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Australian Water Resources Assessment 2012

Water Information
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GPO Box 1289, Melbourne VIC 3001
Tel: (03) 9669 4000 Fax: (03) 9669 4699
Email: awra@bom.gov.au Website: www.bom.gov.au

The report, a summary document and other information about the *Australian Water Resources Assessment 2012* are available at: www.bom.gov.au/water/awra/2012

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Larnebarramul Swamp, Victoria | Alison Pouliot

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Foreword

The Commonwealth *Water Act 2007* created a number of additional functions for the Bureau of Meteorology (the Bureau), including the provision of 'regular reports on the status of Australia's water resources and patterns of usage of those resources'.

The *Australian Water Resources Assessment 2012* (the 2012 Assessment) is the second of these reports. It presents assessments of Australia's water resources and climatic conditions in 2011–12 and discusses regional variability and trends in water resources and patterns of water use over seasons, years and decades. It extends the content presented in the first assessment report (2010 Assessment) by including additional information about streamflow salinity, land use, population, soil types, physiographic regions, rainfall zones and rainfall deficits.

The Bureau's water resources assessments are repeated on a regular basis (currently every two years), with a focus on consistency in reporting of particular streams of modelled and measured water resources data. The 2012 Assessment is intended to assist understanding of the impact and sustainability of current water management practices and inform the design of water resource policies and plans. This will support the goals of the National Water Initiative and contribute to the water reform agenda.

The 2012 Assessment uses data provided from organisations across the country and research outputs of the Bureau's Water Information Research and Development Alliance with CSIRO. It has required significant effort from a large number of people and I am proud of the dedication and professionalism of the teams involved.

Graham Hawke

Deputy Director
Environment and Research Division
Bureau of Meteorology

September 2013

Introduction

1. Introduction

1.1 Background

The Commonwealth *Water Act 2007* gave the Bureau of Meteorology (the Bureau) responsibility for compiling and delivering comprehensive water information across Australia. This includes conducting timely, rigorous and independent assessments of the status of Australia's water resources.

The Bureau's first national water resources assessment was published in 2011 for the 2009–10 year (July 2009–June 2010). It built on earlier assessments undertaken by various Australian Government agencies and partners at irregular intervals over the last 50 years, each with a slightly different purpose and approach.

The Bureau's water resources assessments are undertaken at regional and national spatial scales and time scales ranging from months to decades. These reports are intended to assist assessment of the impact and sustainability of current water management practices and inform the design of future water resource plans, supporting the goals of the National Water Initiative and contributing to the water reform debate.

The Bureau's water resources assessments provide:

1. consistency in reporting across the nation and over time, enabling spatial and temporal comparisons of water resources by end users;
2. free access to water information via the web;
3. comparable information at regional and national scales;
4. a high level of transparency about the information and data used, and the modelling and analysis techniques employed;
5. scientifically robust analyses of changes in water availability, quality, and use over time-scales of months to decades; and
6. a presentation of Australia's water resources without reference to jurisdictional boundaries.

1.2 Scope and purpose

The *Australian Water Resources Assessment 2012* (the 2012 Assessment) presents assessments of Australia's climate and water resources over the 2011–12 year (July 2011–June 2012). It discusses regional variability and trends in water resources and patterns of water use over recent seasons, years and decades, using currently accessible data.

The 2012 Assessment is focused on aspects of national and regional water availability rather than water allocation, trading or quality (though salinity of surface streamflow and groundwater is included). Water use is addressed for various selected urban centres and irrigation schemes.

The 2012 Assessment includes the:

- Introduction;
- National Overview;
- 13 regional assessments;
- Glossary;
- Technical Supplement; and
- References.

A summary report and the data used to develop the figures is available from the Bureau's website.

The National Overview provides a continent-wide assessment of climate and water flows and stores across Australia in 2011–12. This includes national landscape water balance model outputs for the year, including rainfall, evapotranspiration, landscape water yield and change in soil moisture, as well as consideration of changes in surface water storage in each region. The National Overview examines important Australian climate drivers and their impact on rainfall over the year. It also provides an overview of urban and agricultural water use in 2011–12 for selected areas. Information on relevant nationally significant weather and flooding experienced in 2011–12 is also presented.

The regional chapters highlight changes in water availability and use in 13 regions that cover the Australian continent and Tasmania. Analyses presented include climate impacts on water resources over 2011–12 and also in recent decades (1980–2012). Modelled regional spatial data and time series data from selected monitoring sites provide more detail at particular locations.

With each assessment the same sites are used for data analysis. As new data becomes available the data used in analyses is updated for these selected sites. This allows clear comparisons to be made between assessments.

Finally, the Technical Supplement provides background on the landscape water balance modelling techniques, methods, the data and the analyses used to generate information in the report.

Information and data provided in the 2012 Assessment reflect the quantity and quality of data currently available for analysis. It is expected that as data supplied to the Bureau under the *Water Act* and the Water Regulations 2008 are further stored, standardised and quality assured by the Bureau, analysis and reporting will be enhanced. Feedback from users will also be used to improve future reports in terms of methods used, interpretation and content.

