Australian Government

National Land & Water Resources Audit

An Initiative of the Natural Heritage Trust

Land salinity

Status of information for reporting against indicators under the National Natural Resource Management Monitoring and Evaluation Framework

www.nlwra.gov.au

About the National Land & Water Resources Audit

The National Land & Water Resources Audit ('the Audit') provides data, information and nationwide assessments of Australia's land, water and biological resources to support sustainable development. It is an initiative of the Natural Heritage Trust. It commenced in 1997 and published the first set of detailed assessment reports in 2002.

The Audit (2003–08) has six key areas of activity:

- developing a consistent national reporting mechanism for collating natural resource information collected under the National Natural Resource Management Monitoring and Evaluation Framework
- collating information to support the national State of the Environment (SoE) reports
- developing nationally consistent, but regionally relevant integrated resource condition reports
- facilitating reporting on the ongoing collection of natural resource information for key theme areas, including those related to the National Natural Resource Management Monitoring and Evaluation Framework
- reporting on national data and information management (in collaboration with ANZLIC — the Spatial Information Council)
- developing national assessments (as requested) and supporting program evaluations.

For further information see http://www.nlwra.gov.au

The Audit's mission

To provide data, information and nationwide assessments of Australia's land, water and biological resources to support sustainable development.

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We invite all interested people, both within and outside the government, to make use of the Audit's reports, information, its Atlas and products. We encourage you to discuss the Audit's findings with the various partners and contributors that have prepared this information.

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Foreword

Effective management of natural resources requires good quality data and information at the right level of detail to be available for those who need it. Australia invests significant resources each year in the collection and maintenance of data to inform natural resource management decisions.

Since 1997, the National Land & Water Resources Audit has played a vital role in the national coordination, collation and reporting of this information. The Audit collaborates with a range of partners, including the Australian Government, state and territory governments, regional natural resource management bodies, industry, the private sector and community organisations.

This booklet is part of a series that describes the status of data and information relevant to national indicators agreed under the National Natural Resource Management Monitoring and Evaluation Framework. It specifically reports on the status of information relating to indicators of land salinity. Clarifying the current status of data and information on land salinity is a vital step towards more strategic future investment.

Noteworthy advances in identifying information needs related to land salinity include:

- a strong partnership between Australian governments through the National Coordinating Committee for Salinity Information
- significant progress on identifying relevant information management systems and standards for storing salinity information
- progress on land salinity indicators and reporting, building on the Audit's *Australian Dryland Salinity Assessment 2000* (NLWRA 2001)
- progress on filling key data gaps, particularly mapping of land salinity and identification of networks of bores suitable for monitoring salinity.

Geoff Gorrie
Chair, Audit Advisory Council

Acronyms and abbreviations

ANZLIC	the Spatial Information Council (formerly known as the Australia New Zealand Land Information Council)
ASIP	Australian Salinity Information Project
ASRIS	Australian Soil Resource Information System
AWDIP	Australian Water Data Infrastructure Project
AWRIS	Australian Water Resource Information System
BRS	Bureau of Rural Sciences
EC	electrical conductivity
EM	electromagnetic
GFS	groundwater flow systems
National M&E Framework	National Natural Resource Management Monitoring and Evaluation Framework
NCCSI	National Coordinating Committee for Salinity Information
NLWRA	National Land & Water Resources Audit (the Audit)
TDS	total dissolved salts

Contents

Executive summary

This booklet summarises the current capacity to report on land salinity indicators pertaining to the land salinity 'matter for target' agreed under the National Natural Resource Management Monitoring and Evaluation Framework (the National M&E Framework). The four indicators are:

- depth to groundwater (indicator 1)
- groundwater salinity (indicator 2)
- baseflow salinity (indicator 3)
- location, size and intensity of salt-affected areas (indicator 4).

The National Land and Water Resources Audit (the Audit), in collaboration with the Bureau of Rural Sciences and all states, conducted trials in each state to examine the applicability and scalability of the land salinity indicators (BRS 2007). The trials confirmed that the land salinity indicators, when combined with the appropriate contextual information, could be used to identify areas at risk from, or currently experiencing, degradation due to the effects of groundwater-induced land salinity.

Groundwater monitoring bores (photo by Craig Liddicoat)

Salt-affected pastures near Kingston, South Australia (photo by Craig Liddicoat)

The National Coordinating Committee for Salinity Information (NCCSI) developed a set of protocols that outline the range of methodologies that can be used to measure and report on the indicators. These protocols were endorsed by the Audit Advisory Council in March 2007.

Data and information systems operating within different jurisdictions have been established at different times, at different scales and for different purposes, and there is currently no national database for land salinity information. Nationally consistent information is critical if natural resource managers are to respond correctly to the important nationwide issue of land salinity. This booklet identifies information on the various state, territory and national databases relating to the land salinity indicators.

To improve coordination and reduce duplication of data and information systems, the NCCSI proposes that:

- data on the three indicators relating to groundwater and surface water salinity (indicators 1 to 3) be collated and managed via the national system being developed through the Bureau of Meteorology's Australian Water Resources Information System
- data for the remaining indicator (indicator 4) be collated and managed through the Australian Soil Resource Information System
- the four land salinity indicators be reported, together with all National M&E Framework indicators, through Australia's Resources Online — a national web-based reporting system being developed by the Audit.

Contextual data are essential for the interpretation of indicator data, and will be pivotal in understanding and communicating changes and trends in land salinity. Relevant contextual data need to be collated and stored in close association — and able to be integrated — with the national indicator datasets, where necessary. Several national datasets providing important contextual data have been identified and are listed in this booklet.

The booklet also outlines some of the information products used for reporting on land salinity, which can take a variety of forms, to satisfy different objectives and audiences. Products range from those derived directly from the indicator data (eg salinity maps) to those that include contextual data (eg conceptual models of salinity processes) to those that combine results and interpretation from several indicators (eg salinity fact sheets).

The collection, collation and reporting of land salinity information across multiple agencies and natural resource managers, all with different needs and perspectives, is a continuing challenge. This booklet shows that the Audit and its partners are making significant progress towards this goal.

Introduction

In 2001, the National Land & Water Resources Audit (the Audit) published the first national assessment of dryland salinity in Australia (NLWRA 2001). While a very useful snapshot of the status of dryland salinity across Australia, this report was limited by the availability of the right data, in the right areas and at the scale required to successfully understand and quantify salinity processes. It also excluded the significant issue of groundwater-induced salinity in irrigation areas.

This booklet summarises Australia's current capacity to report on land salinity; one of the 'matters for target' agreed under the National Natural Resource Management Monitoring and Evaluation Framework (referred to as the National M&E Framework). The framework was developed in 2002 to assess progress towards improved natural resource condition. One of the framework's key requirements is a set of indicators for monitoring progress on each of the 'matters for target' set under the framework (Appendix 1 provides information about the framework). The indicators identify the factors that need to be measured to track and report trends on resource condition.

The Audit is responsible for coordinating the ongoing development of the National M&E Framework indicators; it is also responsible for supporting national collation of, and reporting against, each indicator.

