NATIONAL PROGRAM FOR
Sustainable Irrigation

Scoping study

Common hydrological features in Australian irrigation areas

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Disclaimer

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Executive Summary

This scoping project investigated the following two questions:

The primary audience is policy makers, that is decision makers who can affect the distribution of funding to invest in new developments or support the movement of existing developments towards sustainability.

- What is the best way to present material on the common hydro-geological systems where irrigation areas are situated.
- Which hydro-geological systems should be represented?

From the investigation we:

- Confirm the primary audience.
- Acknowledge the potential for secondary audiences.
- Identify the need for more than one delivery mechanism.
- Investigate content, typologies, and management issues with key State, Territory and national contacts.
- Develop a hierarchical typology to identify the hydrogeology under particular areas of irrigation, and the likely management issues which might occur.

State Agencies are keen to have a national web product which links to their local information sets.

- Identify ways in which to map hydrogeological types and irrigation across the country.
- Assess the potential for case studies including pulling together a resource set as appendices to this document.

Case studies are most powerful when they include personal stories, local attempts to manage issues, and identify the support needed to move forward.

- Recommend a standard case study content.
- Develop a landscape layout of one case study.
- Construct an electronic navigation tool for accessing information which could be translated into web format.
- Access preliminary publishing costs for a hardcopy A4 portrait book similar to ‘Water Innovation’.

It is concluded that there is potential and support for a project which supports an increased appreciation of the contrasts and similarities across irrigation regions, supports investment opportunities and highlights key issues for sustainability.

Supporting Investment

Information to support investment can be provided in a hierarchical fashion. At the highest level a map base or on-line tool which highlights the basic hydrogeological types in each area of Australia together with potential issues can be developed quickly from the resources collated here. References (or links) to State based information can support further investigation of potential areas of investment. In some instances there may be local or regional information which can be used to prove up a particular opportunity. However, the likelihood is that significant on-ground investigations will be required to provide a high level of confidence in investment.

Investment can be supported through broad scale mapping and links to State and regional information.

Case studies also provide salutary examples of the potential and timescale of problems which might arise.

Supporting Sustainability

Existing irrigation schemes often have comprehensive analyses and reports as an information base. There is a challenge for landholders in terms of managing large scale problems which they have little capacity to deal with. Case studies provide a key avenue of highlighting the challenges from different points of view. Importantly, carefully capturing messages from the landholders and local NRM officers will provide an avenue to humanise the hydrogeological challenges, highlight the different mixes of policy and action which are effective, and list the key actions which government can implement to assist landholders face the challenge.

Case studies are a primary vehicle to capture the variability of local issues, emphasise the human face of the challenges, and communicate key actions necessary to achieve sustainability.

Significant investment is needed for a quality product.

The Investment Required

There will be significant investment required if such a product is to be developed.

Key tasks include:

- Confirmation with the NPSI Management Committee the key messages and content to be delivered.
- Completion of the typology through digitising, mapping and presentation.
- Reworking of standard images of hydrogeological types for consistency and presentation.
- Capturing stories and histories from local groups and land holders.
- Taking and using professional quality photographs.
- Working with key NRM contacts in the States to rework existing information into robust case studies.
- Editing of material for consistency and flow (specialist input from a hydrogeologist, irrigation expert and scientific editor)
- Reworking of preliminary layouts to satisfy printing standards including colour schemes.
- Printing, binding and distribution.
- Co-development of a web product to distribute information.

It is likely that the cost for these tasks will be of the order of $200,000 including information collation, workup, hardcopy and web delivery.

The product could be delivered in approximately 6 months.

1 Project Objectives

URS was engaged to undertake a 3 – 4 week Scoping Study investigating the following questions:

- **What is the best way to present material on the common hydro-geological systems where irrigation areas are situated.**
- **Which hydro-geological systems should be represented?**

In undertaking this Scoping Study we were required to include:

1. A hard copy and electronic layout of how material would be presented and the audience skill level it is being written for.
2. A table of contents and a brief description of the systems that are to be covered and the locations each system represents.
3. Example case studies of actual regions.
4. For the various systems a set of diagnostic tips that would help the reader identify the type of system.
5. Are there computer models available that illustrate system function and are there opportunities for integrating these?
6. Consider the format of " Water Innovation" – Editor, Kathleen H Bowmer ISBN 0-0580670-1-5

2 Methodology

URS approached this study in the following way:

- Confirmation of intended audience and desired outcomes of the project through discussions with the Project Coordinator and NPSI Management Committee members where available.
- Identification of the prospective audience and confirmation of the level of communication required in any publication.
- Development of a draft Information Framework for use in identifying the information to be captured and reported via an appropriate mechanism(s).
- Design and use of focus questions in interviews with key State and Territory Agency personnel including a scan of existing typologies in each jurisdiction.
- Collation of readily available regional information for each State/Territory via literature and web searches, State submissions, and publications.
- Development of a draft hydrogeological typology and confirmation of this with State, National and CSIRO contacts wherever possible.
- Selection of potential case study areas and collation of information for each area to support a gap analysis.
- Development and population of a presentation template for one case study.
- Preparation of a Summary Report and Brief.

3 Target Audience and Potential Delivery Methods

There is potentially a range of audiences to be targeted and a range of delivery mechanisms which could be used.

3.1 A Range of Audiences

The primary audience has been identified as "policy makers". That is, decision makers who can affect the distribution of funding to invest in new developments or support the movement of existing developments towards sustainability.

This audience could include banks, insurance companies, CEO's of catchment management groups or water authorities, politicians, industry leaders, and community leaders outside the irrigation sector.

However, there is potential for the work to reach additional audiences including the communities that irrigators support, NRM professionals who work with irrigators, businesses who interact with irrigators, and the next generation of irrigation farmers.

3.2 The Message

The basic premise of the scoping project is to seek ways in which to inform 'policy makers' of hydrogeology in irrigation areas and to determine which hydrogeological types should be presented.

However, our discussions with stakeholders reveal a range of purposes for communicating, and a possible range of emphases in presentation. Many of these directions require similar data sets.

Three key opportunities clearly present themselves:

- Building capacity in irrigation management for all those involved
- Supporting investment decision for new irrigation.
- Supporting investment decisions to ameliorate current impacts.

A critical issue remains for the NPSI Management Committee which is best posed by asking the apparently simple question:

What is the name of this publication?

Answering this question will provide much needed context for the document by:

- Reaffirming the focus on State and Federal policy makers.
- Confirming the content and messages to be delivered.
- Providing guidance on the tools and formats which can be utilised to support the messages.

3.3 Matching Information to Audience Needs

The International Commission for Science (ICSU, 2003) identified significant challenges in communicating science to policy makers and the community; and recommend that at least the following issues be addressed :

- Deliver science relevant to the policy agenda.
- Encompass risk assessment and uncertainty in outputs.
- Integrate assessments across a range of disciplines.
- Promote increased system level analysis.
- Balance societal, economic and environmental issues.
- Utilise appropriate temporal and spatial scales.
- Ensure messages recognise the range of cultures which are part of the decision making process.

CARE (200?) emphasise the need to recognise that policy makers are people, not institutions. The lesson from this is that examples and stories of human endeavour can carry significant weight with decision makers.

In work in progress on a parallel NPSI project, Day (2005) reports the need to:

- Recognise and build upon existing programs and past work
- Increase understanding of investor behaviour and how these decisions affect regional and State plans.
- Integrate business decisions with social and environmental outcomes.

- Make a special effort to capture and promote the social aspects of decision making which are often ignored.
- Recognise the dollar imperative – many business decisions are currently made on achieving 'sustainable returns' within the (often short term) "foreseeable future".
- Share communications across 'groups'.

With such a broad range of potential audiences we believe there is a need for a high level enlightening view of hydrogeology / irrigation interactions avoiding the detail and jargon and delivering the key messages. The document should provide a means for the audience to further investigate issues of interest via the use of bibliographies, key contact lists, websites, etc.

For the purposes of our information collation we have targeted a grade 10 or 11 student doing an assignment. This paradigm has concentrated the review on the need to promote an understanding of the basic processes and key issues. Feedback has variously suggested we target primary school students or university level, but we feel comfortable that a level of information to suit end of high school is appropriate.

3.4 Delivery Mechanisms

Influencing policy makers or investors requires an understanding of their needs and objectives as well as a commitment to long term and multiple channels of communication and advocacy. For this reason, more than one delivery mechanism is probably required, and there is a need to capture and reuse information into the future.

The Management Committee has identified a 'coffee table book' as a key delivery mechanism. This will require a significant investment in the further development of case studies, the use of a technical editor, professional document design or conversion of the preliminary design contained here to a printing house standard, professional photography, print runs, binding and distribution.

The information sets, graphics and photographs required to support the development and delivery of the book are a precious resource. To provide a platform for storage and reuse of the information it is important that - as a minimum - these resources should be captured within the NPSI Knowledge Base. With little additional investment a structured HTML design could readily be delivered as both a web page or CD.

There is considerable interest at the State level in having a national website which provides links to State and local information. This opportunity provides an avenue to take the broadscale hydrogeological typology recommended in this report through the hierarchy to a local scale of particular importance to communities, catchment managers, regional investors, and irrigators.

Notably, if different delivery mechanisms are used the earlier question regarding what title to use becomes relevant to each publication or website that is created.

3.5 Form of Delivery

Various forms of hardcopy delivery were considered including Water Innovation (Bowmer, 2004), National and State SOE[1] reports, the Workboot series by Kondinin Group, Tasmania's State Water Development Plan (Anon., 2001), project newsletters for the Tangguh LNG Project in Indonesia, Queensland's Golden Energy Opportunities CD (Anon., 2004), various sustainability reports, the recently completed Groundwater Status Report for the MDBC (URS, 2005) and CSIRO's Groundwater Flow Systems booklets (Walker et al, 2003a and 2003b). Opinion was sought from social engagement specialists and others not directly involved in the project on the effectiveness of the various mechanisms based upon the target audience. Based on this review we believe a combination of the style of the Groundwater Flow Systems booklet complemented by attractive case studies is the most appropriate form of hardcopy delivery.

[1] SOE – State of Environment

4 Information Needs

A draft information framework (see Appendix 5) was derived early in the project to facilitate data searches, target data collation activities, concentrate the typology development and support the case study content. The core of the framework was a concentration on those key elements of information which were considered important in supporting a range of publications or other delivery mechanisms regardless of format.

For convenience we developed the draft framework in a way which could readily be translated to a web site format, or used to structure chapters in a book.

The fundamental elements of the Framework included:

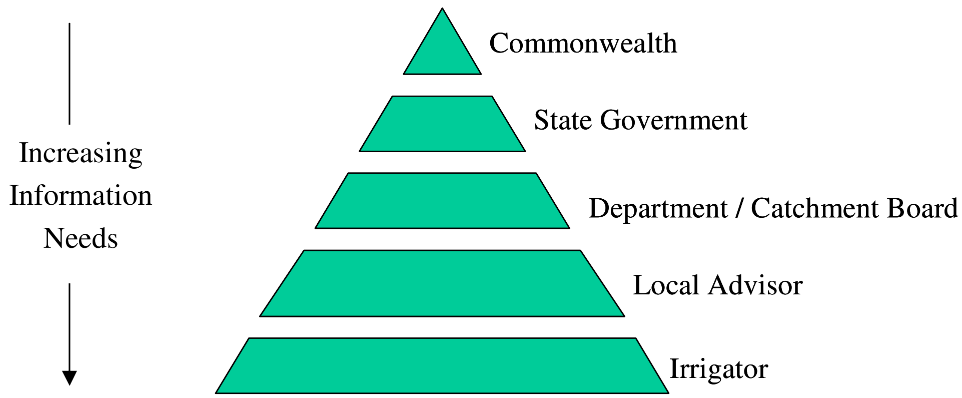
- Hydrological types – what are they, where are they, what are their key features, and what are the potential management issues associated irrigation on them.
- The current distribution of irrigation with typology.
- Conceptual models of each type including 2D and 3D models.
- Irrigation case studies.
- Further information (eg links, references, regional contacts)

The remaining sections of the report deal with each of these elements.

Following further data collation we have reworked the framework (shown in Appendix 5) into a draft Table of Contents (see Section 9) and a example website configuration in Microsoft Powerpoint.

5 Hydrogeological Types

Our discussions with State and Territory contacts confirmed the need for local information rather than national information in understanding the complexities of hydrogeology and irrigation at the farm and even catchment scale. That is, there is a hierarchy of information needs as one moves from the national to the regional to the local management scale.