1.3 Focal questions

The 2012 Assessment aims to provide information to help address a variety of questions at a range of spatial and temporal scales subject to the availability of appropriate data. The scales vary from national in the National Overview to regional and local in subsequent chapters. Time scales also vary depending on the data used and the intent of the analysis. The types of questions addressed include:

1. Which ocean and atmospheric circulation patterns influenced rainfall in different parts of the country in 2011–12? (section 9 in the National Overview).
2. How much of the rainfall received in 2011–12 ended up in rivers and groundwater and how does this compare with the past? (section 3 in the National Overview; section 4 in the regional chapters)
3. Was there any significant flooding or dry periods in 2011–12 as a result of particular weather conditions? (section 11 in the National Overview; section 5 in the regional chapters)
4. How much of the rainfall received in 2011–12 was evaporated or used by plants and how does this compare with the past? (section 3 in the National Overview; section 4 in the regional chapters)
5. How moist were soil profiles across the country in 2011–12 and how does this compare with the past? (section 4 in the National Overview; section 7 of the regional chapters)
6. Are there any regional trends evident in seasonal rainfall, evapotranspiration, soil moisture, landscape water yield or groundwater levels? (sections 4, 5 and 7 in the regional chapters)
7. How do seasonal inflows to and outflows from selected nationally significant wetlands vary from year to year and are they changing? (section 5 in the regional chapters)

Tyto wetlands, near Townsville | Andrew Rankin (Queensland Image Gallery)

8. Where does the water for cities and irrigation areas come from and is this changing? (sections 6 and 7 in the regional chapters)
9. What seasonal to decadal patterns and trends are evident in water storage inflows and volumes, and in groundwater levels, particularly in relation to rainfall? (sections 5, 6 and 7 in the regional chapters)
10. How does water use in cities and irrigation areas vary from year to year, particularly in relation to water availability? (sections 6 and 7 in the regional chapters)

1.4 Assessment approach

The techniques used to produce the 2012 Assessment are explained in this section. The descriptions provide context to the information presented in the regional chapters.

Further information about the methods used to derive and analyse water and climate data is provided in the Technical Supplement.

1.4.1 Reporting units

The 2012 Assessment report is structured around 13 regions covering the Australian continent and Tasmania that are based on drainage division boundaries (Figure 1.1).

Drainage divisions represent the catchments of major surface water drainage systems, generally comprising a number of river basins. Drainage divisions provide a scientifically robust framework for assessing hydrological flows in the landscape while also allowing information to be presented and discussed in broadly identifiable biophysical regional and climatic contexts.

In Australia, 12 drainage divisions were first defined in the 1960s by the Australian Water Resources Council and the boundaries were formally published in the 1990s (Hutchinson and Dowling 1991). They were recently modified by the Bureau and its research partners at Geoscience Australia and the Australian National University, based on the most current topographical data. This dataset is described in the *Geofabric Product Guide* (The Bureau 2013b).

In the new drainage divisions, the South East Coast has been split into two regions to distinguish New South Wales coastal river basins from Victorian and