The Audit works with theme-based national coordination committees to identify strategic issues and oversee progress. Each committee is sponsored by an Australian Government agency. In the case of the land salinity indicators:

- the theme-based national coordination committee is the National Coordinating Committee for Salinity Information (NCCSI), which was established under the Natural Resource Management Ministerial Council committee structure to advise on policy issues associated with salinity information (the committee also reports to the Audit Advisory Council on the development of national information standards)
- the sponsor for the committee is the Australian Government Department of Agriculture, Fisheries and Forestry

Table 1 Agencies represented on the National Coordinating Committee for Salinity Information (NCCSI)

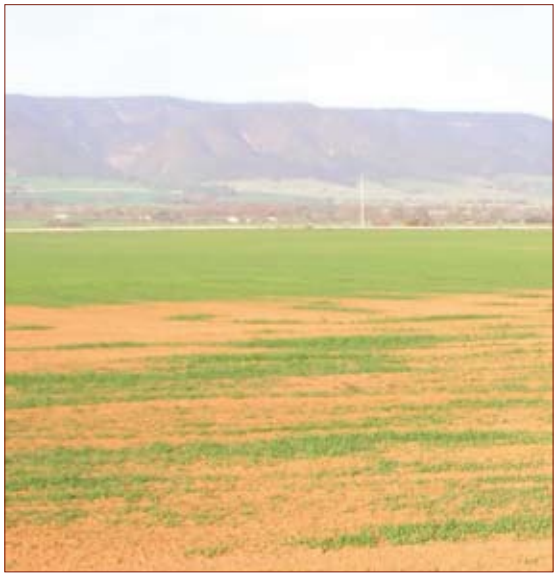
Jurisdiction	Agency represented on NCCSI
NSW	Department of Environment and Climate Change Department of Water and Energy
Qld	Department of Natural Resources and Water
SA	Department of Water, Land and Biodiversity Conservation Rural Solutions SA
Tas	Department of Primary Industries and Water
Vic	Department of Sustainability and Environment
WA	Department of Agriculture and Food
Australian Government	Department of Agriculture, Fisheries and Forestry Bureau of Rural Sciences Geoscience Australia Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land and Water
National	National Land & Water Resources Audit
Other	Murray–Darling Basin Commission

- secretarial services are provided by the Bureau of Rural Sciences (BRS) as part of the Australian Salinity Information Project (ASIP). The NCCSI oversees the ASIP.

The NCCSI includes representatives from Australian and state government agencies (Table 1).

The NCCSI meets three times each year to consider the following key issues:

- coordination and partnerships
  - providing a forum for national leadership and coordination of information, data and knowledge about salinity and salinity management



Crop failure on salt-affected ground (photo by Craig Liddicoat)

  - facilitating collaboration and partnerships between data collectors, managers and users

- information needs and indicators
  - supporting Audit objectives and related reporting issues

- data infrastructure and systems
  - improving data collection, management and sharing for any national assessment of land salinity
  - providing national oversight of key data infrastructure programs and projects for salinity
  - providing agreed data protocols, guidelines and standards to enable Australia-wide, state, territory and regional data to be assessed in a comparable way

- trials and information delivery
  - identifying significant gaps in existing salinity data and information

- communication and products

- analysis and assessments
  - providing advice on the results of assessments to the broader community, to raise awareness and to ensure that information products are well understood.

National indicators

The National M&E Framework identifies four indicators for land salinity, under the heading 'areas threatened by shallow or rising watertables'. Box 1 lists the four indicators, and Figure 1 shows the relationship between the indicators in a landscape context.

Box 1 Land salinity indicators

The four land salinity indicators from the National M&E Framework are:

- depth to groundwater (indicator 1)
- groundwater salinity (indicator 2)
- baseflow salinity (indicator 3)
- location, size and intensity of salt-affected areas (indicator 4).

An initial assessment of the land salinity indicators in 2004 suggested that there were significant data gaps (Beaten Track Group 2004). The Audit, in collaboration with BRS, funded trials in each state to examine the applicability and scalability of the land salinity indicators (BRS 2007). In particular, the trials looked at issues associated with the indicators in terms of:

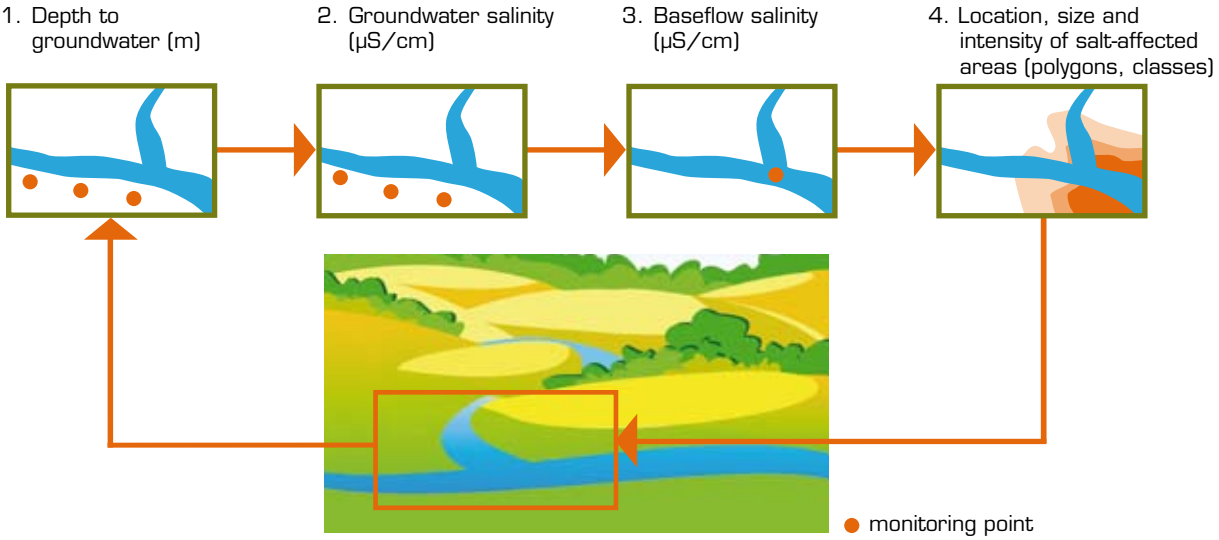
- practical application
- data and information requirements and management
- presentation of a range of products that may be useful in reporting against the indicators
- contextual information needed to aid interpretation and evaluate change.

The trials confirmed that the land salinity indicators, when combined with the appropriate contextual information, could be used to identify areas at risk from, or currently experiencing, degradation due to the effects of groundwater-induced land salinity. Using the results of the trials, the NCCSI developed a set of protocols that outline the range of methodologies that can be used to measure and report on the indicators. In March 2007, these protocols were endorsed by the Audit Advisory Council. More details on land salinity indicators, including full protocol documentation, can be found on the Audit's website.[1]

Different jurisdictions monitor land salinity at a range of scales to meet the needs of different audiences (Table 2). However, the use of nationally consistent indicators and protocols allows these

[1] http://www.nlwra.gov.au by following the prompts to natural resource topics and then land salinity.

Figure 1 Relationship of the indicators in a landscape context



diverse sets of data to obtain nationally consistent and relevant information. In order to prioritise areas for investment in salinity mitigation, it is also important to identify agricultural and environmental assets, either under threat from salinity or subject to degradation by salinity. It is recommended that a baseline salinity map that identifies agro-environmental assets, existing and past salinity management investments and relevant resource datasets such as climate and groundwater flow systems would assist identification of high risk areas.

ors and their protocols is an iterative process. Issues regarding development of the indicators are discussed in the section on data availability and gaps, below.

