate, specifying the fluxes in real landscapes is much more difficult and some terms still have errors of greater than 20 percent. Fluxes such as floodplain losses, groundwater-surface water interactions, regional recharge, and evapotranspiration of groundwater, are all poorly understood and lead to either conservative water planning or inadvertent risks to water security. Fortunately a combination of good hydrological theory and rapidly advancing remote sensing, geochemical tracing and spatial analysis technologies offer excellent prospects for supporting water planning and management with more accurate, and predictable regional water balances. These advances will all need to be included in the runoff and river modelling technology that is used to manage water.

Environmentally sustainable extraction limits and protecting aquatic ecosystems

An objective of the National Water Initiative is to return over allocated or over used water resources to a sustainable level of use. As an example, one of the primary roles of the new Murray-Darling Basin Authority is to prepare a Basin Plan, that sets a sustainable diversion limit for the whole basin and for each water plan area within the basin, to meet defined environmental outcomes. The overall need is to define the water requirements to maintain ecosystems. without complicating decision making in any way, that places onerous demands on ecological knowledge. It requires several steps in reasoning. First, the environmental, cultural and recreational values associated with environmental assets need to be specified. Second, the various ecological functions and processes that maintain these assets need to be understood. Then environmental water and other management actions that are required to either maintain or restore ecosystem functions and processes sufficiently can be defined. This will include aspects of the timing and extent of flows as they influence the ecological outcome.

Land use and climate impact on aquatic system health through changes in water *quality* as well as quantity. These impacts extend from eutrophication and contamination of inland and estuarine systems through to degradation of off-shore ecosystems including the Great Barrier Reef. Understanding the linkages among policy, economics and the biophysical drivers of water quality embodies a host of research challenges underpinning environmental protection.

The R&D challenge is to provide quantitative, predictive ecology for each ecosystem asset. Managers need to know how ecosystems will respond to changes in water regime or quality to be able to set sustainable diversion limits and appropriate land use practise. There is no ecosystem in Australia where this can be done with certainty at present. Ecosystems need to be monitored and evaluated to see why they did or did not respond as expected and the results used to improve predictions. Experiments can be used to test hypotheses on ecosystem response to improve our knowledge of these systems and further improve predictive capacity. We have good understanding of some of the ecological processes, of behaviour of key species, and of how ecosystems have changed historically but this is yet to be transformed into quantitative predictive ecology for setting limits to water extraction or contaminant loads. Without this knowledge it will not be possible to provide reliable protection for ecological assets in water resource plans.

Diversified urban water supplies

Population growth, increasing urbanisation and climate change are undermining the security of urban water supplies. These drivers are also increasing effluent discharge and urban runoff to already stressed waterbodies. Australia's large cities are making capital investments worth in excess of $30 billion in new water supplies, and most are diversifying their supplies away from rainfall dependent storages to include desalination, decentralised supplies and some form of recycling. There is a paradigm shift away from just financial and engineering considerations to broader sustainability considerations spanning lower environmental footprint, social acceptability, energy use and greenhouse gas emissions. This is involving more integrated urban water management, joining water supply with wastewater and stormwater, and considering the many consequences of diversified supplies and reduced per-capita consumption. Research in urban water can make these major capital investments more effective but it is also needed to manage greater planning uncertainty, to develop new technologies and integrate them with existing infrastructure and ensure that public and environmental health is maintained.

The new sources of water have differing levels of reliability and the cost and attractiveness of each of these sources will vary from location to location, making the management of urban water systems more complicated. The integrated urban water grid must be cost effective, minimise energy use, not compromise public health and maximise sustainability outcomes. This requires integrated models of urban water behaviour which address all the management concerns. These are just starting to emerge but need considerable extra development and much better understanding of component parts of the system, particularly new elements, need to be included in the models. For example the models need to know how rainwater tanks and other decentralised supplies perform in each city, how demand varies with water restrictions and the energy use and greenhouse gas emissions of different components. Thus this priority is not just about the systems analysis but also ensuring the system behaviour now and into the future is accurately portrayed.

Innovations in hydrological forecasting

Water markets, water utilities, and environmental water managers would all benefit from an ability to predict water availability a season or more in advance. Accurate seasonal predictions can be used to make better decisions on water use from one season to another. The most acute need for such predictions has been in emergency responses to the prospect of several years of low seasonal inflows combined with critically low storage levels. Then, there is very little ability to buffer uncertainty in the next season's inflow using storage management. In these situations the inability to predict the next season's inflows can result in major costs, such as opportunity costs of delayed crop planting, or conservative water allocations, costs of crop failure and lost future opportunities from overestimating inflows. Fortunately, while Australia's hydrology is highly variable it is also relatively predictable from the large scale driving forces of our climate, such as El Nino. Good initial progress has been made on forecasting techniques and there is much potential for further improvements. The focus will be on numerical and statistical approaches that link to weekly to seasonal weather prediction.

Forecasting systems, and other water information services, can only be made routinely operational if the diverse water and weather inputs are ingested, processed and delivered effectively across all the agencies with responsibility for data collection and use. Research is required to design a comprehensive water information system architecture and related standards that can evolve over time as technologies and system requirements change, providing continuity and consistency for water information to a large community of users. The architecture must be open and freely available to allow organisations to participate to achieve large scale information interoperability.