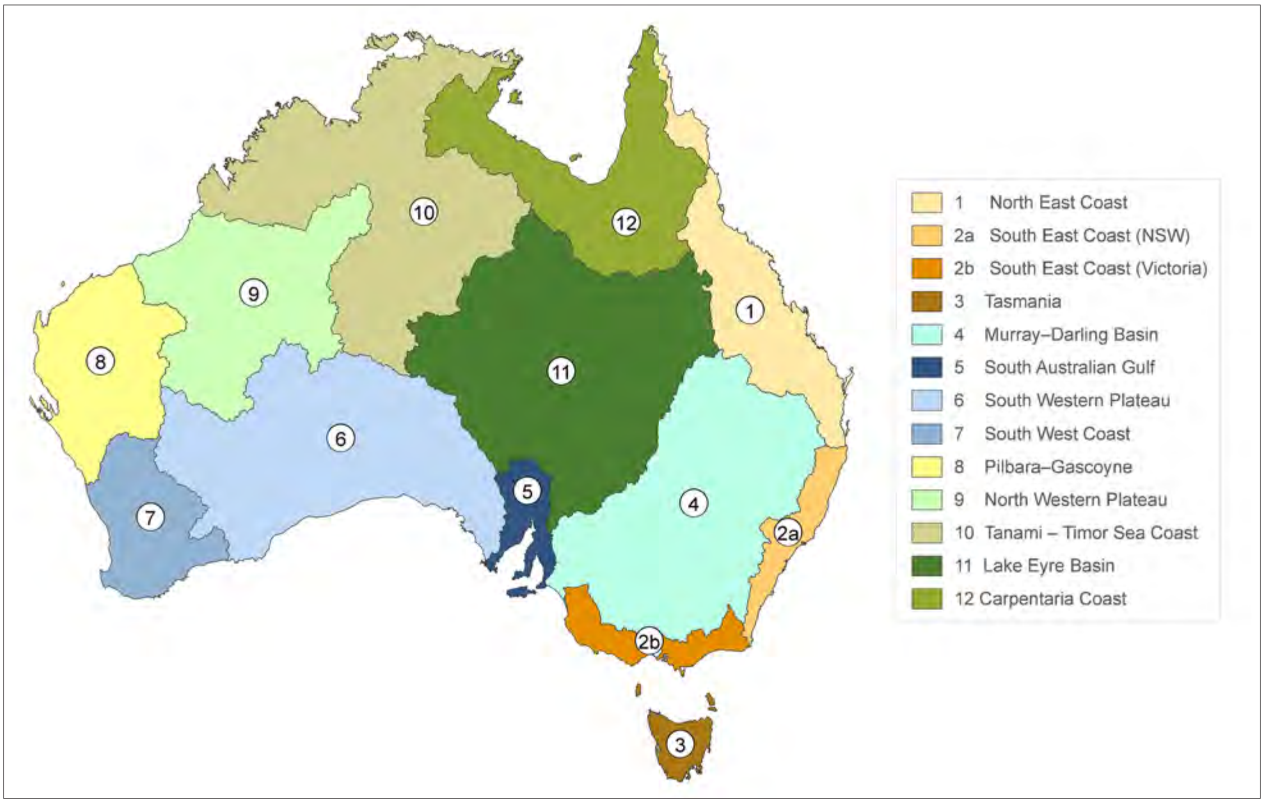


Figure 1.1 2012 Assessment reporting regions

southeastern South Australian coastal river basins (Figure 1.1), to further establish a manageable heterogeneity within and between reporting units.

Within the reporting regions shown in Figure 1.1, various time-series analyses and reporting techniques have been applied depending on the availability of data. Analysis and reporting units at the sub-regional level include hydrological units (surface catchments and groundwater aquifers), water management and planning areas, water supply systems and monitoring sites or clusters of sites (for example, stream gauges on tributaries flowing into a reservoir).

1.4.2 Reporting period

The data and information presented focuses on the 12 months from July 2011 to June 2012 and/or months and seasons therein. Time-series analyses are restricted to consideration of data from 1980, in order to place the 2011–12 period in the context of the variability and trends in recent decades, with the exception of the landscape water balance flows, which are related to the rainfall data and generated model results from 1911 onwards.

Trends in groundwater levels for major aquifers in the regions are reported for the past five years (2007–08 to 2011–12).

1.4.3 Landscape water balance

Water balances are used as a consistent and repeatable means of reporting on water availability. A water balance has a number of standard variables:

- inflows, for example, rainfall;
- outflows, for example, evaporation, transpiration, run-off; and
- change in storage, for example, soil moisture.

Key terms used in the 2012 Assessment are presented in Figure 1.2. The spatially dispersed landscape water flow components, besides rainfall, include:

- Evapotranspiration: the combination of modelled evaporation from the soil and modelled transpiration from vegetation.
- Landscape water yield: the sum of modelled surface run-off and groundwater discharge to surface waters. This approximates streamflow at monthly to annual time scales in high rainfall areas and areas with steep slopes. It is an indication of potential water availability, especially groundwater, in low rainfall or topographically low profile areas.

Together with soil moisture, these are the only terms that are assessed through the use of a landscape water balance model. All other terms are assessed through the use of measured data.