Measuring indicators

Two of the indicators — depth to groundwater and groundwater salinity — are measured at critical points in the landscape (eg upper and mid slopes, break of slopes and discharge zones). Thus, data for these two indicators can be taken from the same piezometers

Table 2 Reasons for monitoring land salinity indicators at different scales

Reason	Relevant scale			
	Subcatchment (local)	Regional	Multiregional (state)	National
Research to define the salinity problem[a]	✓	✓	–	–
Monitor effectiveness of management response[a]	✓	✓	✓	✓
Identify existing and potential problem areas	✓	✓	✓	✓
Assist with local resource management	✓	✓	✓	–
Identify naturally saline areas (eg for management of biodiversity)	✓	✓	✓	–
Engage and educate the community	✓	✓	✓	✓
Report on change in resource condition resulting from investments[a]	✓	✓	–	–
Inform and prioritise new investment	–	✓	✓	✓
Track condition of resources	✓	✓	✓	✓

a Both degradation resulting from salinity and associated remediation may take years or even decades. In monitoring the impacts of management actions, it is important to factor in the time lags associated with the particular type of groundwater flow system.

or monitoring bores. The third indicator — baseflow salinity — can be measured directly where groundwater discharges into streams; alternatively, it can be modelled from records of stream salinity and flow. Measurement of the fourth indicator — location, size and intensity of salt-affected areas — requires mapping of different salinity intensity classes across the landscape.[2]

The following standard salinity units have been adopted, as outlined in the national indicator protocols:

- microsiemens per centimetre (µS/cm, referenced to a temperature of 25°C) for groundwater or baseflow salinity measurements
- decisiemens per metre (dS/m) for soil salinity (electrical conductivity; EC) measurements.

2 See land salinity protocols on the Audit's website.

Indicator data needs

Following the initial assessment of the specific data needs required to report against the National M&E Framework indicators (Beaten Track Group 2004), the data needs were refined after the state trials, and the indicator protocols were endorsed by the Audit Advisory Council in March 2007. Recommended data needs are outlined in Table 3, classified as either protocol or contextual data as follows:

- *protocol data* — required for indicator measurement as defined in the protocol
- *contextual data* — required for interpretation, and for understanding and communicating changes and trends; such data can be further categorised as 'critical' (ie needed to understand the indicator) or 'useful' (ie helpful in understanding the indicator).

Metadata are required for all datasets, and the Audit recommends the use of the Spatial Information Council's (ANZLIC's) profile of the International Organization for Standardization standard for spatial metadata.[3]

[3] http://www.anzlic.org.au/infrastructure_metadata.html

Table 3 Identified data needs for land salinity matter for target indicators

Data need	Indicator 1	Indicator 2	Indicator 3	Indicator 4
Depth to groundwater (m)	***			*
Location (boundaries of salt affected areas or geographic information system [GIS] polygons, coordinates for point data)	***	***	***	***
Groundwater salinity (µS/cm)		***		*
Baseflow salinity (µS/cm)		**	***	
Intensity of salt-affected areas (national classes)[a]	**	*		***
Survey technique	**	**	**	**
Climate (rainfall, evaporation)	**	*	**	**

Table 3 Identified data needs for land salinity matter for target indicators (continued)

Data need	Indicator 1	Indicator 2	Indicator 3	Indicator 4
Groundwater flow system name or type	**	**	**	**
Land use and management (historical and current, including constructed drains)	**	**	**	**
Time since clearing	**	**	**	**
Geomorphic position of outbreak	**	*		**
Piezometer or bore? (bore construction details)	**	**	*	*
Bore pumping and anomalous details	**	**	*	*
Irrigated or dryland?	*	*	*	*
Topographic and natural drainage patterns	*		**	**
Geology (basement rock and regolith properties)	*	*	*	*
Soils (texture and porosity)	*	**	**	**
Vegetation type and extent	*	*	**	**
Geophysical and remote sensing data	*	*	*	*
Baseflow volume (flow rate)			**	
Stream flow rate			**	
Stream salinity (µS/cm or total dissolved salts)			**	
Cultural (assets, cadastre, infrastructure)	*	*	*	*
Dominant source of salt?	*	*	*	*

Key:
*** = specific data needed for the indicator measurement as defined in the protocol
** = critical contextual data needed to understand the indicator
* = useful contextual data that helps to understand the indicator
a See land salinity protocols on the Audit's website.

Data and information systems

There is currently no national database for land salinity information. However, the establishment of an appropriate national information system for collating, managing and disseminating data related to the agreed indicators (including protocol and appropriate contextual data needs) is part of the ASIP work plan.

There are already considerable synergies between existing databases and projects that aim to store and supply information relevant to the land salinity matter for target. Table 4 lists national and multijurisdictional datasets relevant to the land salinity theme.

National web-based reporting systems have been identified, which could collate and report on salinity indicator data:

- the Australian Soil Resource Information System (ASRIS) will collate and report data on the indicator 4 — location, size and intensity of salt-affected areas
- Australia's Resources Online, a new component of the Australian Natural Resources Atlas being developed by the Audit will provide ongoing and timely reporting of land salinity and other National M&E Framework indicators
- an Australian Water Resources Information System (AWRIS) is under development and may be able to collate and report data on the three indicators related to groundwater and surface water
- a range of relevant information systems will provide access to other critical and contextual information — major national and multijurisdictional datasets of interest are listed in Table 4 (the table also provides web links for these datasets).

Australian Soil Resource Information System

ASRIS is managed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The system, which will collate and report on data against indicator 4 (location, size and intensity of salt-affected areas), is a national access point for soil and landscape information.

The system currently stores spatial data on a range of soil attributes, including EC. Although the data may have been collected by various jurisdictions over several years, they display a single snapshot of soil condition. Data availability varies greatly across Australia, and is underpinned by high-quality soil mapping information at a range of scales, from detailed mapping at approximately 1:25 000 to continental scale mapping at 1:2 000 000.

Table 4 National and multijurisdictional datasets relevant to the land salinity theme

Extent of Coverage	Main system [Responsible agency]	Description	Website [ANZLIC ID, where available]
National (Australia-wide)	Australian Climate Archive [Bureau of Meteorology (BOM)]	Rainfall, evaporation and temperature from stations across nation. Includes the subset of 'high quality' climate datasets.	http://www.bom.gov.au/climate/change/datasets/datasets.shtml
	Australian Collaborative Land Use Mapping Program [Bureau of Rural Sciences (BRS)]	Land use data and information for Australia.	http://www.brs.gov.au/landuse
	Australian dryland salinity assessment spatial data (1:2 500 000), National Land & Water Resources Audit [NLWRA] 2001 [BRS]	Data from previous national salinity audit.	http://adl.brs.gov.au/anrdl/php/ http://anra.gov.au [ANZCW1202000019]
	Australian Groundwater Flow Systems, National Land & Water Resources Audit, January 2000 [BRS]	Groundwater flow systems mapping for Australia.	http://adl.brs.gov.au/anrdl/php/ http://anra.gov.au [ANZCW1202000001]

Table 4 National and multijurisdictional datasets relevant to the land salinity theme (continued)