Importantly, the type of information needed will change depending upon perspective. For example, information needed by an irrigator needs to be practical and provide guidance to on-farm activities within the context of the hydrogeological situation, while information at the State Government level might be more strategic and risk based.

State contacts were supportive of the creation of a website with links to their own websites and of a hardcopy publication which references their agencies. They saw that the creation of a national typology and information supported by state and local information would provide the 'best of both worlds'.

5.1 Existing Typologies

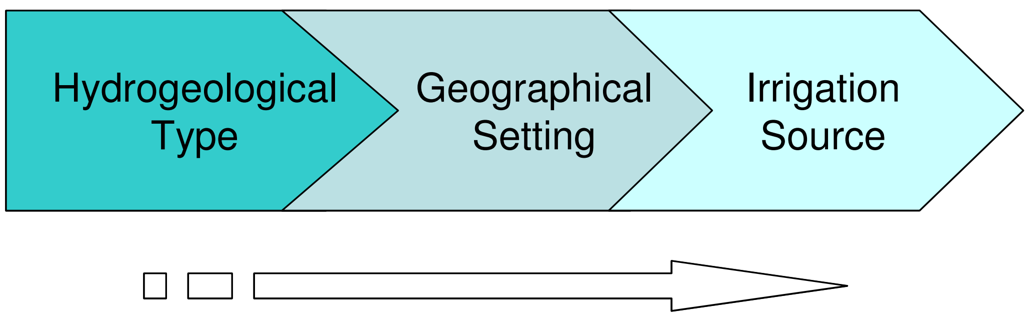
Our research - supported by discussions with State and Territory experts - reveals a considerable variability in the existing hydrogeological typologies used across Australia. Many of these typologies have been developed for particular purposes such as salinity management (eg Groundwater Flow Systems approach), the description of geology, water quality, or for other purposes which are not specifically aligned with the consideration of irrigation development and its attendant management issues.

Many systems are derived at the State, region and subregional scales. Typically there is a lack of consistency in approach across jurisdiction boundaries, and there is too much detail included to support a simple comparative national representation such as required by this project.

A particular difficulty with a typology is the degree of variability in geology (in all 3 dimensions), landscapes and geographic settings.

5.2 Recommended Typology

To encapsulate all hydrogeological settings of irrigation areas within Australia within a common framework we believe it is necessary to take a broad representation of hydrogeological types supported by a hierarchy of information to define particular management issues and increase the relevance of the material to the local user or land manager.



Increased Knowledge and Evidence of Management Issues

5.2.1 Hydrogeological Types

The recommended hydrogeological types are restricted to the following categories based upon their geology and hydrogeological characteristics:

- Shallow unconsolidated sediments
- Unconfined sedimentary basins
- Confined sedimentary basins
- Limestone
- Fractured Rock & Basalts

These types are sufficiently generic and broad enough to encapsulate existing State approaches as confirmed in our discussions with contacts. Characteristics of these types are provided overleaf.

Hydrogeological Types

Table 1 Characteristics of Recommended Hydrogeological Types

<table>
<tr><th>Classification</th><th>Typical Landscape Unit</th><th>Typical Geological Features</th><th>Typical Aquifer Properties</th><th>Comments</th></tr>
<tr><td>Shallow unconsolidated sediments</td><td>Modern rivers and floodplains, coastal and inland dune systems.</td><td>Usually shallow dune sand systems or alluvial sands/gravels.</td><td>Generally moderate to high rates of water movement
Small water storage capacity and bores generally have low flow rates.
Local to intermediate flow connections and effects.
Recharge often occurs annually.</td><td>High risk of aquifer dewatering and contamination.
See Figure 1 for typical cross section.</td></tr>
<tr><td>Unconfined Sedimentary basin</td><td>Generally found in undulating hills to broad flat plains.</td><td rowspan="2">Can be a variety of materials but generally alluvial or marine sediments.

Individual aquifers can range from loosely consolidated to hard, cemented material.</td><td rowspan="2">Generally moderate to high rates of water movement.
Low to high yielding bores and variable water storage capacities.
Local to regional flow connections, commonly with a coastal discharge boundary.
Recharge may occur over short (eg annual) or long term (eg thousands of years).</td><td rowspan="2">Aquifer systems are generally of large extent, but individual aquifers can be of sporadic distribution due to complex geological layering.

See Figure 2 for typical cross section, Figure 3 for illustration of salt water interface and Figure 4 for illustration of basin aquifer layering.</td></tr>
<tr><td>Confined Sedimentary basin</td><td>Generally found in undulating hills to broad flat plains.</td></tr>
<tr><td>Limestone</td><td>Generally found in broad flat plains (eg Nullarbor) but can locally form dissected hilly terrain (eg Chillagoe, North Qld)</td><td>Usually consists of loose or cemented material containing shells or shell material.
Under weathering and water solution can form karst terrain.</td><td>Can range from moderate to extremely high rates of water movement in karst.
Moderate to extremely high yielding bores and water storage capacities.
Local to regional flow connections and effects.
Recharge may be short-term (eg annual) or long term. (eg thousands of years)</td><td>Can be at high risk of contamination from pollutant producing land uses. See Figure 5 or typical cross section.</td></tr>
<tr><td>Fractured rock & Basalt</td><td>Usually found in steep to low undulating hills and ranges with narrow valleys</td><td>Generally present in older basement rocks.</td><td>High rates of water movement along fractures, but otherwise very low water movement within the rock material.
Low yielding bores and low water storage capacities.
Local to regional flow connections and effects.
Recharge - short term (annual) or long term (thousands of years).</td><td>High risk of aquifer dewatering.</td></tr>
</table>

Figure 1 Typical Cross Section – Shallow Unconsolidated Sediments Typology

(Soetrisno, S. (1996) *Impacts of Urban and Industrial Development on Groundwater, Bandung, West Java, Indonesia*. in Groundwater and Land Use Planning, Conference Proceedings, CSIRO, September 1996.)

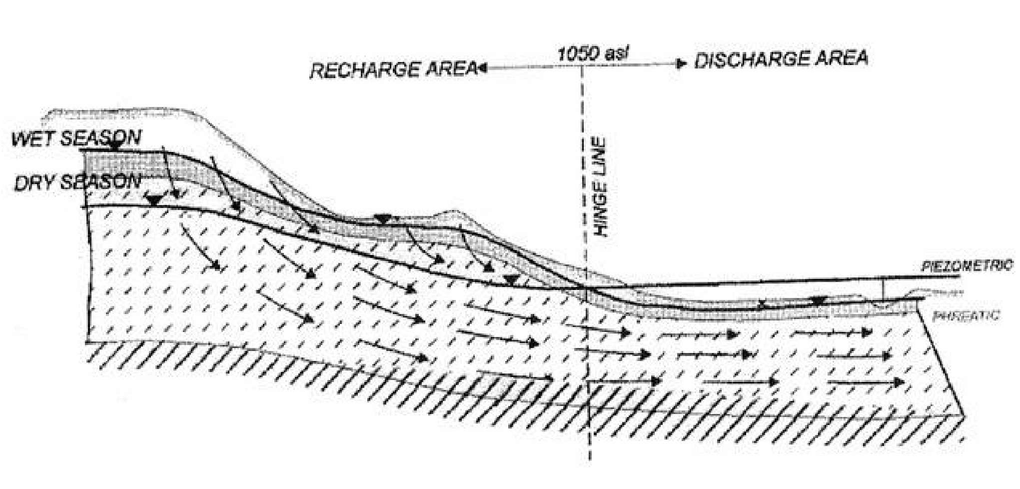


Figure 2 Typical Cross Section – Sedimentary Basin Typology

(Ritzema, H.P. Editor-in-Chief (1994). *Drainage Principles and Applications*. ILRI Publication 16, Second Edition, The Netherlands 1994.)

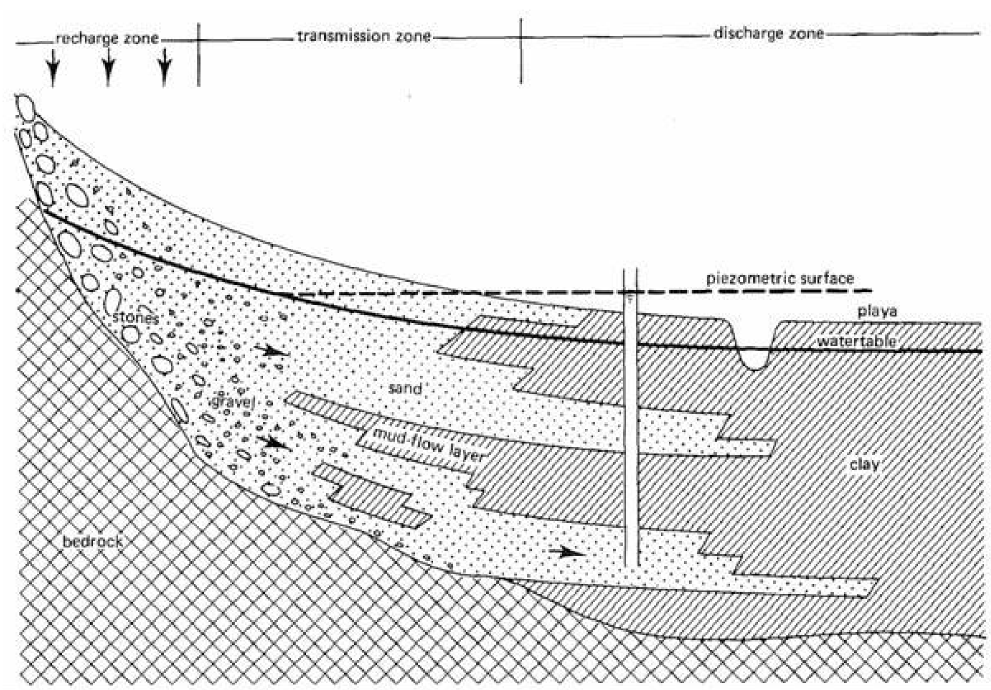


Figure 3 Salt Water Interface

(Ritzema, H.P. Editor-in-Chief (1994). Drainage Principles and Applications. ILRI Publication 16, Second Edition, The Netherlands 1994.)

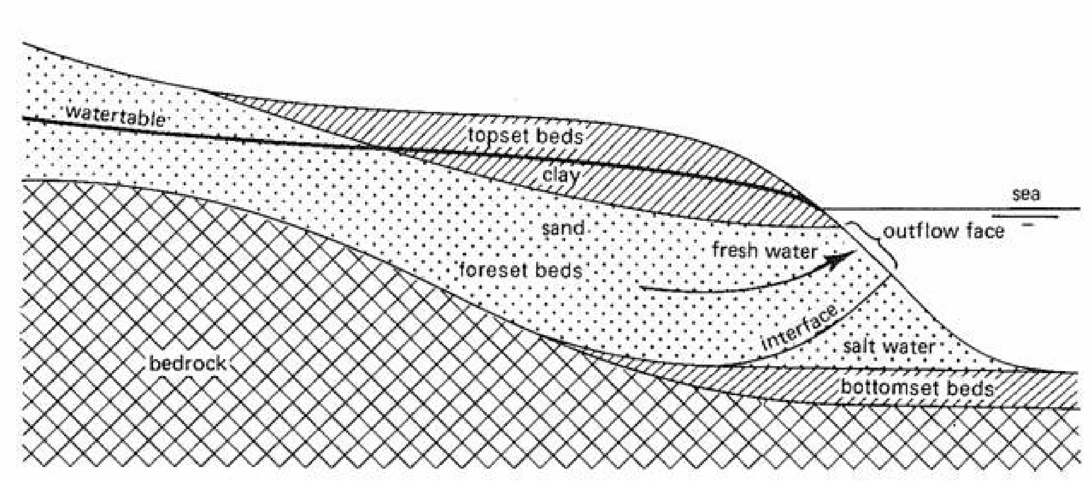


Figure 4 Layered Sedimentary basin Typology

(Driscoll, F.G. (1987). *Groundwater and Wells.* Johnson Filtration Systems Inc. ISBN 0-9616456-0-1.)