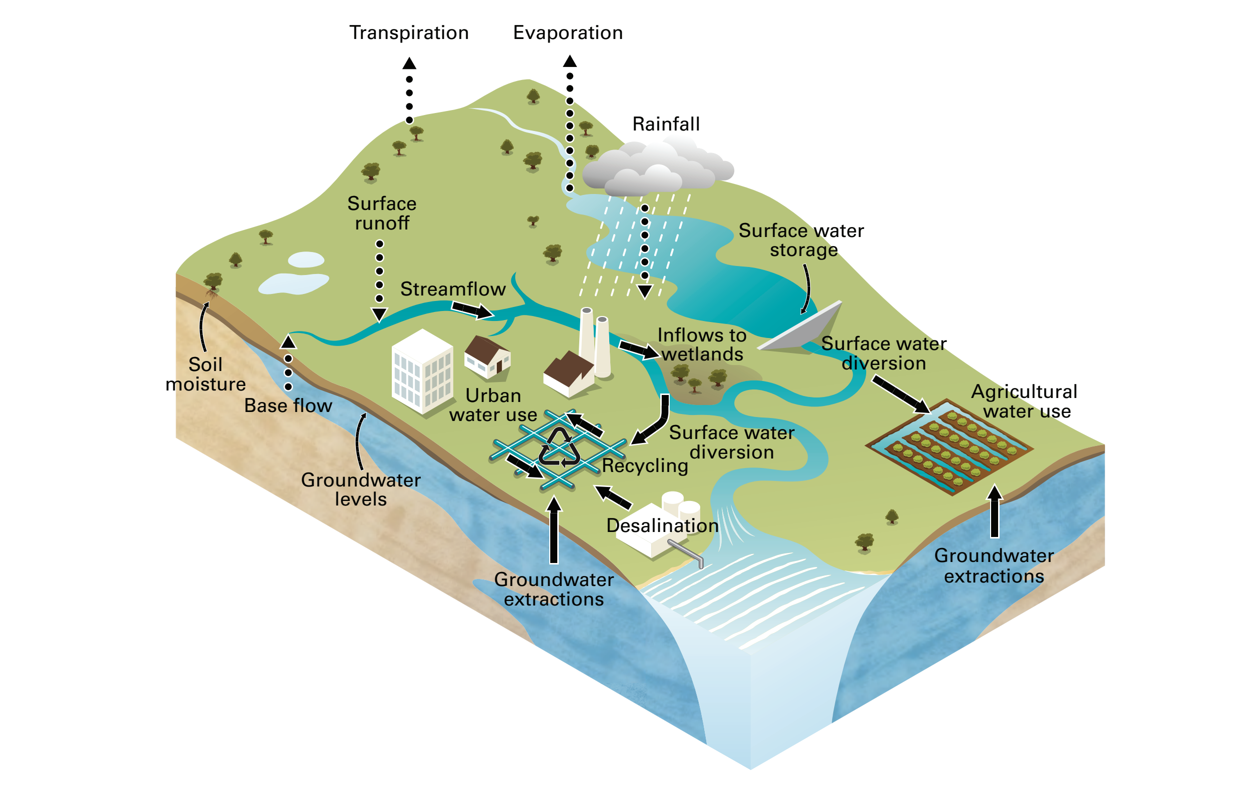


Figure 1.2 Water balance terms reported on in the 2012 Assessment

1.4.4 Mapped rainfall data

This 2012 Assessment uses daily rainfall data to drive the landscape water balance model. National daily rainfall grids were generated using rainfall station data from a network of persistent, high-quality sites managed by the Bureau. The grid resolution is constrained by the density of the network of rainfall stations across Australia, and is approximately 5 km x 5 km (0.05° grid).

For monthly and annual aggregate rainfall information presented on the Bureau website and in other Bureau products (for example, the National Water Account), the Bureau applies a post processing analysis method. This analysis uses rainfall ratios (daily rainfall divided by monthly averages) to incorporate the general influence of topography on prevailing weather systems, which is reflected in the monthly averages (Jones et al. 2009). The analysis provides an objective estimate of rainfall in each grid square and thus enables useful estimates of rainfall in areas with few rainfall stations, such as Central Australia. This accounts for small differences in the rainfall information shown in the 2012 Assessment as compared to other Bureau products.

Areas where rainfall interpolation was assessed to be unreliable have been marked in the maps to assist the reader in identifying the relevance of the spatial information. More detail is provided in the Technical Supplement (section data and analysis).

1.4.5 National landscape water balance modelling

A newly developed nationally consistent landscape water balance model, the Australian Water Resources Assessment Modelling System (AWRAMS) was used to generate estimates of landscape water flows and stores across the country in the 2012 Assessment. The AWRAMS was developed for the Bureau's water-reporting purposes through the Water Information Research and Development Alliance between the Bureau and CSIRO. The purpose of the AWRAMS is to provide up-to-date, credible, accurate and relevant information about the history, present state and future trajectory of the water balance in Australia to inform water resources management policy. The 2012 Assessment is the first in its series that uses a nationally consistent landscape water balance model.

The landscape water component of the AWRAMS is referred to as AWRA-L and simulates water stores and flows in the landscape: the vegetation, soil and local catchment groundwater systems (van Dijk 2010). AWRA-L incorporates a catchment water balance that takes account of vegetation ecohydrology and phenology. AWRA-L is a national, distributed model and runs at a daily time-step. Figure 1.3 shows a schematic representation of the components (inputs, stores, flows and outputs) of the AWRA-L model.