Extent of Coverage	Main system [Responsible agency]	Description	Website [ANZLIC ID, where available]
National (Australia-wide) (continued)	Australian irrigation areas, version 1A, NLWRA [BRS]	Derived from 1996/97 land use of Australia data.	http://adl.brs.gov.au/anrdl/php/
	Indicators of catchment condition in the intensive land use zone of Australia [BRS]	'Current salinity extent' and 'Rivers in salt hazard' datasets. Uses data from previous national salinity audit.	http://adl.brs.gov.au/anrdl/php/ [ANZCW1202000189]
	Land Use of Australia, Version 3 — 2001/2002 [BRS]	National land use mapping.	http://adl.brs.gov.au/landuse http://anra.gov.au (1996/97 data)
	National Agricultural Monitoring System [Primary Industries Ministerial Council]	Climate and production information for dryland and irrigated industries.	http://www.nams.gov.au
	National Vegetation Information System (NVIS) [Australian Government Department of the Environment, Water, Heritage and the Arts, Environmental Resources Information Network]	Regional to national scale vegetation data. (BRS has collated NVIS data with other national datasets to obtain: *Integrated Vegetation Cover* (2003), Version 1.)	http://www.environment.gov.au/erin/nvis/data-products.html

Table 4 National and multijurisdictional datasets relevant to the land salinity theme (continued)

Extent of Coverage	Main system [Responsible agency]	Description	Website [ANZLIC ID, where available]
National (Australia-wide) (continued)	SILO Data Drill [Queensland Department of Natural Resources and Water]	Spatially interpolated point and gridded national climate data.	http://www.nrw.qld.gov.au/silo/
	Australian Soil Resource Information System (ASRIS) [Commonwealth Scientific and Industrial Research Organisation (CSIRO)]	Australian soil resource information system.	http://www.asris.csiro.au
	Australian Water Resources Information System (AWRIS) [BOM]	Australian water resources information system.	Under development
	National Geoscience Dataset [Geoscience Australia]	Geology (1:2 500 000) Online access to mapping and databases, including geology and geophysics.	http://www.ga.gov.au/oracle/ [ANZCW0703002305]
Multi-jurisdictional	[Murray–Darling Basin Commission (MDBC)]	Report: *Murray–Darling Basin Groundwater Status 1990–2000*.	http://www.mdbc.gov.au/nrm/groundwater/ groundwater_status_report_19902000

Screenshot example of how data can be represented on the Australian Soil Resource Information System (ASRIS) website

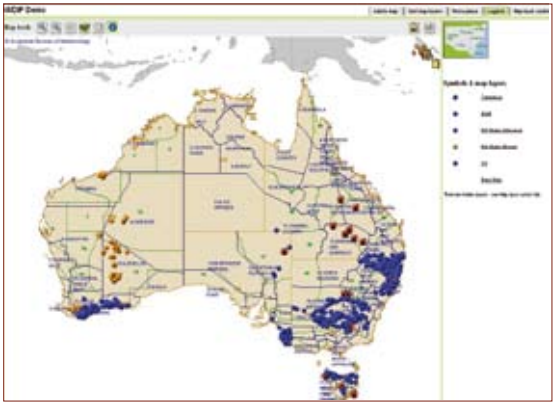
Australian Water Resources Information System

The national web-based AWRIS is being developed by the Bureau of Meteorology.

The system will act as a portal for a range of water information, with the potential capacity to report against:

- surface water
  - salt load
  - flow
- groundwater
  - salinity, as EC or total dissolved salts (TDS)
  - depth to watertable
- climate
  - rainfall
  - minimum and maximum temperatures.

To improve coordination and reduce duplication, information on the three land salinity indicators related to groundwater and surface water is likely to be delivered via the framework being developed by the Australian Water Data Infrastructure Project (AWDIP). The aim of AWDIP is to establish appropriate national information transfer standards to report on water quality indicators.

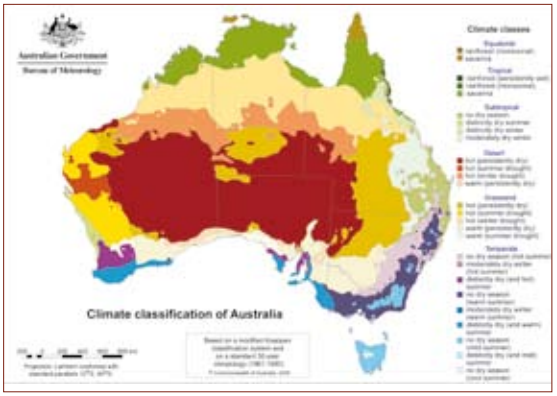


Screenshot demonstration of the Australian Water Data Infrastructure Project (AWDIP) system, showing representation of water data from states and territories

Climate

Changes in rainfall patterns and temperatures can alter the landscape water balance (NLWRA 2001). Maps and detailed climate data are available from the Bureau of Meteorology; an example is shown in Figure 2.

Figure 2 Climate classes of Australia



Source: Bureau of Meteorology

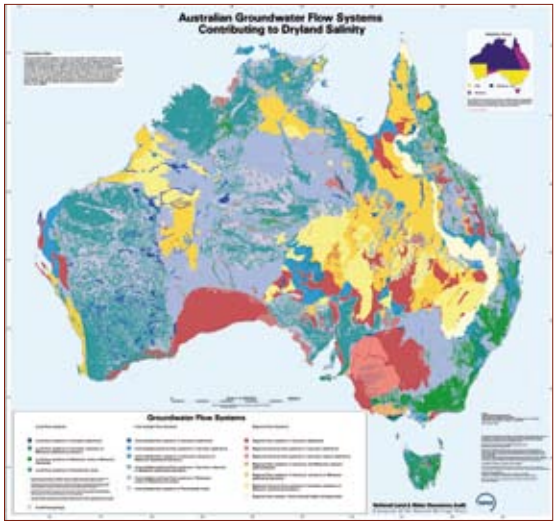
A range of climatic and production information, for dryland or broadacre and irrigated industries, for over 600 regions throughout Australia, is available from the National Agricultural Monitoring System.

In addition, point and gridded national climate data that have been spatially interpolated can be purchased through the Queensland Department of Natural Resources and Water.

Groundwater flow systems

Groundwater flow systems (GFS) provide a crucial context for understanding the behaviour of groundwater and salinity (Walker et al 2003). Nationwide (1:5 000 000) mapping of GFS contributing to dryland salinity was undertaken through the Audit in 2000. This national-scale GFS information resides within the Australian Natural Resources Atlas and the Australian Natural Resources Data Library. Many catchment managers are currently working at concurrent scales in GFS (eg 1:250 000, 1:100 000, 1:25 000) using different datasets at each scale. This is an evolutionary activity that is important for catchment management and knowledge frameworks. Figure 3 provides an example of GFS mapping.

Figure 3 National groundwater flow systems mapping

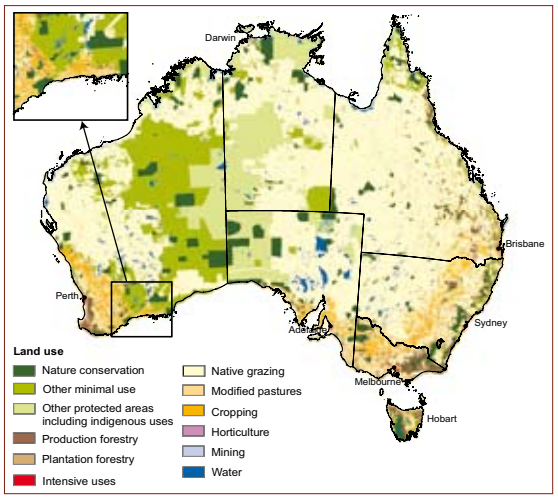


Source: Coram et al (1999)

Land use

Australia's natural salinity has been exacerbated by changes in land use since European settlement (NLWRA 2001). Land use mapping is available from catchment to national scales through the Australian Collaborative Land Use Mapping Program. An example of the type of data produced by this system is given in Figure 4.