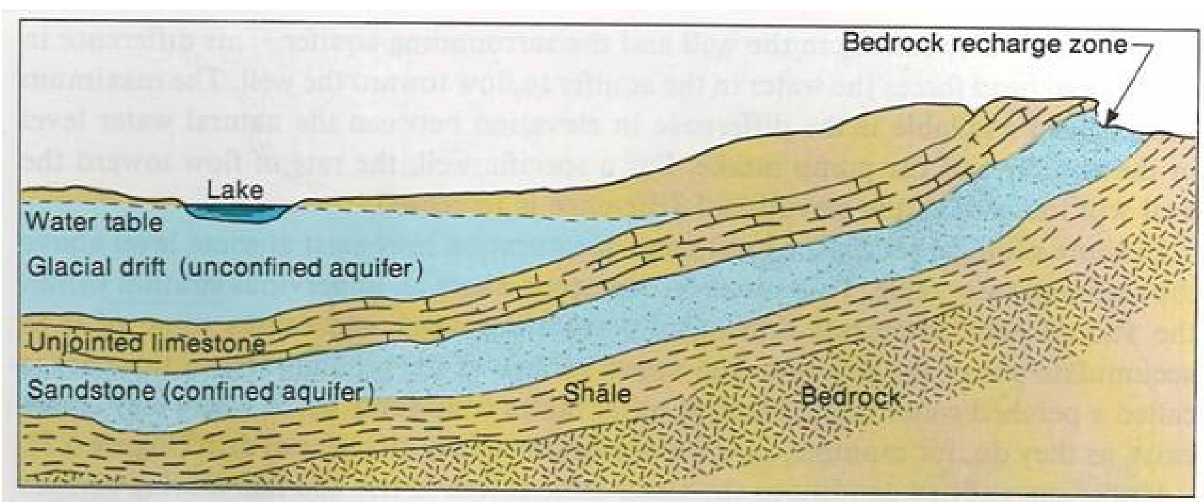
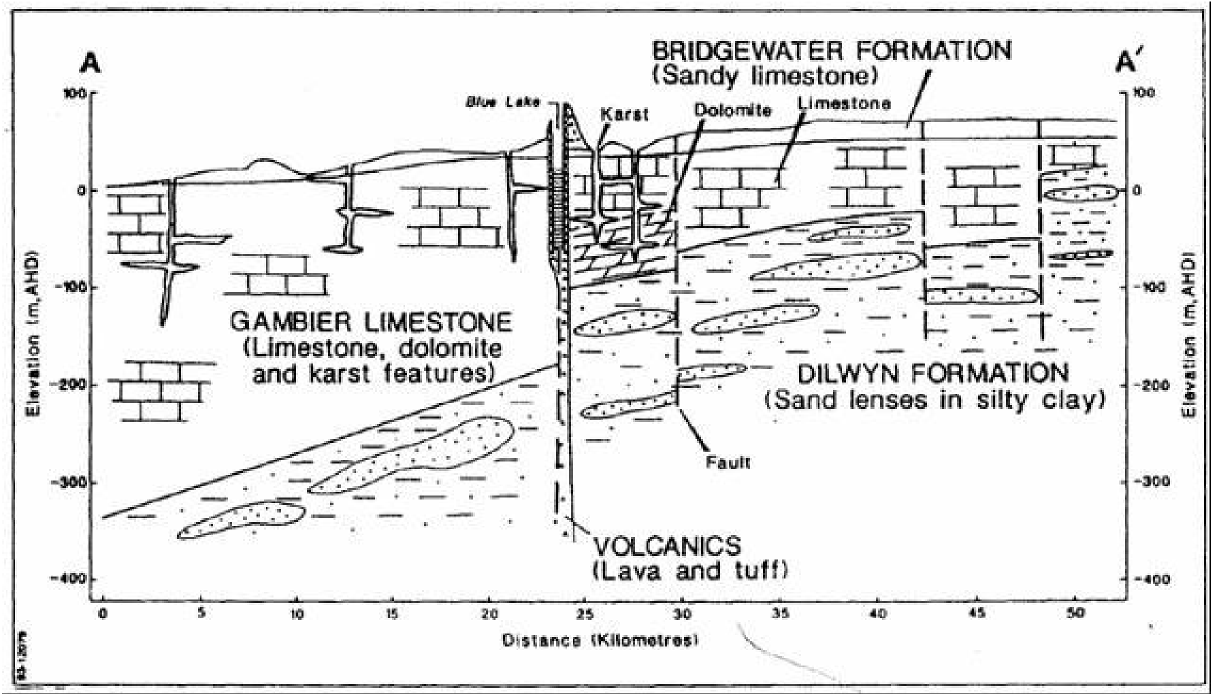


Figure 5 Typical Cross Section – Limestone Typology

(Telfer, A. (1996). *100 Years of Stormwater Recharge: Mount Gambier, South Australia.* from Proceedings of Aquifer Storage and Recovery, Adelaide, October 1996.)



5.2.2 Geographical Settings

Geographical settings are vital in understanding the boundary conditions on these types. For example, the issues associated with unconsolidated sediments 20 km away from the nearest river may be very different from the management issues adjacent to a river. Similar issues arise with respect to the proximity of coastal seawaters, bounded aquifers, etc.

It is difficult to provide a comprehensive list of the geographic settings associated with irrigation in Australia, except by reference to information from our contacts, and examination of particular case studies. Information is more readily found on formal irrigation areas than areas of private irrigation.

Even at the State level there is a significant gap in information on the distribution of irrigation.

We recommend the use of case studies as the primary vehicle to explore and promote these issues.

5.2.3 Irrigation Source

The source and application of irrigation water is also an important factor in the response of groundwater systems and the management issues faced by irrigators. Again the wide variety of irrigation types and practices makes it difficult to fully enunciate this situation on an Australia wide basis. As the National Land and Water Audit (2002) found, this situation is unlikely to be resolved very well even if substantial resources are assigned to this task.

Again it is advisable to utilise case studies as the specific avenue to demonstrate issues and opportunities.

An example of the classification for some irrigation areas is shown in Table 2.

5.3 Identifying Hydrogeological Types

The easiest way for readers to assess the hydrogeological type of existing irrigation areas, or potential irrigation areas is through the use of maps.

We completed a search of available maps including the National Land and Water Resources Audit site, AGSO, Commonwealth contacts, CSIRO personnel working on similar projects at a local scale, etc.

The best available maps to support the Hydrogeological Types identified here are those produced some time ago for the Australian Groundwater Atlas. We have examined these colour A1 maps and consider that with a few days digitising and reworking them could provide sufficient information to support the project. Scanning the maps could only produce black and white versions due to limitations of technology in Adelaide (see Appendix 4). Digital versions of the maps do not appear to be available.

It is likely that 2 days digitising, collation and presentation work would be sufficient to produce the necessary map layers from the originals.

State and local maps could form a secondary level of information within the book, but there will be a need to manage the tensions between the use of a common national classification type and state, regional and local variations.

Table 2 Example Classification for Some Individual Irrigation Areas

State	District or Region	Hydrogeological Type	Landscape	Irrigation Characteristics	Observed Impacts of Irrigation					
					Nutrient Enrichment	Soil waterlogging	Groundwater salinisation	Watercourse salinisation	Seawater intrusion	Aquifer dewatering
SA	Clare Valley	Fractured rock	Plateau of corrugated ridges, weathered surface shale with deep fissures	Uses local groundwater, impending use of imported River Murray water		✓	✓	✓		✓
	Barossa Valley	Sedimentary basin (unconfined and confined) with some fractured rock	Rolling hills with uplifted sections and valley bases with alluvial sands and silts.	Local groundwater use with limited use of imported River Murray water		✓	✓			✓
	South East SA	Limestone	Extensive plains with low rolling hills.	etc.			✓			✓
WA	Harvey region (WA)	Unconsolidated sediments with sand systems or alluvial sands/loams and clays.	Sandy coastal plain	Imported water from reservoirs	✓					

5.4 Distribution of Irrigation

The distribution of irrigation in Australia is again difficult to discern outside of the major irrigation areas, and we are aware from communications with MDBC (eg SunRise 21), MIA and MIL that only recently have these distributions been completed in these intensive agriculture areas. Part of the problem is that the footprint of irrigation often changes from year to year.

The best available data at a national scale appears to be that from the National Land and Water Audit as shown in Appendix 4.

Again, additional work with State agencies and private irrigation companies may be able to create an improved picture of the situation.

5.5 Matching Irrigation and Type

For national readers we believe that there is sufficient information to place irrigation areas on revised Australian Groundwater Atlas layers to provide maps and tables showing the interaction between irrigation and hydrogeological type.

6 Hydrogeological & Conceptual Models

A review of existing hydrogeological models suggests that there is little opportunity of placing these models on a system for ready access to non-expert users. In many instances an intimate knowledge of the local hydrogeology is required, data inputs must be interpreted appropriately, and data outputs must be analysed and refined to improve calibration for particular purposes.

It is concluded that the incorporation of hydrogeological models in any product could be misleading and confusing. The best that can be hoped for is to reference the existence of such models and provide State/Regional contacts for follow-up by the interested reader.

Two and three dimensional conceptual models of local hydrogeological settings are available and should be incorporated in case studies. In many instances these conceptual models need to be refined for the reader as they often contain many technical terms and concepts, lack consistency between prospective case study areas (see Appendix 6) and need to be refined to add landscape activities (eg irrigation).

In a number of instances the inclusion of a time series or snap shot of resource condition (eg groundwater level) may be possible.

Most conceptual models require refinement in conjunction with local experts to suit the purposes of publication, and will require reformatting and change of colours to provide consistency and optimise print quality in a coffee table publication.

7 Case Studies and Document Layout

We concentrated significant effort on collating information for a range of prospective case studies. Our aims were to:

- Identify the real potential for working up existing information into full case studies.
- Expose some key issues at a case study level and match these with key issues identified by State and Regional stakeholders.
- Prepare a case study in the proposed layout.
- Scope the potential for a standard case study format, including a gap analysis.

7.1 The Potential for Case Studies

We collated information for 8 out of 10 targeted case studies across the range of jurisdictions and hydrogeological types encountered in Australia.

Location	State	Hydrogeological Type
Loxton	SA	Sedimentary Basin
North Adelaide Plains	SA	Multi-layered Sedimentary
Daly River	NT	Limestone (karst)
Ord River	WA/NT	
Burdekin River	Qld	Unconsolidated Sediments
Meander River	Tas	Limestone (karst)
	* NSW - MDB	
	* NSW - Northern	
Shepparton IA	Vic	Sedimentary Basin
Clare Valley	SA	Fractured Rock

* Case study information is available from NSW and we have recently had confirmation of willingness to participate in data provision for the proposed study. Turnaround times did not provide sufficient opportunity for NSW to deliver information on these areas for this report.

It was concluded that in many instances there is substantial information already available for irrigation areas which can be built upon to deliver case studies. However, information for large irrigation company areas seems to be more readily available than for privately owned irrigation areas.

There is generally a lack of human stories. Stories which would enrich the case studies by placing the historical context in human terms, trace the emergence of issues, describe attempts to deal with issues, and highlight the support needed to address issues. It is acknowledged that such stories might quickly become out-of-date and could lead to a shorter life for the book.

7.2 Key Management Issues

Table 1 lists a number of potential management issues which might arise from water movement associated with each of the hydrogeological types.

During the case studies we also attempted to capture key management issues:

Location	Key Management Issues
Loxton, SA	Drainage and channel leakage of irrigation water from River Murray has created a groundwater mound up to 15m higher than the River. Over time problems arose including waterlogging of irrigable land, seepage and salinisation of the adjacent river floodplain and increasing River Murray salinity levels.
North Adelaide Plains, SA	Groundwater extractions for irrigation have decreased pressures in the aquifer. As well as on-going water level decline, salinity increases have also been noted. The resource is over-allocated.
Daly River, NT	Competing needs of irrigators, the environment and cultural owners need to be balanced.
Ord River, WA/NT	Rising groundwater levels have already occurred on the Ivanhoe and Packsaddle Plains. Rising groundwater levels could lead to increased groundwater discharge to the rivers as well as land degradation and could alter groundwater ecosystems within the subsurface environment.
Burdekin River, Qld	Inadequate surface water storage Ecological sensitivity Saline intrusion
Meander River, Tas	Groundwater and surface water contamination from nutrients, pathogens, BOD.
Shepparton IA, Vic	Conjunctive groundwater and surface water use in a complex system. Unsustainable groundwater extraction is leading to a drop in water levels. Mounding of the watertable beneath surface water irrigation areas has **not** been as significant an issue since the start of the drought but is expected to become a significant issue under more normal conditions.