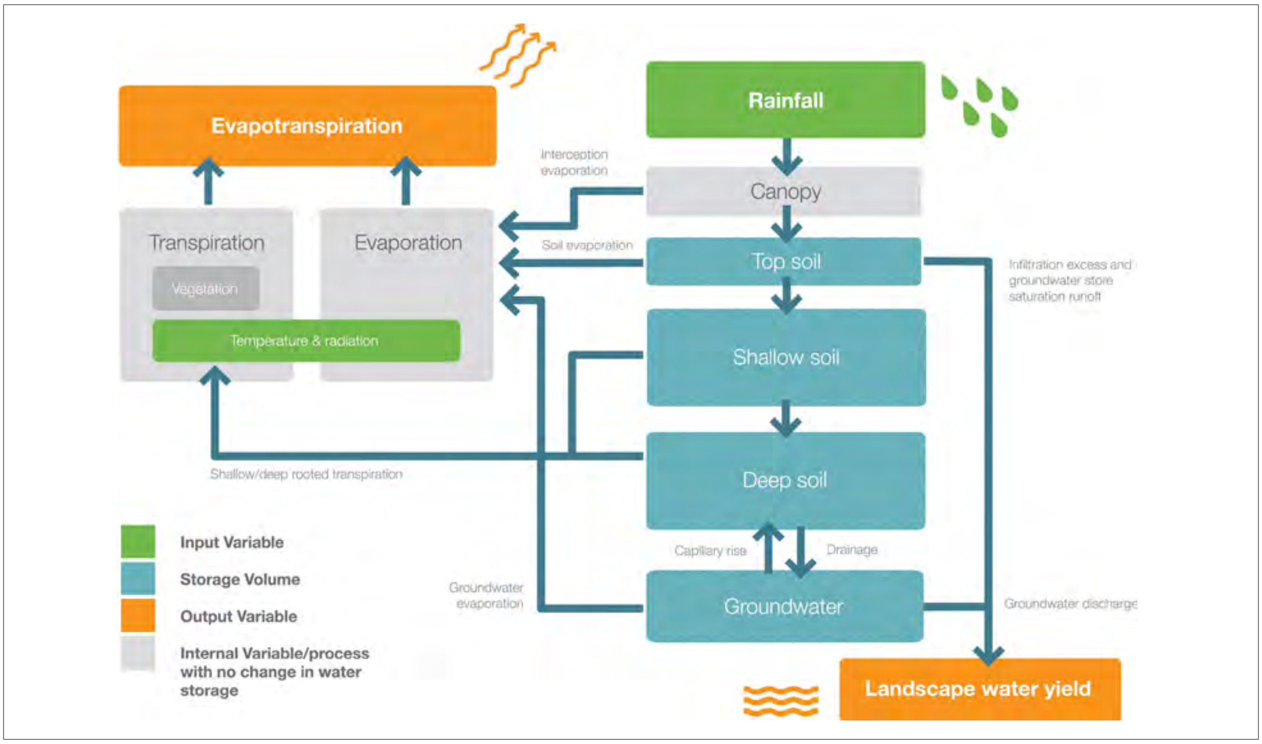


Figure 1.3 Schematic representation of inputs, outputs, flows and stores in the AWRA-L landscape water balance model

AWRA-L simulates water stores and flows on the landscape based on the following principles:

- Net rainfall is determined after accounting for interception and direct evaporation losses.
- Run-off occurs from the surface top soil through saturation or infiltration excess processes.
- Soil moisture storage and fluxes are described in three soil layers: surface top soil, shallow, and deep soil. They include evaporation, transpiration and drainage processes. Root uptake of water occurs from both the shallow and deep soil layers.
- Groundwater balance typically comprises drainage from the deep soil layer, capillary upward flow, discharge into streams and change in storage.

AWRA-L was run nationally on a 0.05° grid (approximately 5 km x 5 km), consistent with the resolution of available climate data required as input to the model.

For the 2012 Assessment, the model was used to derive estimates of monthly and annual landscape evapotranspiration and water yield for each grid cell. These estimates don't include estimates of the impact of surface water bodies or human activities such as irrigation. Estimates of landscape water yield were produced by taking the total of modelled surface run-off and groundwater discharge estimates. The model was also used to provide estimates of changes in the soil moisture store over 2011–12.

The 2012 Assessment differs from the 2010 Assessment in that an improved calibration of the AWRA-L model was used in analyses in the 2012 report. The 2010 Assessment used combined outputs of the Waterdyn and AWRA-L models. The combined model outputs were not required for the 2012 Assessment as the new calibration has resulted in a more satisfactory representation of the landscape water flows (see Technical Supplement for more information on the model choice). The annual and seasonal patterns in total flows given in the regional chapters of the 2012 report supersede those in the 2010 report.

1.4.6 Percentiles, deciles and anomalies

National rainfall and landscape water balance analysis outputs are presented in the form of monthly and annual totals for the 2011–12 water year in conjunction with their decile rankings when compared with the historical record.

Percentiles and deciles show the ranking of the observations or estimated water balance terms for the year relative to all values in the historical record. They provide a clear indication of above or below average estimates relative to the long-term record.

The advantage of presenting percentiles and deciles in addition to absolute values is that a given estimate may vary considerably at different locations due to variations in climate and landscape characteristics whereas percentiles and deciles express this variability relative to the long-term average at a particular location.

As observations and, in particular, estimated model outputs can be imprecise both spatially and temporally, it is more credible to give relative indications of spatial and temporal differences and trends.

Using these statistical tools to relate current year data relative to history avoids putting undue emphasis on the absolute difference between years.

Calculation of percentiles, deciles values and variability in climate datasets held by the Bureau typically use all years of record to best describe pronounced conditions in these datasets.

For example, to calculate the 'wettest month on record', data from all years in the record are required; however, limitations in the temporal and spatial extent, as well as the quality of data, also have a bearing on the most appropriate reference period.

With this in mind, the 101-year period from July 1911–June 2012 was used to calculate percentiles and deciles for rainfall and modelled landscape water balance terms.

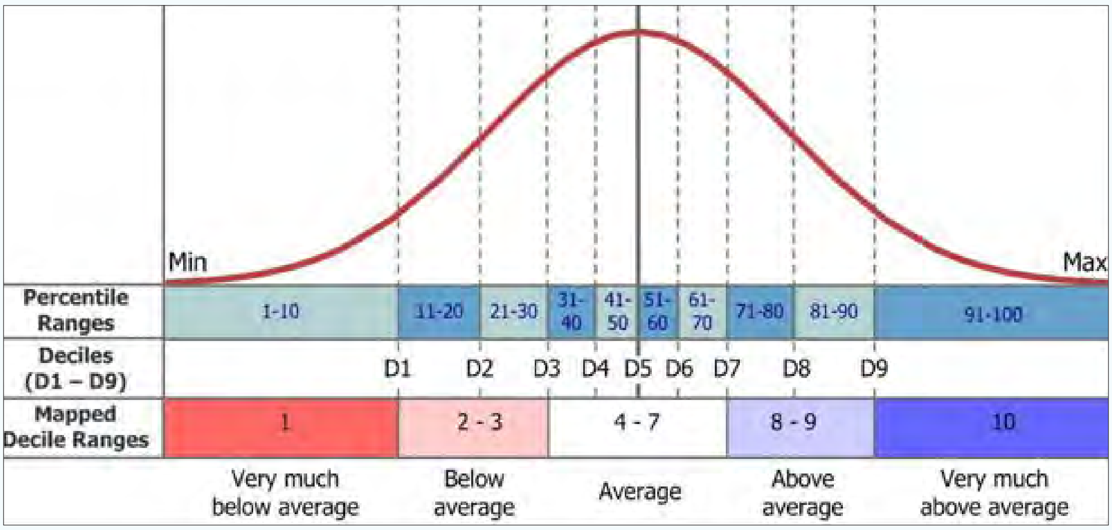
Box 1.1 Deciles and percentiles

Deciles and percentiles are forms of descriptive statistics widely used in science to provide an easily interpretable and standardised summary of the position, or scale, of a value, measurement or observation relative to the full distribution of the long-term record.