Figure 4 National land use mapping



Source: NLWRA

State and territory information systems

The states and territories have developed their own land salinity data and information systems over different timeframes, and for different purposes (see Table 5).

This table does not include localised monitoring datasets, such as data from ground-based electromagnetic (EM) surveys or data collected by catchment or regional natural resource management groups. Several salinity audits and status reports have been recently completed by some states. They include:

- *Stream Salinity Status and Trends in South-west Western Australia* (Mayer et al 2005)
- *Salinity Investment Framework: Agricultural Land and Infrastructure* (WA) (George et al 2005)
- *Updated Assessment of Extent of Salinity in Tasmania* (Bastick and Lynch 2003)
- *Salinity Audit — Upland Catchments of the New South Wales Murray–Darling Basin* (NSW Department of Environment and Climate Change 2007, in review)
- *Salinity Audit Stream EC Trend Analysis for Inland New South Wales* (Harvey et al, in press)
- *Current and Predicted Minimum and Maximum Extents of Land Salinisation for the New South Wales Upland Portion of the Murray Darling Basin* (Summerell et al, in press)
- Salinity SIP (State Level Investment Project) product list, Queensland Department of Natural Resources and Water (for details, see the related website[4]).

4 http://www.nrw.qld.gov.au/salinity/publications.html

Table 5 State and territory land salinity information systems

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
ACT	Groundwater	Water Resource Information System (WRIS)/Territory and municipal services (TAMS)	WRIS (database). Contains abstraction and construction (bores and dams) licences, eg bore permits with drilling logs. Status of monitoring: Ongoing Scale of monitoring: Regional	1998 on
	Surface water	Surfacewater Resource Information (HYDSYS) and water quality (WQ) databases/TAMS	HYDSYS — flow data. WQ database — physical and chemical parameters eg electrical conductivity (EC), pH, temperature, dissolved oxygen (DO), metals etc. Status of monitoring: Ongoing Scale of monitoring: Regional	1974 on http://incp.environment.act.gov.au/water/index.aspx (restricted subset of information)
NSW	Groundwater	Groundwater data system (GDS) and HYDSYS databases/ Department of Water and Energy (DWE)	Bore construction database provides historical records and point monitoring data. Monitoring database includes continuous and infrequently monitored sites. No routine groundwater EC monitoring, although project-specific quality monitoring occurs in some sources. Status of monitoring: Ongoing (standing water level; SWL); Ad hoc (EC) Scale of monitoring: Point	Drillholes: 1900s on SWL: highly variable Groundwater EC: 1980s on
	Surface water[a]	DWE	Ongoing monitoring of stream flow and stream EC across NSW. Status of monitoring: Ongoing Scale of monitoring: Catchment	Stream EC: 1970s on http://waterinfo.nsw.gov.au/

Table 5 State and territory land salinity information systems (continued)

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
	Location, size and intensity	Department of Environment and Climate Change	Three snapshots of dryland salinity outbreaks have been mapped (early 1990s, mid 90s and 2001). Latest mapping is the most reliable. Irrigation salinity is not mapped. Status of monitoring: Periodic Scale of monitoring: Property	1990s to 2001
NT	Groundwater	HYDSYS database/ Department of Natural Resources, Environment and the Arts (DNRETA)	NT-wide database, containing groundwater and surface water data. Only depth to groundwater is measured. Groundwater salinity (EC) not recorded. Status of monitoring: Ongoing (SWL only) Scale of monitoring: Catchment and regional	SWL only: 1950s on http://www.nt.gov.
	Surface water[a]	HYDSYS database/ DNRETA	No systematic measurements of stream EC. Only surface water flow and water levels are measured. Status of monitoring: Stream EC not monitored	
	Location, size and intensity	DNRETA maps/ DNRETA	Baseline data has been established in Alice Springs town area. Areas at risk of sea water intrusion have been identified on coastal alluvial plains. Risk assessments have been made of other areas of the NT and are used in assessing development proposals. Status of monitoring: Ad hoc (no NT-wide monitoring program)	http://www.nt.gov.au/nreta/nretamaps/

Table 5 State and territory land salinity information systems (continued)

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
Qld	Groundwater	Department of Natural Resources and Water (DNRW) and 'Sunwater' in major irrigation areas	Ad hoc monitoring (no official program) in dryland salinity (National Action Plan for Salinity and Water Quality; NAPSWQ) bores. Major irrigation areas monitored for management. Sea water intrusion areas also monitored. Data are available but not via the internet. Status of monitoring: Ongoing in irrigation areas; ad hoc in dryland areas. Scale of monitoring: Catchment and regional	Irrigation: 1970 on Dryland: 2001 on
	Surface water[a]	HYDSYS database/ DNRW	Work has been done to separate baseflow component from 'ambient surface water network' (which collects stream salinity and flow data). Summary data are available online. Status of monitoring: Ongoing Scale of monitoring: Catchment	Flow: 1909 on Salinity: 1974 on Summary data available through 'WaterShed': http://www.nrw.qld.gov.au/watershed/index.html
	Location, size and intensity	DNRW	No monitoring program. Ad hoc recording of point locations of salinity outbreaks. Status of monitoring: Ad hoc (no monitoring program) Scale of monitoring: Catchment and regional (based on ad hoc info)	1991 on

Table 5 State and territory land salinity information systems (continued)

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
SA	Groundwater	SA Geodata Department of Water, Land and Biodiversity Conservation (DWLBC)	Oracle database accessible through 'Obswell' website. Groundwater salinity data from dryland areas are not accepted into the database due to different sampling methods. Status of monitoring: Ongoing Scale of monitoring: Property, catchment and region	Irrigation: 1960s on Dryland: 1990s on https://info.pir.sa.gov.au/obswell/new/obs Well/Main Menu/menu
	Surface water[a]	HYDSYS database/ DWLBC	Summary data available through 'Surface Water Archive' website. Status of monitoring: Ongoing	1970s on http://www.dwlbc.sa.gov.au/subs/surface_water_archive/a1pgs/index.htm
	Location, size and intensity	Soil Landscapes database/DWLBC	Geographic information system (GIS) database of soil attribute data, including groundwater-induced salinity. Complete assessment for agricultural areas of SA. Electromagnetic (EM) surveys have been undertaken at property/catchment scales. Status and scale of monitoring: Complete for the assessment across SA, at catchment scale; ongoing for the monitoring in the focus areas (independent datasets)	1976 to 2005 [ANZSA1000001295]

Table 5 State and territory land salinity information systems (continued)

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
Tas	Groundwater	Groundwater Quality and Borehole Database (BORIS)/ Department of Primary Industries and Water (DPIW) and Mineral Resources Tasmania (MRT) Resource Management and Conservation Division (RMC) Access database/DPIW	Major historical database held by MRT. Status of monitoring: Ongoing Scale of monitoring: Catchment and regional Future development of key monitoring sites and centralised Access database to be coordinated by DPIW. Status of monitoring: Ongoing	Drillholes: 1906 on Dryland: 1970s on [ANZTA0009000029 – Mineral Resources Tasmania ground-water quality and borehole database (BORIS)] Not on web.
	Surface water[a]	Water Information System of Tasmania (WIST)/DPIW	Focus on flow. Stations not sited appropriately for baseflow. Status of monitoring: Ongoing Scale of monitoring: Catchment	1990s on http://water.dpiw.tas.gov.au/wist/ui
	Location, size and intensity	DPIW	Initial assessments via aerial photography, land systems mapping and ground EM. Some EM31 monitoring transects established. Status of monitoring: Ad hoc Scale of monitoring: Catchment	1990s on