Location	Key Management Issues
	Salinity in highland areas has resulted from clearing of trees, increased infiltration and rising groundwater levels. Surface water quality and river health is impacted by contaminants including salt, nutrients from irrigation drainage, sewerage treatment plants, sediment mobilisation, urban stormwater and intensive animal industries. Altered flow patterns in waterways have impacted aquatic biodiversity, water quality and the waterway environment.
Clare Valley, SA	Due to the nature of the fractured rock aquifers, the volume of good quality underground water is unknown and it is difficult to predict the long-term sustainability of the underground water resource. ▪ large drawdowns in water table levels during the summer are recorded but these have been shown to recover during an average rainfall winter. ▪ some wells show a large seasonal variation in salinity. When water levels drop, some wells show an increase in salinity.

The principle issues raised are:

- maintenance of a water balance (ideally near steady state conditions for the water table),
- groundwater contamination, and
- surface water contamination.

7.3 Case Study example

Loxton was chosen as a case study to work up further as an example of the layout. This work was completed in parallel with the collation of information for other case studies.

After reviewing the proposed content our graphic designer suggested the use of landscape A4 as this provides a balance for the plots, figures, photographs and text.

Key elements included in the case study are:

- An introductory paragraph acknowledging the genesis of the irrigation area.
- A timeline of development and emerging issues.
- A location map showing approximate location in Australia.

- A plot of growth in irrigation over time.
- A highlighted list of key issues and a list of key management actions
- An irrigators' story and their opinion on what help is needed[2]

The draft case study layout is provided in the separate pdf document, raw information sets used in the compilation of this case study are included in Appendix 6.

7.4 Towards a Standardised Case Study

The information collated from each of the potential case study areas is highly variable and sometimes at different levels. For a professional publication it is clear that considerable work will be required on each case study to rework or recreate consistent diagrams, textual content, tables and pictures in a common format and style.

The proposed standard case study should have the following content:

- Location Map – Australian
- Location Map – State/Region.
- 1 or 2 page Map of Irrigation Area highlighting key points of interest, hydrogeological types, landscapes, geographic settings and photos.
- Irrigation Area
- Source(s) of water supply and annual volumes
- Management arrangements (eg irrigation company vs private, planning mechanisms, actions)
- Type(s) of irrigation and crops
- Climate
- Growth of irrigation over time.

[2] Note we contacted three irrigators who were willing to take part in interviews, but needed more time to consider their responses / appropriateness / representativeness than was allowed in this project. Similarly capturing the benefits of local actions needs further time and engagement with the local community, NRM officers, etc.

- Key Management Issues (past, current, future)
- Value of irrigated agriculture to the local, regional and national economy.
- Hydrogeological Type(s)
- Landscape(s)
- Geographic Setting(s)
- Current policy context, desired future policy context and gaps.

7.5 Future Case Studies

The areas identified as potential case study sites were chosen on the basis of hydrogeological type, jurisdictional coverage, known issues, and type of irrigation (company vs private).

Clearly the sample is biased towards irrigation company areas. This is because these areas are often better known and defined, and have information available. Information on private irrigation areas tends to reside within water management plans (if anywhere) and is typically of a different focus to the type of information provided by companies.

Availability of information is a key determinant of the amount of effort (and hence cost) which will be required to develop formal case studies for publication.

The set of 8 case studies provided here does provide a reasonable coverage of most of the issues. Case studies for NSW (2) can be added delivered as long as significant lead time is provided to DIPNR.

We believe that 10 case studies is enough to show the variability and issues associated with irrigated agriculture on different hydrogeological types in Australia.

Section 10.2 provides a minimum cost estimate to bring each case study up to the same standard.

8 References and Further Information

Each of the States has long lists of hydrogeological studies and information. We collated some of this information during this project's interviews, and even more during the compilation of the case study information. However, there is a real need to bring this information together in a robust set.

As one of our respondents has noted, it is insufficient to simply provide lists of references (especially grey literature). Providing contacts or references to a way to get hold of this information is critical.

We believe there is an opportunity for a partnership with the States in this enterprise including the incorporation of a critique of the references as per the NPSI Knowledge Base.

9 Table of Contents

Based upon our review, we recommend the following Table of Contents:

1 Overview of Irrigation in Australia

1.1 History and growth

1.2 Where is irrigation occurring

1.3 What are the potential areas for new irrigation

2 Hydrogeological types

2.1 A typology

2.2 Characteristics of the types

2.3 Landscape settings

2.4 Distribution of irrigation

2.5 Geographic settings

3 Key issues associated with irrigation on different hydrogeological types

3.1 Water balance

3.2 Groundwater contamination

3.3 Surface water contamination

4 Case Studies of Irrigation

4.1 Case study 1

4.2 Case study 2

4.3 Case study 3

4.4 Case study 4

4.5 Case study …

5 References, contacts and further information

10 Viability of the Project

Based upon our discussions with stakeholders it is clear that there is considerable support for a web based tool which links to State Agency websites. It is less clear whether there is substantial support for a hardcopy publication.

10.1 Ability to meet needs of policy makers

While a coffee table book could be created the critical question to ask is "Who's coffee table will it sit on?"

There is no doubt that a critical element in effecting change is to demonstrate the human side of the problem and we believe this can best be done through the use of pictures, case study stories combined with scientific results interpreted as far as possible in everyday language.

The book will need to have plenty of stories if it is to be attractive. However, the pace of change in our understanding of irrigated areas and in irrigated agriculture is significant. Stories and information could become out of date very quickly limiting the life of a book.

The likelihood of a once off publication leading to significant change in policy makers perceptions is low. However, such a publication does have a role to play in a prolonged and concerted advocacy effort.

The nature of the information collated as part of a project like this has a life beyond a single publication and it is critical that the investment is protected through the long term storage of the information in an electronic form. The creation of a website or tool to support the publication would be relatively straightforward if developed as part of the initial design and would serve not only a storage purpose, but also provide an additional avenue for communication. And it will be of more value to most people who have a specific reason for seeking info (as in investors, govt decision makers etc)

10.2 Indicative Costs of Case Studies

Case studies will required significant work to achieve a common look, feel and content. Based upon our review we believe that each case study will require approximately 6 days to complete at approximately $1000 per day this represents a $60,000 investment for 10 case studies.

10.3 Indicative Costs of Mapping and other tasks

Map generation, artist and drafting work will also be substantial. It is likely that this and other incidental work will require up to $40,000.

10.4 Indicative Costs of Publication

CD & Web Delivery

If developed as part of the initial design it is likely that the delivery of a CD and web tool would require a budget of approximately $10,000.

Hardbound book similar to Water Innovation:

CL Creations have provided a cost for the above in the range $85,000 to $100,000 without technical support and engagement of individuals in the case study areas.

10.5 Total Costs

Full costs for production of the hardcopy publication plus web application is likely to be of the order of $200,000.

11 Recommended Project Brief

Hydrogeological features of Australian Irrigation Areas

The main Australian irrigation areas are made up of a number of common hydrogeological types. These systems are not well understood and this lack of understanding may be leading to less than optimal decision making.

Development of a quality publication that details in simple terms how the various hydrogeological systems operate, establish the hydrogeological context of Australian irrigation and provides case study examples will be of assistance to many across the industry and give greater confidence by irrigation stakeholders in policy decision making.

A scoping study has prepared a background paper which has recommended a suitable typology and assessed the viability of delivering this product together with a web based tool. The electronic tool will aid in updating information over time and provide wider access to the content of the book as well as providing links to State and Regional bodies which are the first point of contact for more detailed information.

Project Objectives:

The objectives of the project are to:

- Develop and deliver a quality full colour hardcopy publication supporting the aims of this project.
- Develop and deliver an electronic web-based tool which mirrors the style and content of the hardcopy publication.

Project Activities:

The main activities of the project will be:

- Engage the NPSI Management Committee to confirm the contents, title and key messages of the proposed publication.
- Develop a Communications Plan for the proposed publications.
- Confirm the hydrogeological typology and develop the map and tabular products recommended by the scoping study.
- Engage State, Regional and Expert contacts in the collation of case study information to a common standard and format.

- Compile and print a first class full colour hardcopy publication in a coffee table style.
- Develop a web-based tool which mirrors the style and content of the hardcopy publication.

Supporting Material:

The Scoping Study report has collated significant information regarding possible case studies, hydrogeological typologies and potential map products. Tenderers are advised to read this publication and note the accepted style of publication, the recommended Table of Contents and the standard case study contents for the proposed publication.

Selection Criteria:

Tenders are invited from individual consultants or organisations with demonstrated knowledge and experience of hydrogeology, irrigation and communication. Tenders will be evaluated against value for money and the following criteria:

- Demonstrated skills and experience in project management.
- Demonstrated experience in the interaction between irrigation and hydrogeology.
- Geomorphological knowledge and expertise.
- Experience in the development and application of hydrogeological typologies.
- Demonstrated experience in liaising with irrigation stakeholders, regional irrigation bodies, State agencies and Commonwealth agencies.
- Demonstrated experience in delivering high quality publications.
- Ability to deliver web-based tools and products.

Indicative Budget:

An indicative budget for this project is $200,000 excluding GST.

Contact:

Murray Chapman
Program Coordinator
Sustainable Irrigation Program
0357633214

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Summary Report
Groundwater Flow Systems Framework
Essential Tools for Planning Salinity Management
MDBC Publication 15/03, ISBN 1 876830 64 6

13 Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of National Program for Sustainable Irrigation and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated 25th January 2005.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 8th February 2005 and 24th March 2005 and is based on the information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Appendix 1

Notes from Interviews with NPSI Management Committee Members

<u>**7th February 2005**</u>

Denis Flett GM-W

–called and emailed for follow-up.

Ted Gardner Qld DNRM

– spoke briefly, emailed for follow-up *(see note on 16th February discussion with Murray Chapman below)*

Peter Hayes, Southcorp

- Trade off of look vs outcome
- Need to look beyond influencing individual irrigators to communities and investors
- Communities are wider than irrigators and include industries and banks.
- Need for "whole-of-project" life investment and an understanding of what will be left at the end – what legacy will we leave behind?
- No longer sufficient to prop up investments using interventions. Need to understand: Acceptable type of cropping
- Best practice
- Equity vs debt funders
- 3D and 4D (time) models showing changes of system in the long term.
- Recommended: talk with Peter Day re his work related to sharing of landscapes. Scoping up how to get communities engaged. The current project should reinforce Peter's findings / adopt recommended approaches.

Gerrit Schrale, PIRSA

- Need for a coffee table book aimed at any farmer.
- Use classical cross-section for irrigation on highlands
- Establish direct link between irrigators and returns to river.
- Groundwater irrigation areas require a brief write up – Padthaway irrigation development story would be a good one.
- Issue – not giving adequate displacement
- Stirling – irrigation of high EC water (3000 – 5000 EC); comment on sustainability.
- Combined discussion of Burdekin and delta groundwater where saline intrusions occur.
- Riverine system – prior stream systems, river beds fast transmitters of return water, salts, etc.
- Irrigation development and necessary losses – key message is have to establish harmony with the deep drainage of the landscape.
- Increase understanding what is going on via:
  - Identifying principles
  - Colour pictures
  - Key messages.
- Key objective – get the message out.

- Deliverable – a glossy book valued because of content, increased awareness of groundwater systems and linkage to irrigation.

Ross Dalton, DAFF

1. Policy / on-ground action

General approach of NPSI program to identify:

- Gaps in policy framework
- Externalities of groundwater use
- Recommendations for actions/adoption of findings

2. Approach for this project – 'taking a punt" and trading off accessibility vs content.
   - Similar thinking to NLWRA in terms of audience and potentially web based delivery.

<u>16th February 2005</u>

Notes from a teleconference with Murray Chapman and Ted Gardner (unable to contact Ross Dalton or Lois Hunt in the short time frames for this event).

Ted's view is that the main audience is non-technical policy makers who require information which is simple but not misleading.

He sees a need to address a range of irrigation systems with special issues. This will reflect the landscape which they fit into - for example, Emerald has shallow water tables on basalt, Condamine alluvial strip, Lockyer, Callide, groundwater systems with recharge. Proserpine/Bundaberg/Mackay/Burdekin – delta with groundwater use and artificial recharge and floodplain issues (K Bristow). For Queensland we need to talk to John Hillier especially for the Burdekin.

What are the special problems that 'deep leads' cause?