A decile represents any of the nine values that divide a ranked dataset into ten groups with equal frequencies, so that each part represents a tenth of the record. Percentiles simply split the data into 100 equal parts; therefore, a decile is the aggregation of a set of ten percentiles.

If the graph presented in the figure below is assumed to represent the ordered distribution of a long-term record of observations (for example annual rainfall totals), then:

- Decile 1 (D1) is the highest value of the first (lowest) grouping; therefore in 10% of the years on record the annual rainfall total did not exceed the D1 value. This is equivalent to the 10th percentile value.
- Decile 9 (D9) is the highest value of the ninth (highest) grouping; therefore in 10% of the years on record the annual rainfall total exceeded the D9 value. This is equivalent to the 90th percentile value.
- The median, or decile 5 (D5), is that value which marks the level dividing the ordered dataset in half, that is, the midpoint of the ordered annual rainfall totals. This median value is equivalent to the 50th percentile value.
- This example also illustrates the classification of decile ranges used in this report to define values relative to the average (median) range that is within the 'average' range, 'above / below average' or 'very much above / below average'. For example, Decile range 10 is the grouping of values that exceed Decile 9.



1.4.7 Flood classification analyses

National and regional flood peak analyses for the 2011–12 period are presented. The Bureau definitions of minor, moderate and major flooding are defined on a State-by-State basis in consultation with stakeholders for key monitoring sites based on impacts on infrastructure and properties (see www.bom.gov.au/water/awid/index.shtml for the definitions of the flood classes).

A national analysis in the National Overview shows locations where peak river levels exceeded the major flood threshold during 2011–12. Flood maps are also provided in the regional chapters presenting all key flood gauging sites within each region and the maximum flood level that occurred during 2011–12.

1.4.8 Trend analyses

Climate and landscape water balance analysis for the regional scale (chapters 3–15) is the same as that used at the national scale. However, spatial trend analyses are also included at the regional scale. Trend values were determined from a linear or straight line fit using ordinary least square regression. Trend maps enable comparisons of how rainfall and other water balance terms have changed in different regions of Australia over time.

These trend maps need to be interpreted with caution. Readers are advised to interpret the trend maps in the context of the accompanying time-series. For example, a calculated trend could be due to a relatively rapid 'step' change, with the remainder of the series showing no trend. Spatial surfaces such as rainfall are based on point observations and, therefore, the removal or addition of a station in the network can affect the temporal analysis (particularly if it is located in an area with significant topographical influence) and may introduce an artificial 'step change'.

The maps aim to provide a very simple spatial assessment of the general direction and, to a limited degree, the scale or magnitude of the fitted linear trends in the climate and landscape water balance time-series. The significance of estimated trends is often low as is presented in the regional trend analyses. The trend estimates are constrained by the assumptions associated with the statistical analysis that are described in the Technical Supplement.

The trend map values should not be used to imply future rates or directions of change. Due to the complex interactions between natural and human drivers of climate change and variability, the climate of any location is always changing. Future rates of change will depend on how these drivers interact in the future, which will not necessarily be the same as in the past.

1.4.9 Site-based anomaly and time-series analyses

Water data from a wide range of organisations across Australia are currently being received by the Bureau (under the *Water Act* and Water Regulations 2008). This includes data and information on:

- climate (including rainfall);
- streamflow;
- surface storage levels and volumes;
- groundwater;
- agricultural water supply and use;
- water allocations and trade;
- urban water supply and use;
- urban water restrictions; and
- water quality.

At the time of publication, only a subset of data pertaining to these categories had been received, stored and checked by the Bureau and made available for analysis and presentation in this report. This included datasets on climate, streamflow and surface storage, and selected datasets related to groundwater, urban and irrigation water supply and use.

The location of monitoring sites for rainfall, streamflow, storage volumes, flood heights and groundwater level and salinity addressed in this report are shown in figures 1.4 and 1.5. A total of 292 river gauges, 315 flow salinity gauges, 25 wetland gauges, approximately 3,000 rainfall stations, 13,644 groundwater bores, 280 storages and 1,244 flood sites have been used in this report.

Where possible, selected sites, stations and datasets were identified to help present temporal variability in water availability and use around the country over the past 12 months in comparison to the past three decades.

Seasonal and annual discharges at selected river monitoring sites for 2011–12 are compared to the deciles of the datasets at these sites for the years following 1980. Variation of the annual river salinity at selected river monitoring sites for 2011–12 is also presented.