Table 5 State and territory land salinity information systems (continued)

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
Vic	Groundwater	State Observation Bore Network (SOBN) and dryland salinity (DLS) Bore databases/ Department of Sustainability and Environment (DSE) and Department of Primary Industries (DPI)	Work is underway to unify the major state (SOBNDLS Bore databases, along with regional/ community group databases. Data will be made available via the 'Victorian Water Data Warehouse' (Vic Water Data). Status of monitoring: Ongoing Scale of monitoring: Catchment and regional	1970s on http://www.vicwaterdata.net/vicwaterdata/home.aspx [currently data is available from the SOBN database only]
	Surface water[a]	Vic Water Data/DSE	Stream flow and salinity data from the state hydrographic monitoring network is accessible via the 'Victorian Water Data Warehouse'. Status of monitoring: Ongoing Scale of monitoring: Catchment	Flow: 1900s on Salinity: 1970s on http://www.vicwaterdata.net/vicwaterdata/home.aspx
	Location, size and intensity	GIS dataset/DPI	Salinity discharge layers have restricted access due to public concerns about land valuation. Status of monitoring: Limited remapping and updating. Scale of monitoring: State-wide	1980s to1990s

Table 5 State and territory land salinity information systems (continued)

	Type	Main system/ Responsible agency	Description/Comments	Currency of data/ website [ANZLIC ID]
WA	Groundwater	AgBores database/ Department of Agriculture and Food (DAF)	Access groundwater database for agricultural areas of WA. Status of monitoring: Ongoing Scale of monitoring: Catchment and regional	1970s on [ANZWA1608000625]
	Surface water[a]	Water Resources Information System (WIN)/Department of Water and DAF	Water Resources Information System for surface water and groundwater monitoring in irrigation areas (eg Ord River scheme). DAF is installing gauging stations in selected subcatchments. Status of monitoring: Ongoing Scale of monitoring: Catchment	1950s on http://portal.water.wa.gov.au/portal/page/portal/MapsDataAtlases/WaterQualityAssessment
	Location, size and intensity	Land Monitor/ WA Land Information Authority	Remotely sensed salinity monitoring data, valley hazard and vegetation mapping. Data restricted at high zoom levels. Status of monitoring: Completed Scale of monitoring: Regional	1989 to 1998 http://www.landmonitor.wa.gov.au/

a Surface water databases generally contain information used in deriving data for the indicator 'baseflow salinity'.
Note: Monitoring methods and frequencies are variable across the different indicators and jurisdictions.

Data availability and gaps

The intent of the indicator framework is to identify critical information that would be needed to monitor changes in land salinity over time. Contextual information (like changes to land use) will be important for interpreting the results of the monitoring activity.

Other issues of data availability and gaps, discussed in this section, are:

- data and information status for indicator reporting
- further development of the indicators for land salinity
- further development of the data for land salinity.

Spreading saline discharge in a subcatchment area (photo by Chris Henschke)

Helicopter-borne electromagnetics (photo by Tim Munday)

Data and information status for indicator reporting

The availability of land salinity indicator data varies across the country (both spatially and temporally). The variation depends on differences in funding priorities for establishment of monitoring infrastructure and provision of capacity to support ongoing monitoring programs, based on the:

- value of assets under threat from salinity
- geographic spread of natural resources.

Figure 5 shows the extent and location of monitoring information for the four land salinity indicators. Table 5 provides information on the status and currency of monitoring data associated with major state and territory databases. Monitoring data also reside in databases held by community and regional natural resource management groups (eg catchment management organisations and nongovernment organisations such as Landcare and Waterwatch). Further work and collaborative effort is required to use these data for national reporting purposes. To make use of varied sources of data, it may be appropriate to introduce a classification system for different standards of data collection.

Some organisations restrict the availability of indicator data, particularly at localised scales, due to privacy or land valuation concerns. These issues will need to be addressed in any nationally collated datasets.

Information collated against specific indicators will be reported as a national compilation within the Australian Natural Resources Atlas and Data Library. Where possible, emerging web-based technologies will be employed so that the most current data are held by the custodians of the information — for example, state and territory government agencies — and delivered via web servers when required for a national assessment or compilation.

Web-based interfaces being developed under, for example, the AWDIP, will allow data collected at a point to be accessed and displayed in a required national reporting format. The Audit is developing Australia's Resources Online as a reporting tool, to allow national reporting against the natural resource indicators. This tool has been tested successfully for vegetation extent information, and will be deployed as the data and information technologies and capacities allow.

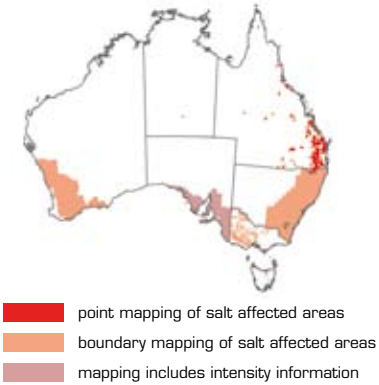
Figure 5 Data availability: geographic extent of information for the land salinity indicators at the state and territory scale

Indicator 1
Depth to groundwater

Indicator 2
Groundwater salinity

Indicator 3
Stream electrical conductivity (EC) sites (for baseflow salinity)

Indicator 4
Location, size and intensity of salt-affected areas



Notes:
1. In the higher rainfall regions of northern Australia, salinity is generally leached out; however, sea water intrusion may be an issue in these areas.
2. Similar piezometer or bore monitoring networks are used in reporting for the two indicators 'depth to groundwater' and 'groundwater salinity' (apart from in the Northern Territory, where groundwater salinity is not monitored).
3. For indicator 3, stream electrical conductivity (EC) monitoring sites are shown in the figure, to represent locations where this indicator can be modelled.
4. The image for indicator 4 reflects different methods of salinity mapping undertaken by the states and territories (eg point mapping of salinity outbreaks, mapping boundaries of salt-affected areas, and whole-of-landscape mapping according to a range of intensity classes). These images also provide an overview of areas where comparisons between indicator data might be possible.The extent of data may represent assessment or monitoring activity.

Source: National Coordinating Committee for Salinity Information

Indicator development

The land salinity indicators (and the protocols that define their use) will be developed further in response to the evolving priorities and needs of users. Recent state trials of the indicators have raised some considerations for future refinement of the indicators; these considerations will need to be the subject of ongoing discussion. General considerations are as follows:

- Contextual data are critical; if contextual information is inadequate, indicator data may be misinterpreted.
- Resources for gathering suitable data or an even geographic spread of data are often lacking.
- Data may not be appropriate for reporting at multiple scales.
- The 'scalability' of indicators (ie the ability to apply indicator data on salinity causes, trends and management options from a monitoring location to similar locations or larger areas) is highly dependent on contextual data. In some 'regional' (generally broad, flat) GFS, indicator data are more likely to be representative of a larger area. Similarly, where detailed soil or landscape mapping is available, this may provide a basis to 'scale up' indicator data (eg if the percentage of the landscape prone to salinity is known). However, where knowledge is limited (eg in complex landscapes, 'local' GFS, or where monitoring records are short) the ability to apply indicator data to different locations or at different scales is limited.
- Older bores may not have been constructed and logged to appropriate standards. Bores constructed to required standards and with an adequate history of data may not be in appropriate landscape positions to provide useful salinity information. Appropriate monitoring bores should be earmarked by the different jurisdictions as part of their salinity monitoring networks.