GHD report 10 years ago predicted we would now have saline water within 1m of the surface – what has happened – Good news story.

Publication needs to be interesting, entertaining and pertinent.

Explore potential to use formats other than Water Innovation, including books by the Kondinin Group (WA), CSIRO series of catchment hydrology books – last year or two (ring folder).

Bibliography – it is important to have a bibliography, especially one which captures grey literature, but importantly need to provide contacts on how to get hold of the literature.

In summary,

- Major clients are policy makers (banks, government, qangos, …)
- Don't talk transmissivity, Storativity (ie avoid jargon)
- Need to collate data from different states and regions
- Need a list of areas and the 'guts of each'
- Ideally the book will then provide an overview of the situation with the opportunity to delve in deeper if you have the interest.

URS noted that first week's Progress Report did not list names of state contacts – advised that this was because we hadn't finished that part of the review by that stage.

Discussed the detail of case studies and agreed that there is a need for a 'round up' of potential sites and issues as above, but it would be a good idea to work up one case study in detail (eg Loxton).

Appendix 2

Notes from Interviews with State Contacts

We utilised 5 focus questions to steer data extraction and conversations with state representatives:

1. How do you classify the hydrogeology in your State? Do you have a map of this distribution? Is information available through GIS, jpeg, other?
2. What hydrogeological settings/types are irrigated in your State?
3. What are the key management issues related to irrigation on each type? Are these dependent on scale of irrigation – how sensitive are your types/settings?
4. What are the best case studies of this for your State? Do you have 3D cut-aways, conceptual models, cross-sections etc? Are these available within one week?
5. How do you communicate sustainable irrigation management principles to irrigators, investors and NRM groups? Is this done by hydrogeological type? If so how?

STATE (Region)	**Contact (Department)**	**Response**
NT (Alice Springs Southern)	Bob Reid ph (08) 8951 9211 (DIPE Conservation and Natural Resources Section)	1. Groundwater occurrence maps, 100 km either side of Stuart Hwy, available electronically. 2. Ti Tree Basin is an extensive (3,000 sq km) multi-layered Tertiary Sand aquifer, Coffey Geosciences have developed a numerical groundwater MODFLOW model. Table grapes are the most significant crop. Minor other irrigation at Rocky Hill, 100 ha table grapes with groundwater from Amadeus Basin (Upper Proterozoic to Carboniferous). 3. Uncertainty in volume to allocate is the biggest issue (refer to Glen Harrington recharge work in the Ti-Tree Basin). To date, neither salinisation of groundwater nor shallow waterlogging are issues due to deep water table and well drained surface soils. Unlikely that these will become issues in the management timeframe, but degradation of supply due to inflows of higher salinity water will in time be an issue. 4. Ti Tree Basin, no other graphical resources readily available, refer to individual reports for resources (e.g. Ti Tree Basin modelling study). 5. The 100 km strip mapping provides the basis for reference and consultation material.
NT (Darwin	Stephen Tickell ph (08) 8999 3613	1. NLWA classifications at the detailed scale. See web site for general aquifer type map suitable for this study http://www.ipe.nt.gov.au/whatwedo/water-

STATE (Region)	Contact (Department)	Response
northern)	(Department of Infrastructure Planning and Environment)	resources/ground/resources/aquifers.html 2. Daly Basin Cambrian cavernous limestone around Katherine, used for irrigation of mangos and fodder crops, Proterozoic dolomite, mango irrigation. Extension (Stage 2) to Ord scheme into the NT (Keep River) proposed with surface water 3. Environmental allocations in the Daly Basin, Daly River is groundwater fed during dry season, will be the main limitation, see website links. Keep River proposal – will be irrigating high salinity estuarine sediments 4. Many technical reports available, simple graphics on the web sites e.g. http://www.ipe.nt.gov.au/whatwedo/water-resources/ground/people/katherine.html 5. Recent public meetings for the Daly Basin and also Ti Tree Basin (see reports on website) http://www.ipe.nt.gov.au/whatwedo/dalyregion/reports.html
South Australia	Scott Evans ph 8463 6949 (Department for Water Land and Biodiversity Conservation - Knowledge and Information Division)	1. See groundwater resource map. 2. All, ranges from fractured rock environments (e.g. Clare Valley) to extensive Limestone aquifer (e.g. Murray Group Limestone in the Riverland where irrigation is with imported surface water). 3. Usage beyond sustainable limits, reduction in pressures and impact on GDE's (GAB), cyclic concentration of groundwater (Upper South East), shallow waterlogging and water table rise due to water importation (Angas Bremer), drop in storage and ingress of surrounding saline water (NAP), leaking bores causing salinity rise in productive aquifers (NAP), off-site impacts of using imported water (River Murray salt loads in the Riverland) or salinisation of soils / watercourses (Clare Valley) 4. See above 5. Water Allocation Plans for Prescribed Areas with community consultation. The WAPS are available on the DWLBC website and document the management issues and actions in each area..
Western Australia	Phil Commander ph 9278 0300 philip.commander@environments.wa.gov.au (Department for	1. Irrigation areas fall into broad groundwater management units. Hydrogeological maps are produced for areas with high interest (1:250 000 scale). In the Perth basin the system is managed by layer, i.e. shallow unconfined Quaternary sediments, confined Leederville aquifer and confined Yaragadee aquifer. 2. Main settings include groundwater extraction in Perth basin,

STATE (Region)	Contact (Department)	Response
	Environment)	shallow coastal limestone and from shallow alluvium at Carnarvon which is recharged annually by the Gascoigne River. Surface water is used in the Ord Scheme and from dams in the South West (Waroona to Bunbury). 3. Water quality decline and falling water levels. 4. Perth basin is subdivided for management, Swan valley (extraction from Leederville Formation) would be a good study, Wanaroo has many issues including urban development, also the Ord Scheme. 5. Most areas of intensive groundwater extraction have management plans form pre-1995 which are currently being revised with the assistance of Local Area Committees to provide a channel for community consultation.
QLD	Linda Foster DNRM 07 3896 91055	In Qld most groundwater for irrigation is in unconfined/semi-confined alluvial aquifers with rainfall or river recharge. Reasonable GIS coverages for surface water irrigation systems but this is now with SunWater, although DNRM has access. The groundwater irrigation areas have less infrastructure and therefore less data – hence less GIS coverages. There are 4000 bores across state monitoring WLs and water quality and some special monitoring of saltwater intrusion. Contours of water levels in GIS – linked to models. Groundwater management occurs in Proclaimed areas such as Burdekin, Bundaberg, Lockyer and Pioneer. Key Management Issues – Surface water – Quality not an issue but demand is outstripping supply. Overland flow ha\s to be regulated under Water Act 2000 and this is an issue. Also the Act allows entitlements to be separated from property once a Water Resource Plan is done. Water now allocated as a Development Permit. Some rising water tables in some parts of irrigation areas (eg Condamine & Pioneer) but not as big a problem as in other states. Conjunctive use (SW & GW) being developed to combat this problem. GW being made more attractive to use. Groundwater – In Proclaimed Areas demand is outstripping supply. In Pioeer there are significant restrictions and in the Lockyer the aquifer almost goes dry. This is seen as a short term problem, however, because the aquifers are unconfined and

STATE (Region)	Contact (Department)	Response
		recharge on an annual basis. Most irrigation occurs in shallow alluvial aquifers around coastal areas. In deeper aquifers, (ie confined) there is very little groundwater irrigation. In GAB, for eg, groundwater irrigation is only used for drought-proofing. Case Studies – 3D sections could be developed from conceptual models developed as part of the Water Resource Planning process – eg. At Burdekin, Bundaberg and Pioneer. They have groundwater data and contours and have developed MODFLOW models. Stakeholders – Are involved in Community Reference Panel which is formed when the Water Resource Plan is being developed. Under the Water Act everything goes to the community reference panel. DNRM produce models and define hydrogeological types during this process. Closing – There is a lot of this material in the National Land and Water Resources Audit but they are now moving away from the concept of sustainable yield through to Water Resource Management plan with integrated (SW & GW) models.
Qld	John Hillier (Queensland)	1. Hydrogeology is described in terms of the basic geology and then into subareas for management purposes. Management boundaries which relate to the extent of the hydrogeological boundaries are available as GIS layers. The Great Artesian Basin is a major regional aquifer system through much of Queensland but is not commonly used for irrigation supplies. With the exception of the recharge beds which outcrop adjacent to the Queensland Highlands the aquifer is too deep to be impacted by irrigation activities at the surface. 2. Irrigation is undertaken using groundwater extracted from the following Hydrogeological Types: • Shallow unconsolidated sediments • Semi-confined sedimentary basin • Basalts Small scale irrigation supplies are drawn from GAB recharge beds or other fractured rock systems

STATE (Region)	Contact (Department)	Response
		3. Groundwater development generally occurred before estimates of sustainable yield were made. Aquifers in shallow unconsolidated sediments and semi-confined sedimentary basins are mostly fully or over committed (eg Callide Valley). Supply issues are therefore the major management issue in these hydrogeological settings. Supply is also an issue for irrigators in the Basalts due to the discontinuous nature of the aquifers in this area. Coastal irrigation areas commonly have problems with saline intrusion resulting from groundwater extraction and consequent lowering of the water levels in the aquifer. On the Atherton Tablelands some groundwater is extracted from basalts for irrigation and some from surface water supplies. Salinity problems are emerging salinity problems caused by increased recharge from irrigation on soils overlying a metamorphic terrain. In the Cattle Ck catchment rising watertable due to increased recharge from vegetation clearance and irrigation (compound problem). 4. Referred to Department of Natural Resources and Mines. 5. Estimates of sustainable yield are made by computer modelling followed by extensive community consultation until there is agreement on the most likely scenario. This then forms the basis of the management plan. The management plan for the GAB is currently being prepared and incorporates the current moratorium on all drilling in GAB. This will not be based on computer modelling of sustainable yield.
Qld	Guy Bignell (NRM Mackay Queensland)	1. Hydrogeology is communicated in terms of the geological aquifers 2. In the Mackay area irrigation is undertaken using groundwater extracted from the following Hydrogeological Types: • Shallow unconsolidated sediments

STATE (Region)	Contact (Department)	Response
		• Semi-confined sedimentary basin 3. Saline intrusion is the major issue in the Pioneer Valley at Mackay. Irrigation water is sourced from both groundwater and surface water on an approximately equal basis. 4. Case studies are available upon request. 5. The resource managers focus on the impacts to the resource alone. The resource is managed by reducing the allocations to ensure that groundwater levels are maintained at least 1m above mean sea level. Any changes to water allocations are communicated directly to irrigators' groups and associations. The irrigators' associations then communicate this to the irrigators.
VIC	Greg Holland	Most useable aquifers are alluvial systems or Basin sediments. Surface water irrigation occurs in large gravity-fed systems such as Shepparton IA and Kerang IA. These are defined in GIS coverages and water table levels are monitored across the region. Water table contours produced on an annual basis. Not much GIS coverage, but electronic maps and bore locations are in system. GMAs exist as polygons. Aquifers are in Riverine Plain, Alluvial aquifers and Fractured rock. Groundwater is managed through Groundwater Management Areas for which Permissible Annual Volumes have been determined. Diversion from streams occurs for small irrigation areas – on most major tributaries. Roster schedules are listed for unregulated streams. Water Management Planning with a more integrated approach is a requirement from the White Paper but GMW doesn't have the methodology to differentiate between GW and SW in integrated systems. New irrig. Developments need to conform with Irrigation Development Guidelines. DPI has Scoped these out with landowners and they focus on sustainability. In existing irrig. Areas water management planning focuses on sustainable use of water – Shep Irrigation Region Management Plan is the model. Key is conjunctive use but not conjunctive management. But this is only in Shep Irrig. Region. Needs to be extended to other

STATE (Region)	Contact (Department)	Response
		areas. Hydrogeological assessments must be done and the impacts of irrig. On the water table needs to be assessed. SIR has broad-based rules. Impacts must be assessed generically for a region – develop a Site Use Licence. Entitlements must be "unbundled" under the White Paper. Community groups are involved in development of Plans.
Vic	Phil Dyson (Victorian uplands)	1. The Groundwater Flow System approach has been adopted Statewide however in areas where regional groundwater systems apply a greater level of detail is required. Maps of groundwater flow systems have been compiled for each 1:250,000 scale mapsheet except Gippsland and the Mallee although in some instances the mapped scale is 1:500,000 or 1:1,000,000. These mapsheets are in the process of being standardised and merged into one dataset. 2. Fractured rock aquifers are generally not suitable for irrigation supply. In upland areas water for irrigation is commonly taken from either surface water or from groundwater sources in Upland Alluvium and Basalt flow systems. Some minor development of water supplies in outwash fans around granitic bodies is starting to occur. 3. The key management issues in irrigated upland areas typically focus on supply and drawdown issues due to the limited size of the resource. 4. Referred to local water authority contacts. 5. Communication of sustainable irrigation management principles is generally undertaken through workshops and presentations communicating the hydrogeological settings which apply in each instance. The presentations focus on GFS principles and commonly utilise cross-sections for explaining the hydrogeological framework and water level responses.
NSW	Mike Williams (NSW)	1. On the basis of aquifer type (alluvial, coastal sand, porous and fractured rocks). There is an incomplete project for a full salinity yield classification.