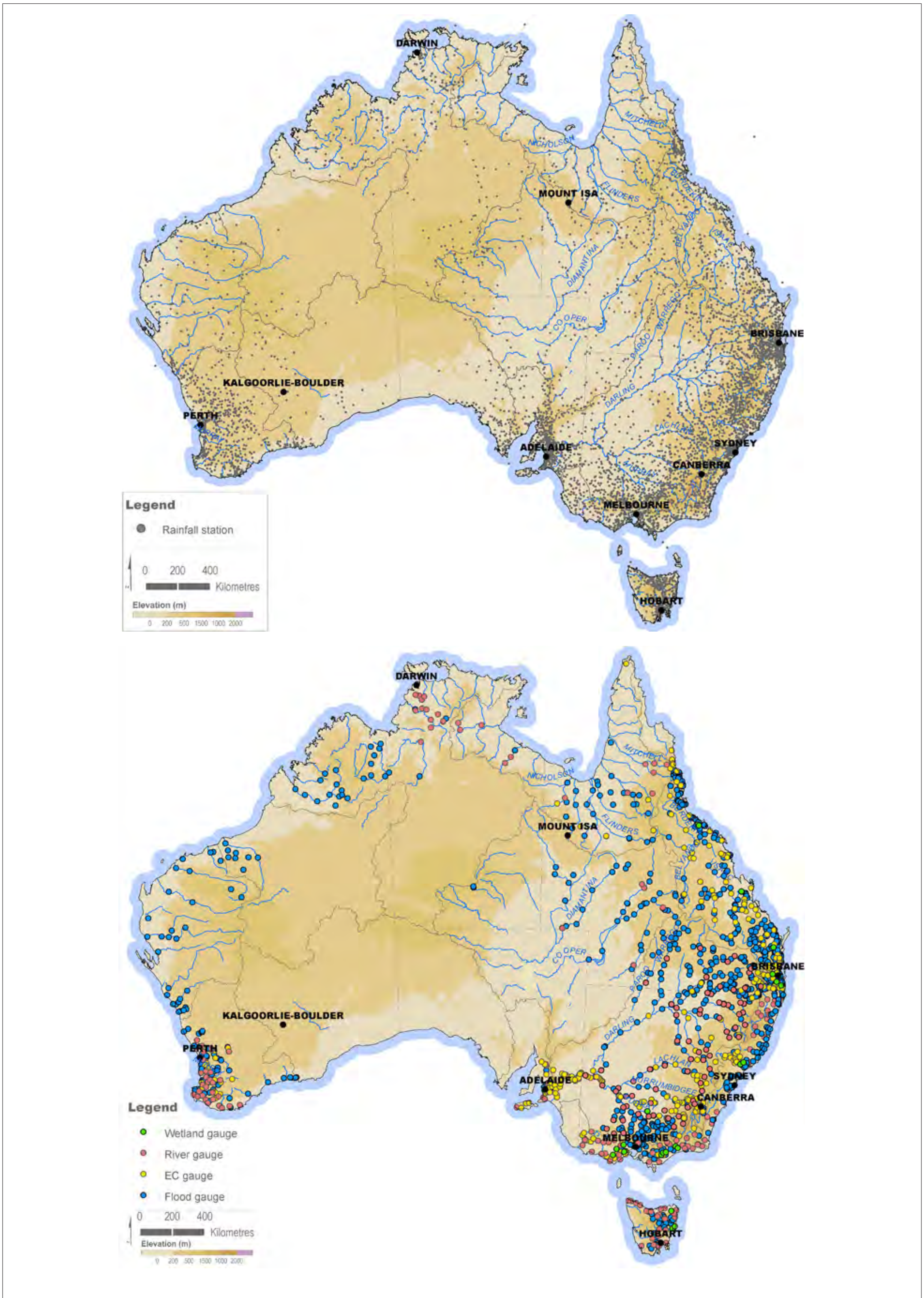


Figure 1.4 Location of (a) rainfall stations, and (b) river gauges selected for analysis in this report