Data development

Considerations for reporting on existing land salinity indicator data include the following:

- Historical data may be skewed by particular monitoring objectives (eg monitoring of problem areas versus monitoring of assets). If greater numbers of monitoring wells are sited in discharge zones, this may (Vic DPI/DSE 2006)
  - suggest that watertables across a broader scale are higher than they really are

  - limit modelling or trend analysis techniques, which are often better served by data from upslope bores (bores in discharge areas usually show a subdued response).

- Some historical regional or state-scale data for indicator 4 may provide information only on the presence or absence of salt-affected land (ie mapped salinity outbreaks), whereas information on a range of intensity classes is desirable. Where intensity information is lacking, it may be difficult to collate datasets according to the protocol.

Development considerations relevant to each of the four indicators are discussed below.

Depth to groundwater

The indicator 'depth to groundwater' is widely regarded as the most useful for understanding salinity processes, determining salinity trends and risk, and evaluating the effectiveness of management responses.

Groundwater salinity

The indicator 'groundwater salinity' is often seen as useful contextual data (rather than a primary indicator), except in irrigation areas, where the salinity of applied irrigation water is of primary importance. In salt-affected dryland areas, capillary rise and evaporative concentration of salt in the unsaturated zone can produce variable soil salinities in the plant root zone (due to factors such as depth to groundwater, soil texture and climate) even if groundwater salinities are the same.

Piezometer construction (photo by Chris Henschke)

Baseflow salinity

Baseflow salinity is a good indicator of the mean salinity of GFS. Nevertheless, many jurisdictions view this indicator as providing useful contextual information rather than being a primary indicator. Measuring baseflow salinity (salt concentration) alone, without baseflow discharge rate, does not provide enough information to calculate groundwater salt contribution to a stream.

Location, size and intensity of salt-affected areas

The protocol for the indicator 'location, size and intensity of salt-affected areas' requires an assessment of intensity according to four classes — non-saline, slightly saline, moderately saline, and severely saline.[5] Intensity measurements are undertaken through various methods (eg air photo interpretation, EM surveys, soil EC sampling, radiometrics, remote sensing, LiDAR[6], etc) and different organisations have historically developed different salinity classification systems. The protocols for the land salinity indicator will help in aligning existing datasets with the national intensity classes.

Except in localised project areas, little re-surveying has been conducted, making it difficult to report on trends with time at regional, multiregional and national scales. Remote sensing methods may, in the future, allow cost-effective capture of intensity information across broad scales. Alternatively, a modelling approach may prove feasible in situations where monitoring data from detailed study catchments can be scaled up to reflect broader trends.

This indicator monitors the symptoms of salinity once salinity has already become a problem. In this case, the management focus is likely to be on remedial action or adaptation (ie living with salt). Therefore, some groups may not see this as a priority indicator where the concern is assessing salinity risk and taking preventative action before the expression of salinity at the surface. On the other hand, mapping of known salinity discharge sites is routinely used for salinity model calibration and GFS conceptualisation; risk and hazard assessments then incorporate these data.

5 See land salinity protocols on the Audit's website.

6 LiDAR = light detection and ranging; an active remote sensing system that uses visible wavelengths of the EM spectrum — as described by CSIRO Office of Space Science and Applications: http://www.cossa.csiro.au/lb/lbbook/glossary/glossl.htm

Data and information products

Monitoring of the land salinity indicators can be used to generate a variety of products, to meet the needs of various audiences, including policy makers, regional and local natural resource managers, industry and the general public.

Products that can be derived directly from the indicator data include:

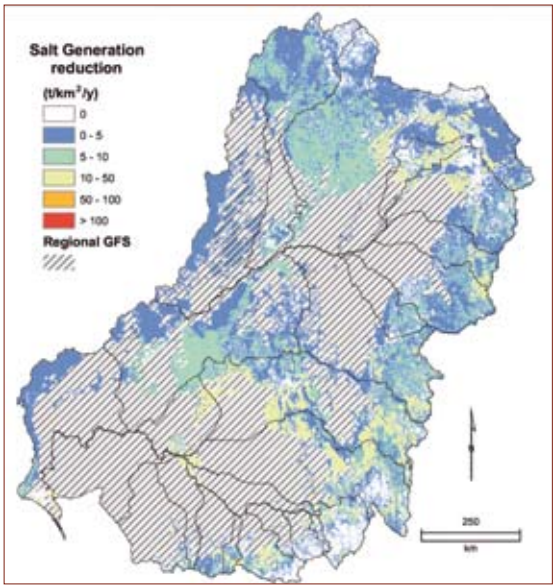
- hydrographs
- salinity maps (for 'location, size and intensity of salt-affected areas')
- maps of monitoring sites with summaries of salinity information
- groundwater salinity maps for irrigation areas.

More informative products ('enhanced datasets') usually go a step further and bring together important contextual information. Examples include:

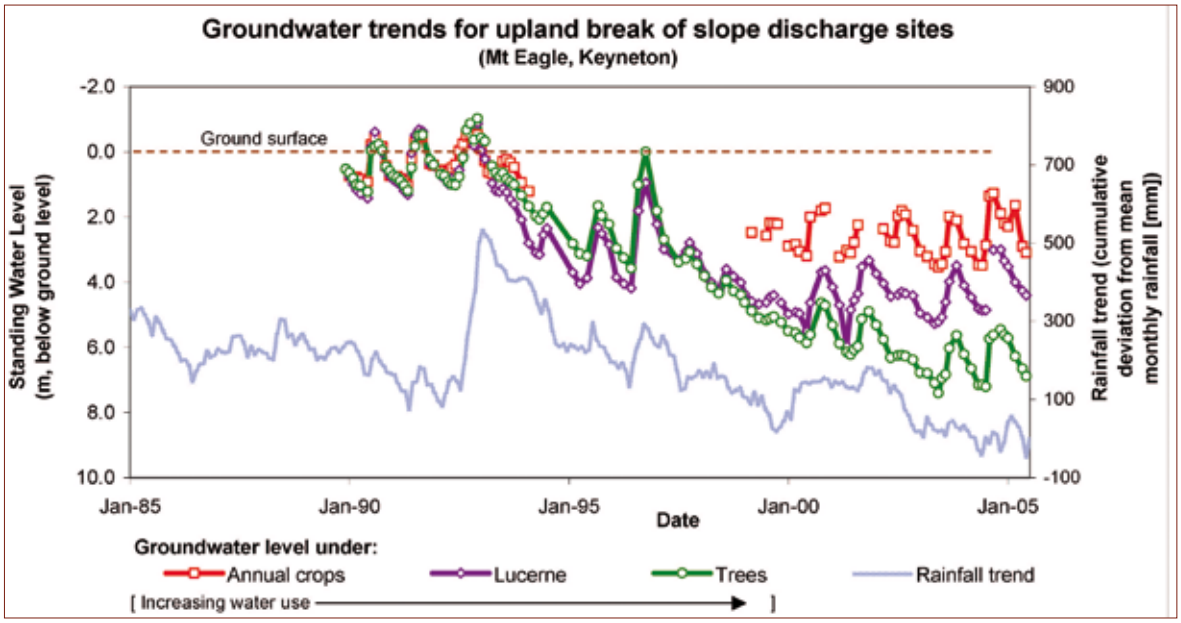
- trend analyses
- depth to groundwater surfaces
- bore locations and recorded salinities overlying mapped GFS
- estimates of subcatchment or catchment salt load and salt balance
- conceptual models of salinity processes.