STATE (Region)	Contact (Department)	Response
		For management purposes the main GWMA (Groundwater Management Areas) have been defined. To allow the Water Management Act (2000) to be implemented we are current defining all aquifers in the state on this basis using classification above. Maps are available based on aquifer type. It is proposed to prepare a more detailed salinity yield map. Salinity yield, current GWMA and WMA classification (by mid year) are available as GIS layers. 2. Major irrigated areas rely on alluvial aquifers. Minor for porous rocks and coastal sands. Local irrigation from fractured rocks (limestone included in this group) primarily for high value permanent planting. 3. Issues that tend to be independent of aquifer type are management of environmental water share or requirement, impact on stream flow, impact on GDE and how the defined 'sustainable' yield will be shared among consumptive users. Horizontal groundwater quality decline in coastal aquifer, vertical in the inland. At the present time maintaining water access for all existing users through a prolonged drought particularly the basis rights to irrigations is a cause for 'noise' in aquifers where it has not occurred in the past (even if it was predicted and foreshadowed to users). Cumulative impact is a major issue with large groundwater users more able to modify management practice than small due to the viability base. 4. Depends what you are trying to demonstrate. Given the current water sharing plan status for aquifers in NSW the use of appropriate case studies would need to be established. 3D cut-aways, conceptual models and cross-sections are available in various documents and media but not within one week. 5. Communication with irrigators, investors and NRM groups is undertaken by issue and priority. Management principles are underpinned by an extensive technical basis and GWMA

STATE (Region)	Contact (Department)	Response
		committee negotiation prior to community engagement.
TAS	Bill Cotching DPIWE	1. In Tasmania we are using the groundwater flow systems framework developed in association with Phil Dyson. A map of the State has been produced at 1:250,000. An example pdf format map for the northwest NRM region is attached. A full state map and GIS is available from DPIWE. 1:100,000 scale mapping has been completed in parts of the Northern & Southern Midlands and this will be available later in 2005. 2. Four formal irrigation schemes operate in Tasmania. At Winnaleah in the northeast, Cressy/ Longford in the Northern Midlands, Clyde River near Bothwell in central Tasmanian, and the Coal Valley from the Craigborne dam in the southeast. Further information is at: http://www.dpiwe.tas.gov.au/inter.nsf/ThemeNodes/LBUN-4YC7N5?open A new large storage dam is to be built on the Meander River in the north of the State that will allow for increased irrigation in the Meander Valley. Irrigation water is likely to be used for increased dairy, vegetable and crop (eg poppy) production. There are significant volumes of irrigation water applied in agricultural areas of the State including: • The drained swamplands in the far northwest and northeast; • Basalt low hills and plateaux in the northwest and northeast; • Dissected terraces of the Launceston basin in central Tasmania; and • Low slopes and valley floors in the Derwent and Coal River valleys. Irrigation is predominantly by spray methods. Historically this has been applied using travelling gun irrigators, both soft and hard hose. Over the past 5 years, there has been a significant adoption of centre pivot and linear move irrigators that have high water use efficiency. The dairy industry uses a variety of systems including movable

STATE (Region)	Contact (Department)	Response
		sprinklers on laterals, k-line systems and some use travelling guns or centre pivots. Irrigation of dairy effluent is undertaken on most dairy farms using various technologies. Small travelling irrigators are commonly used for this purpose but injection into the lines of broad acre irrigators is also practiced. Wastewater from municipal sewage treatment facilities is being made available for productive agriculture in many areas of the State. The most significant volumes are being produced in the Hobart area. Flood irrigation is rarely practiced in Tasmania with only limited use in the Derwent valley of Southern Tasmania. 3. Monitoring of irrigation use in productive agriculture has revealed that many irrigators are not starting irrigation soon enough in the season, irrigation is not applied with enough frequency, and one or two irrigations could be eliminated at the end of the irrigation season. Some poor irrigation practice under intensive vegetable production results in off site impacts from the basalt soils of turbidity in local waterways. This is not widespread. Some poor irrigation practice of dairy effluent results in contamination of surface waters with nutrients and pathogens. This is not widespread. There has also been contamination of groundwater in intensive dairying areas but the relationships to the overall farming systems or any particular practice have not been established. Isolated areas of concern exist where dairy effluent is irrigated over karst systems which have sink holes and there is likely to be contamination of groundwater. In the Northern and Southern Midlands the risks of increasing soil salinity and increased discharge of salt to waterways resulting from changed land use, particularly from grazing to irrigated cropping, are currently being investigated. In the southeast of Tasmania, research is underway on the risks and consequences of irrigating with wastewater, particularly in relation to increased salinity.

STATE (Region)	Contact (Department)	Response
		4. The detailed ground water flow systems investigations currently being undertaken in the northern and southern midlands will provide good case studies and the detailed modelling of wastewater reuse in the southeast will provide considerable understanding. These studies will produce conceptual models with cross sections but these will not be available for several months. There is some rudimentary information and 3-D cross sections on the DPIWE website at: http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/RPIO-4YD88T?open 5. A series of training courses were run and a publication was produced as part of a course on wise watering irrigation management held in 2001. It was designed to enable participants to conduct their own soil evaluations, and use the results in the operation of their irrigation program. Module notes include: what is soil?; mineral particles; soil water; calculating RAW; assessing soil texture; commonly irrigated Tasmanian soils; water infiltration into soil; testing for slaking; testing for sodicity and dispersion; impacts of irrigation on soils; indirect impacts on irrigation. There is currently a water use efficiency project being run in the vegetable and dairy industries but there is a short term staff resourcing issue limiting the effectiveness of the project. The project operates via farmer discussion groups with monitoring of water quantities and soil moisture being undertaken on a number of farms. The information gained is presented back to the farmer groups to influence their management practices. There is currently a program underway to provide best practice advice to dairy farmers on dairy effluent disposal. Trained consultants are available and a cash incentive for on-ground works. Information emanating from the current projects investigating ground water flow systems will be used in future training courses on irrigation and salinity management.

Appendix 3

Notes from Other Interviews

<u>**8th February 2005**</u>

Kath Bowmer

Spoke with Kath regarding genesis of the Water Innovation document and captured learnings from the process.

- Very tight publication timeframe.
- Limited budget and support.
- Driven by publishing house which managed to get a number of “names” together who promoted / funded the document.
- Some organisations (eg Hydro Tasmania) provided significant support and feedback, others less so.
- Utilised a sponsorship approach with CSIRO being one major contributor (in-kind).
- Style was a difficulty as different contributors provided input aimed at different audiences, and promoted themselves or repeated other sections (eg COAG water reforms).
- Significant effort spent on indexing – but it was well worth it.

If going to do it again would:

- Allow additional time.
- Be very clear about content of chapters and styles to be used.
- Be clear about purpose / outcome sought rather than as an advertising publication.
- Seek additional support.
- Employ professional scientific / technical editor.

<u>**21st February 2005**</u>

Carolen Barripp (publisher ‘Water Innovation’)

Spoke with Carolen regarding the drivers for publishing Water Innovation and the costs of production. She agreed to provide a quote for a similar publication along the lines of the above as an indicative pricing guide.

<u>**18th February 2005**</u>

Glen Walker

Spoke with Glen regarding the prospective hydrogeological typology and its purpose, and the Groundwater Flow Systems framework (GFS) he has been involved with.

Glen confirmed that the GFS system is targeted at salinity issues but there are lessons to be learned from the approach including the need for a limited number of types, approach the classification using a hierarchy.

We outlined the needs of the project and the proposed hierarchical typology which he commented on eliciting a number of themes which we had already captured, and suggesting a number of improvements.

Glen saw that one of the main issues was the broad nature of the approach since irrigation might have a range of impacts including pesticide movement,

28th February 2005

Peter Day

Spoke with Peter regarding the NPSI project he is working on.

He is particularly focussed on:

- understanding farm <> environment impacts
- industry development <> regional economic development
- potential investor decisions (eg superannuation funds, etc.)

Two focus areas – Sunraysia/Victorian Mallee, Southeast of SA

Basically answering the questions

- What sort of environmental information is needed to support sustainable business decisions?
- Is there potential for a landscape classification to support investment decisions?

Current feedback from Vic is that locals have already “sussed it out” but are willing to be involved.

From SE of SA point of view – “we don’t even know the water balance”.

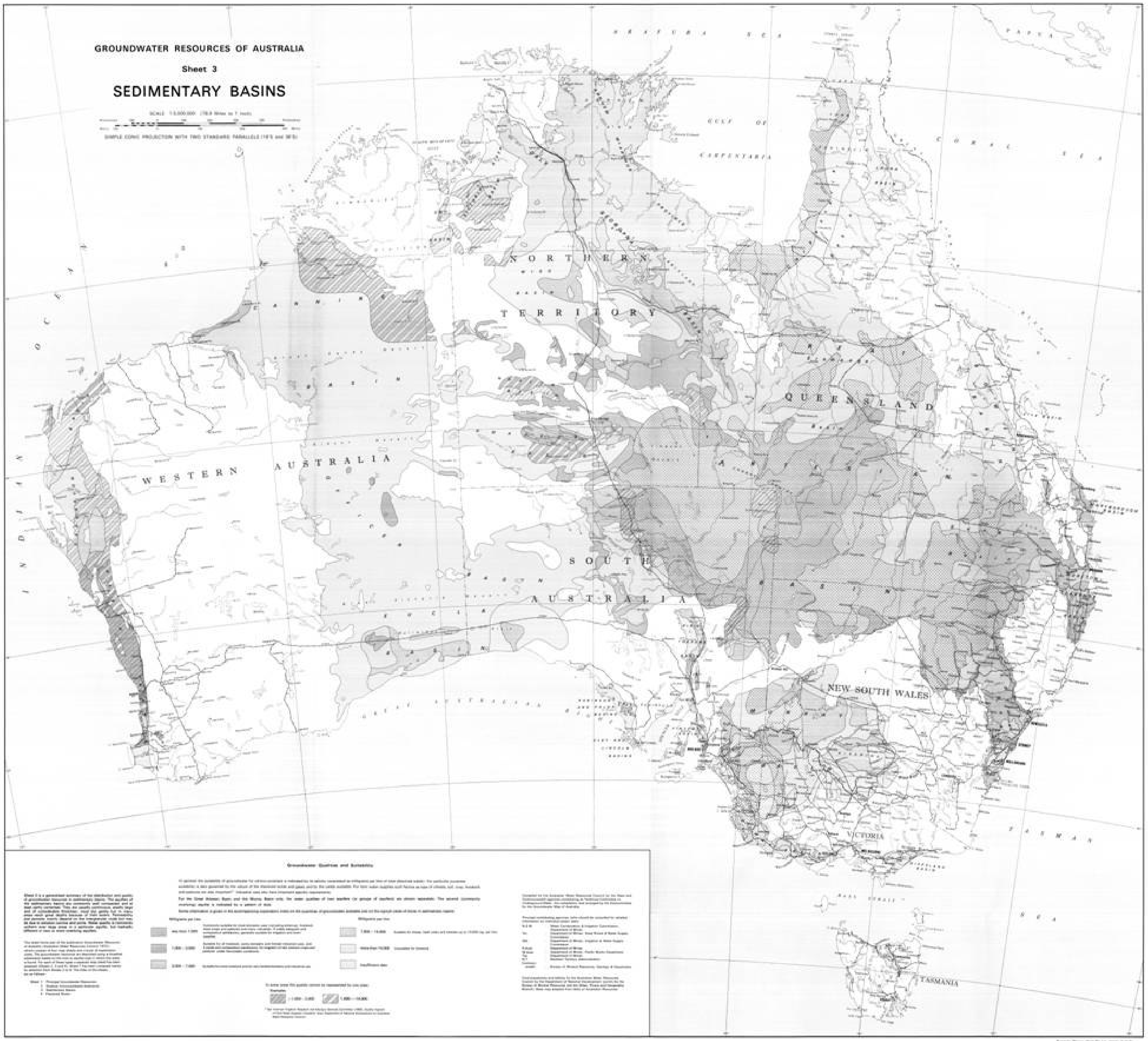
WA Horticulture is interested and willing to come across to SA and support the project.