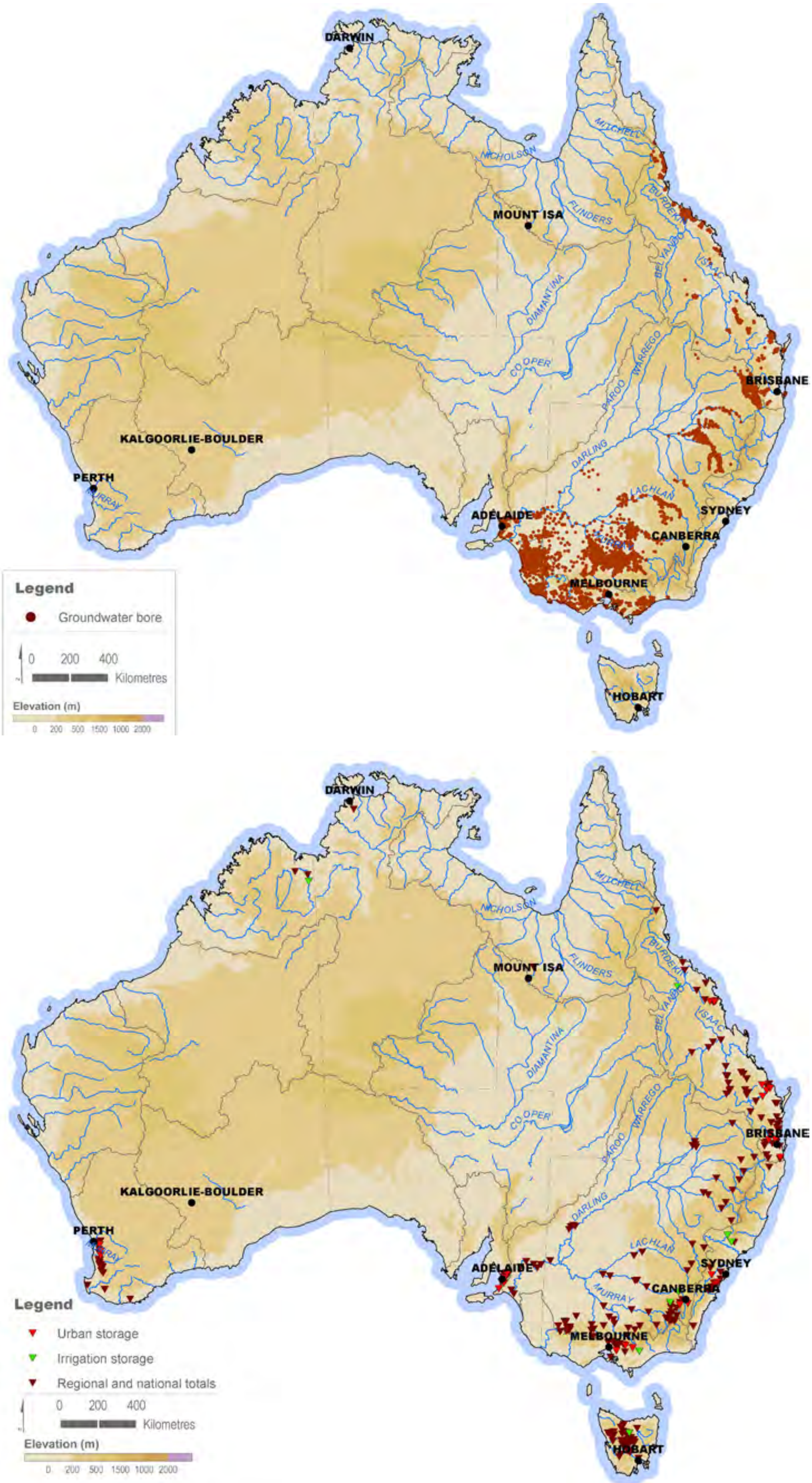


Figure 1.5 Location of (a) groundwater bores, and (b) surface water storages selected for analysis in this report

At river monitoring sites important for describing wetland inflows or outflows, decile ranges for each month were determined based on the monthly flows from 1980 onwards. Results for daily distribution of streamflow decile rankings over time are also presented.

Water quality, particularly river water salinity levels for 2011–12, were plotted for selected river salinity monitoring sites in selected regions where sufficient suitable data were available for this report.

Groundwater level and electrical conductivity readings over the past 20 years were plotted for monitoring bores in selected groundwater management units in regions where suitable data were available for this report.

Urban and irrigation water supply and use level and trends for the major cities and irrigation district within the region were presented where suitable data were available for this report.

1.5 Quality control and review: Who was involved?

Specialist reviewers comprising water domain and regional experts were invited to review the report before publication. These specialists, both from within and external to the Bureau, have expertise in a variety of fields, including hydrology, climatology and water resources modelling.

These reviewers were requested to examine the report with the aim of improving its quality and credibility by evaluating:

- the suitability of data used;
- the validity and robustness of the methods used;
- the appropriateness and presentation of figures and tables;
- the extent to which information is accurate, clear, complete and unbiased;
- whether information is presented within a proper context;
- the clarity of conclusions and findings;
- the extent to which conclusions are unambiguous and supported by results;
- whether any important issues or data were omitted; and
- the overall quality, style and presentation of the material.

Overall, comments and suggestions were received from over 40 reviewers. Stakeholder comments and suggestions that were not able to be implemented in this report will be considered in the evaluation process for future water information products and water resources assessments.

1.6 Terminology

In addition to definitions in the Bureau's *Australian Water Information Dictionary* (see www.bom.gov.au/water/awid/index.shtml), additional frequently and consistently used terminology in this report is defined as follows:

Very much above average	Values are among the highest 10% of the time-series in question (10th decile range).
Above average	Values lie above the highest 30% (70th percentile) but below the highest 10% (90th percentile) of the time-series in question (8th and 9th decile ranges).
Average	Values lie between the 30th percentile and the 70th percentile of the time-series in question (4th to 7th decile ranges).
Below average	Values lie above the lowest 10% (10th percentile) but below the lowest 30% (30th percentile) of the time-series in question (2nd and 3rd decile ranges).
Very much below average	Values are among the lowest 10% of the time-series in question (1st decile range).

1.7 Future reports

The Bureau's water resources assessments will develop over time as the availability and quality of data and modelling systems improve and as analytical and reporting methods are automated. Future reports will benefit from greater access to a range of water information progressively being stored and delivered through the Australian Water Resources Information System: www.bom.gov.au/water/about/wip/awris.shtml

Monitoring sites will be added as the coverage of the report is expanded and as additional information becomes available. In particular, it is anticipated that analysis and reporting of groundwater and water quality will be increasingly evident in future reports as data availability improves.