The most useful information products may be composite products that combine results and interpretation from several indicators, perhaps in the form of a case study or fact sheet.

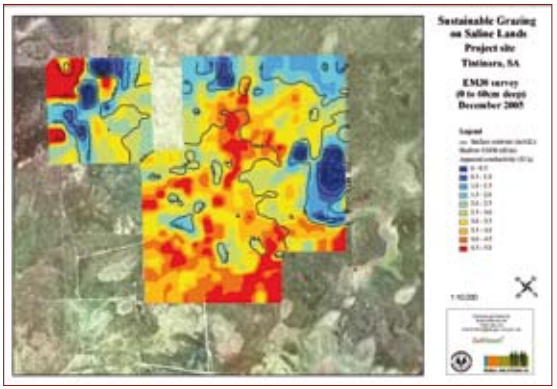
Examples of products



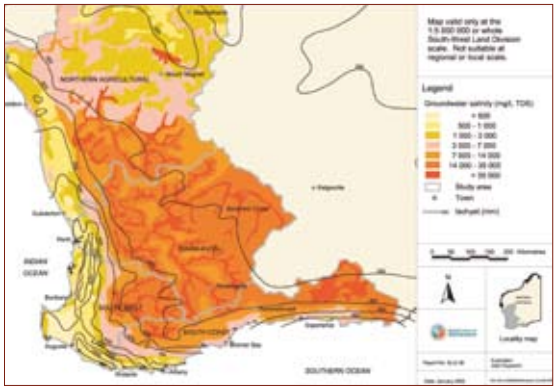
Modelling the salinity impacts of afforestation in the upland catchments of the Murray–Darling Basin (Source: Dowling et al 2004)



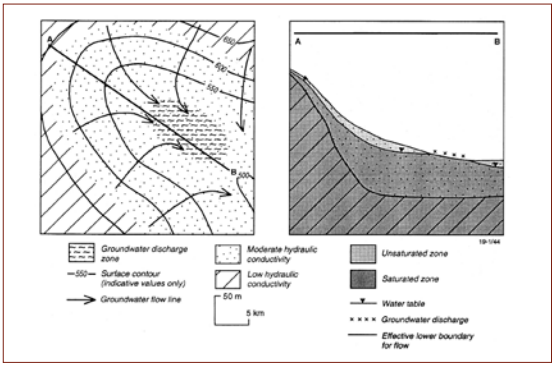
Contextual data (eg rainfall and land use) are invaluable in the interpretation of groundwater trends (Source: Liddicoat and McFarlane 2007)



Property-scale salinity (electromagnetic) mapping
(Source: Rural Solutions SA)



Groundwater salinity map for southwest Western Australia
(Source: Mayer et al 2005)



Conceptual model of a salinity process (Source: Coram 1998)

Screenshot of Australia's Resources Online website

Related land salinity information

A number of systems and products are available that could provide information related to the land salinity indicators. Although they do not report directly on the indicators, these systems and products can provide multiple lines of evidence when evaluating progress against the matter for target and the effectiveness of management actions. Examples of such products are as follows:

- *The Australian Natural Resources Atlas* — the Atlas provides a number of tools and access to theme summaries and reports from the Audit; it includes the Map Maker, which is an online tool for creating maps at regional, state and national levels.[7]
- *The Australian Natural Resources Data Library* — enables discovery of, and access to, data and information products.[8]
- *Australia's Resources Online* — is a new component of the Atlas being developed by the Audit for ongoing reporting on the National M&E Framework indicators.[9]

7 http://www.anra.gov.au
8 http://adl.brs.gov.au/anrdl/php
9 http://www.anra.gov.au/aro

Discussion and way forward

The Audit and its partner organisations have developed methods and protocols, undertaken trials, improved existing data and information, and refined data management and exchange infrastructures. Considering this activity, the current capacity to report on the land salinity matter for target under the National M&E Framework can be summarised as follows:

- Indicator data and information systems vary widely within and between jurisdictions in terms of their purpose, methodology, quality, scale, frequency and currency of monitoring. Despite these differences, jurisdictions are working towards the adoption of national standards to enable the collation of nationally consistent datasets. Many regional organisations are now reporting on salinity as part of their requirements under the Natural Heritage Trust. Increased adoption of consistent indicators and protocols will be required to allow consistent reporting across multiple regions and, ultimately, the nation.
- Indicator protocols need to be reviewed periodically to ensure that they continue to be applicable.
- Products need to be tested and revised to ensure that they meet the needs of decision makers and continue to represent the status of salinity at appropriate scales.
- Soil and water related information systems need continual development, particularly when integrating with contextual information.
- The use of individual indicators in salinity assessment frameworks needs to be trialled to ensure that future assessments of dryland salinity include an ability to show evidence of change as a result of management action.
- Agricultural and environmental assets, either under threat from salinity or subject to degradation by salinity, need to be identified in order to prioritise areas for investment in salinity mitigation.

Ongoing effective coordination will require genuine commitment to a shared vision and clear assignment of responsibilities (and associated costs) for data collection and management at national, state and regional levels.

The partnerships and collaborative spirit developed through the National Coordinating Committee for Salinity Information will enable work to continue towards achieving a coordinated national system for reporting on land salinity.

Appendix 1 The National Monitoring and Evaluation Framework

The National Natural Resource Management Monitoring and Evaluation Framework (the National M&E Framework) was endorsed by the Natural Resource Management Ministerial Council in 2002. It was developed to assess progress towards improved natural resource condition through the development of accurate, cost-effective and timely information on:

- the health of Australia's land, water, vegetation and biological resources
- the performance of programs, strategies and policies that provide national approaches to the conservation, sustainable use and management of these resources.

Assessment of information collated under the National M&E Framework will assist the Ministerial Council to 'identify areas of concern and to better target the use of resources'.

The framework identifies three key requirements for monitoring natural resource condition:

1. a set of natural resource condition indicators (including those for the 'matters for target' identified in the National Framework for Natural Resource Management Standards and Targets) to measure progress towards agreed national outcomes on a medium and long term basis
2. a set of indicators for monitoring community and social processes relevant to or affected by NRM programs, as well as measures of the adoption of sustainable development and production techniques
3. contextual data pertinent to the indicator being considered.

The National Land & Water Resources Audit (the Audit) is responsible for ongoing development of these indicators, as well as supporting the national collection and collation of data, and reporting against each indicator.

Salinity near Ouyen, Victoria (photo by Arthur Mostead)

Such reporting will help to answer questions such as:

- What is the nature and extent of the issue?
- Is the existing or proposed intervention appropriate for the size of the issue?
- What types of intervention work best, are most cost effective, and have the best transferability across regions?
- What was the impact of the policy or program investment — in the intermediate and long term?

Monitoring and evaluation of core indicators supports evidence-based decision making at national, state and territory, and regional levels. However, each level may have a wide variety of data and information needs, in terms of content, context or scale. There is also complexity across the three levels of use associated with multiple needs, values, preferences and timeframes.

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About the 'Status of Natural Resource Information' series

This series of booklets outlines the status of data and information relating to indicators agreed under the National Natural Resource Management Monitoring and Evaluation Framework (2002). Each booklet describes the status of coordination, indicators, information management systems, and data and information products for a particular theme area.

- Estuarine, coastal and marine
- Inland aquatic ecosystems
- Land salinity
- Land use
- Native vegetation
- Significant invasive species (vertebrate pests)
- Significant invasive species (weeds)
- Significant native species
- Social and economic information
- Soil condition
- Water quality

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