I provided Peter with further details of the project including the incorporation of local knowledge/history in the case studies - which he saw as very important.

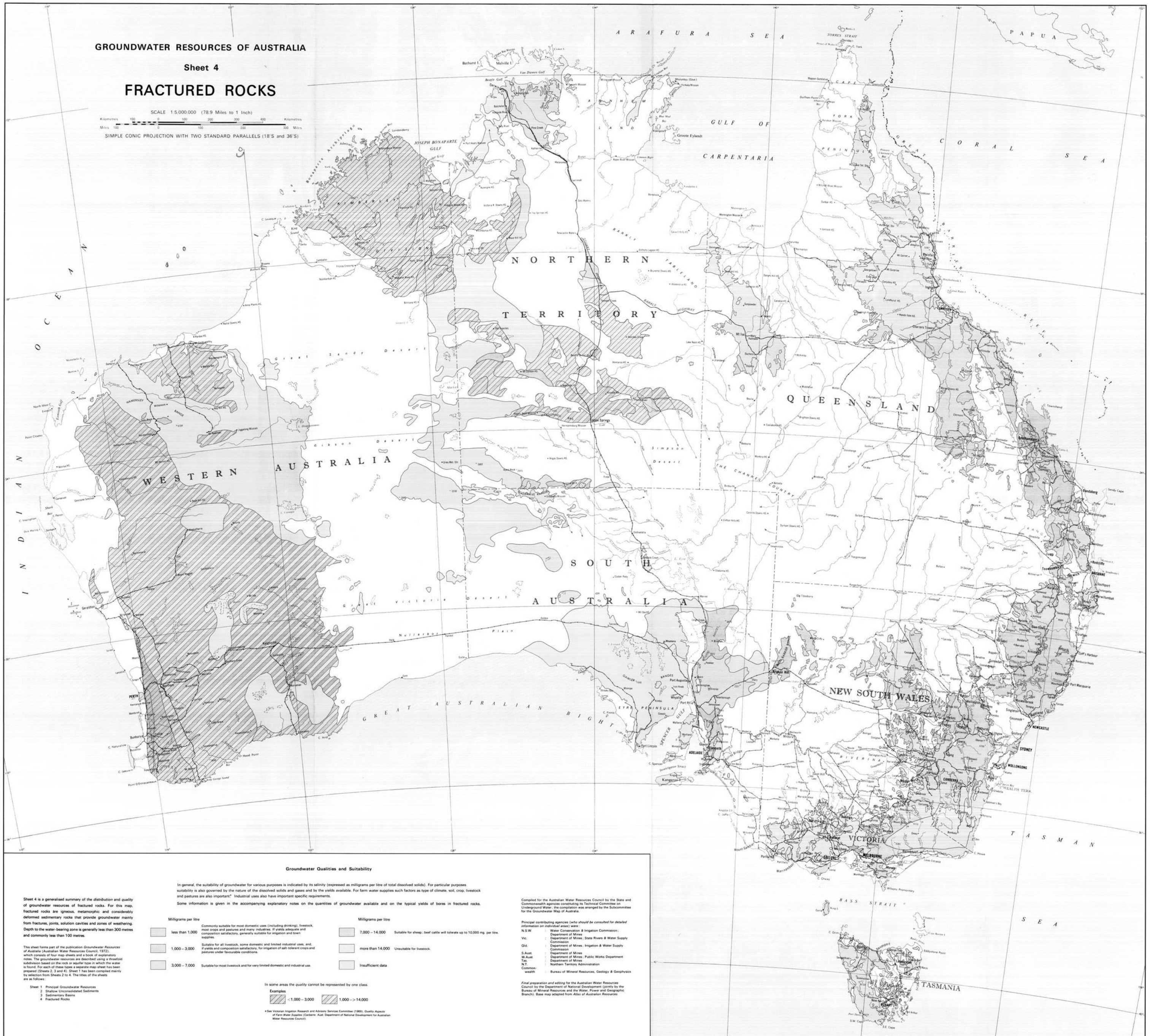
We discussed synergies and overlaps between the two projects and agreed to share information.

Appendix 4

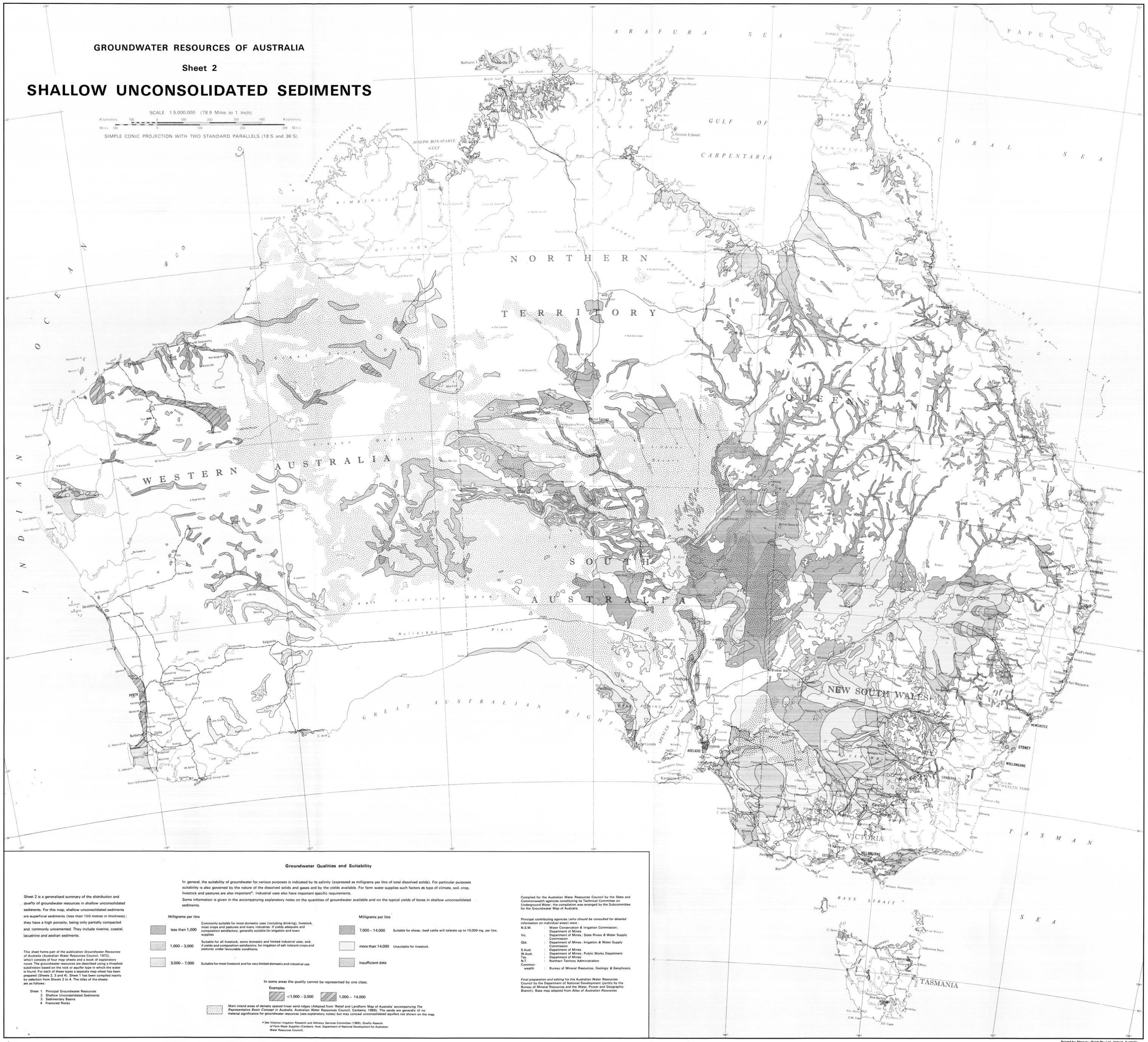
Maps of Irrigation Areas and Hydrogeological Types



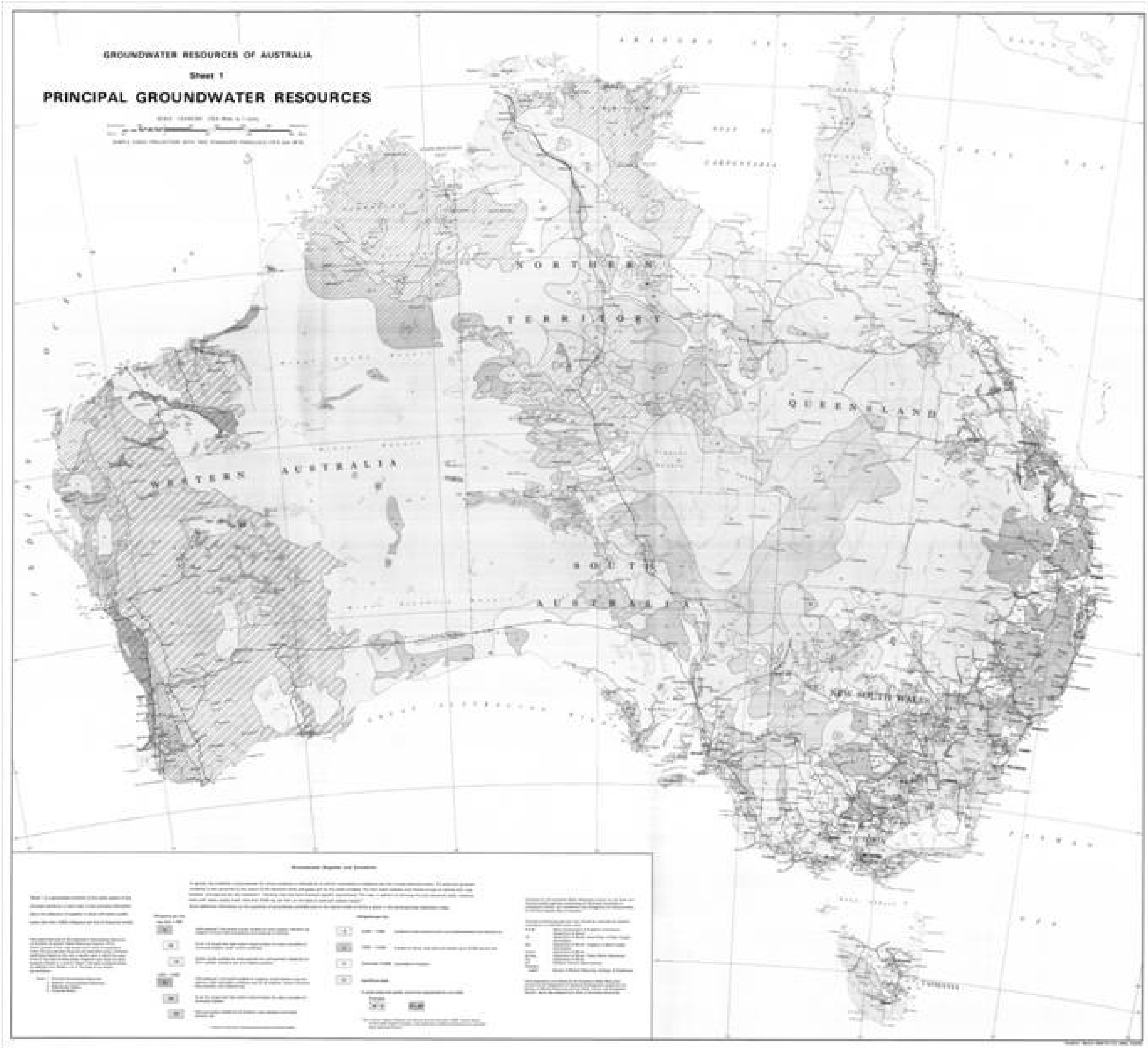
Source: Australian Groundwater Atlas, Australian Water Resources Council, 1975



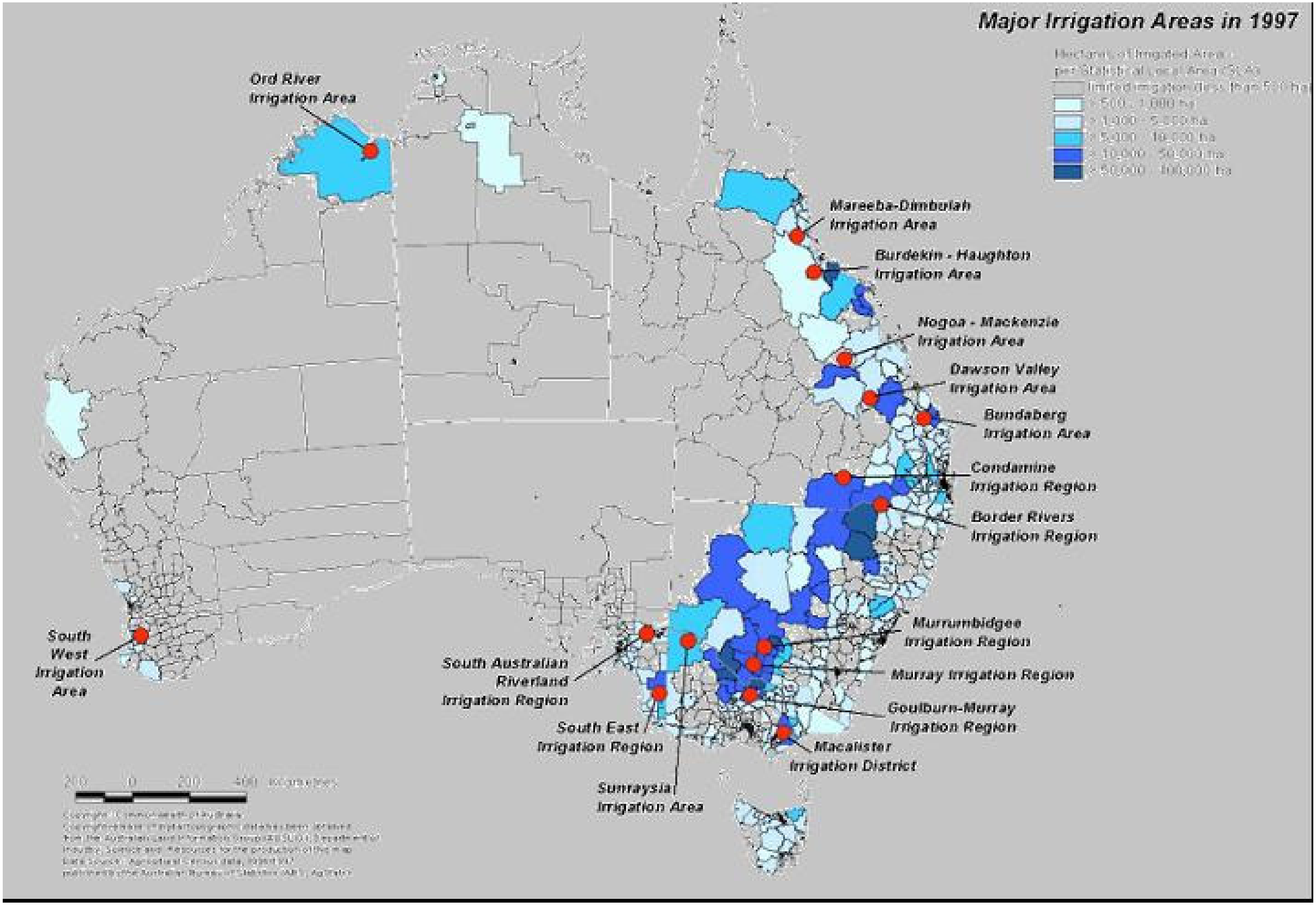
Source: Australian Groundwater Atlas, Australian Water Resources Council, 1975



Source: Australian Groundwater Atlas, Australian Water Resources Council, 1975



Source: Australian Groundwater Atlas, Australian Water Resources Council, 1975



Source: Australian Natural Resources Atlas, 2002

Appendix 5

Draft Information Framework

Framework for Information Delivery

Hydrogeological Types

- Classification Schema
- How classified + table
- Distribution by Aust
- Distribution by State?
- Distribution by Area?
- Glossary of Terms

Conceptual Models

- Conceptual Models (How types differ)

	Geographic Setting		
Type	Near River	Coastal	....
1			
2			
3			
4			

- How types developed (genesis/evolution)
- Physical / defining characteristics
- Hydrogeology + other? (3D, 2D diagrams, etc.)
- Key features of types by geographical setting

Hydrogeology and Irrigation

- Interaction between types, where they occur (settings) and management
- 3D matrix so "settings" are important to establish first then limit to 2D matrices of type vs impact. ie for each setting have a matrix as shown below.

Type	Susceptibility to Irrigation/Drainage		
1	Hi	Med	Med
2	…	…	…
3	…	…	…
…	…	…	…

- Distribution of types with irrigation (Aust, States, Area?)
- Illustrate with links to Case Studies, graphs, tables, pictures
- Link to management tools

Type	BMP Recommendation		
1	…	…	…
2	…	…	…
3	…	…	…
…	…	…	…

Case Studies

- Settings & Existing Mgt and Issues
- Candidates: Ord, Loxton, Burdekin, North Adelaide Plains, Shepparton, Westernport?, Daly, Northern NSW, NSW MDB
- Story – decline or possibly improvement assoc. with mgmt actions.
- Management issues from framework
- Photograph
- Locator map
- 3D or 2D diagram, etc?
- Other available info

More Information

- References
- Links (HTML)
- Contacts
  - State Govt
  - Federal Govt
  - Universities
  - Consultants
- Regional contacts?

Appendix 6

Investigation of Prospective Case Studies

Burdekin River Irrigation Area (Qld)

Key Issues:

Inadequate surface water storage, ecological sensitivity, saline intrusion

Key Management Initiatives

Groundwater recharge

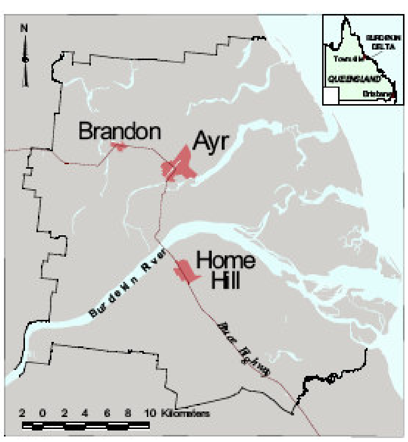
Piped delivery system from river

Improved on-farm water use efficiency

Artificial recharge schemes

The Burdekin River Irrigation Area (BRIA) is located in the dry tropics of North Queensland within the Burdekin River delta and associated flood plains. The region is located approximately 100km south of Townsville and encompasses about 40,000ha of irrigated land, mostly sugarcane (Figure 1).

The area has been irrigated for more than 100 years. Initially, irrigation was from naturally replenished groundwater supplies sourced from the river floodplain sediments of gravels and sands. After the Second World War, surface water irrigation from weirs began to be developed. Over the last 20 years, the need for additional water has outstripped supply and additional management measures have been adopted to sustain irrigation in the area. Following severe droughts in 1935 and 1964, serious concerns over groundwater level decline and seawater intrusion led to the establishment of the North and South Burdekin Water Boards in 1965-66 and the establishment of enhanced recharge schemes in the Burdekin Delta.



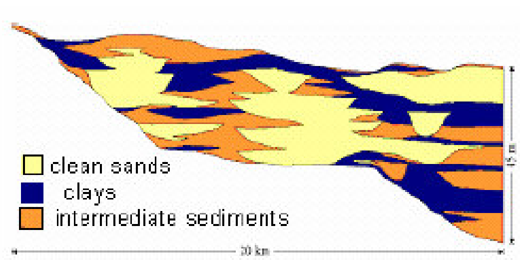
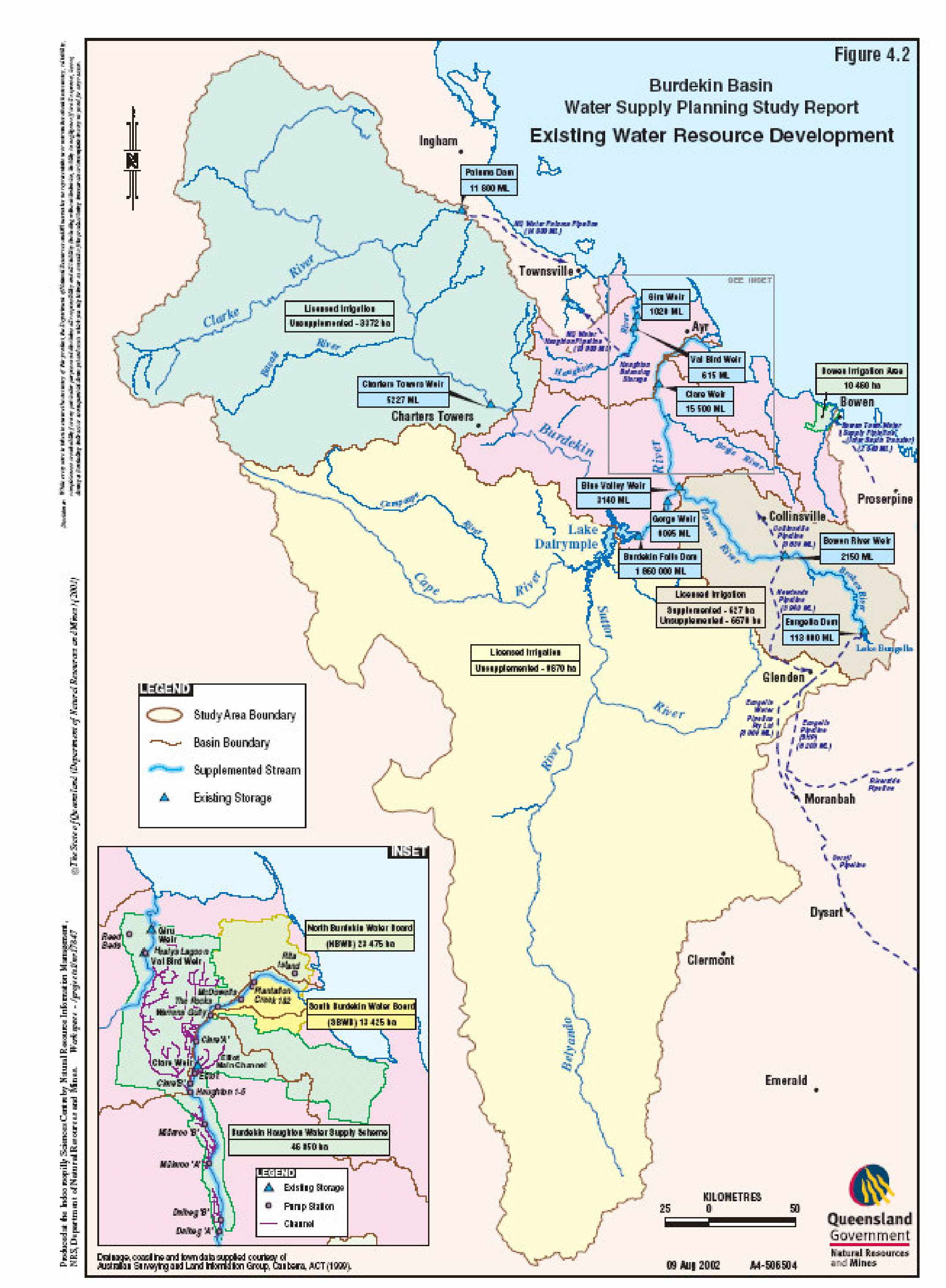


Figure 1: Map of Burdekin Delta.



Management Issues

This BRIA overlies major groundwater supplies and it is close to environmentally sensitive wetlands, waterways, estuaries and the Great Barrier Reef. A key issue is the whether the ongoing use of groundwater is sustainable in the long term. Of particular concern is interaction between current water management practices and farm activities and groundwater quality / quantity and other offsite impacts. The potential for groundwater quality degradation with nutrients, salt and chemicals is recognised (Figure 2). From a long-term sustainability point of view, these are likely to be the most critical issues affecting the natural system.

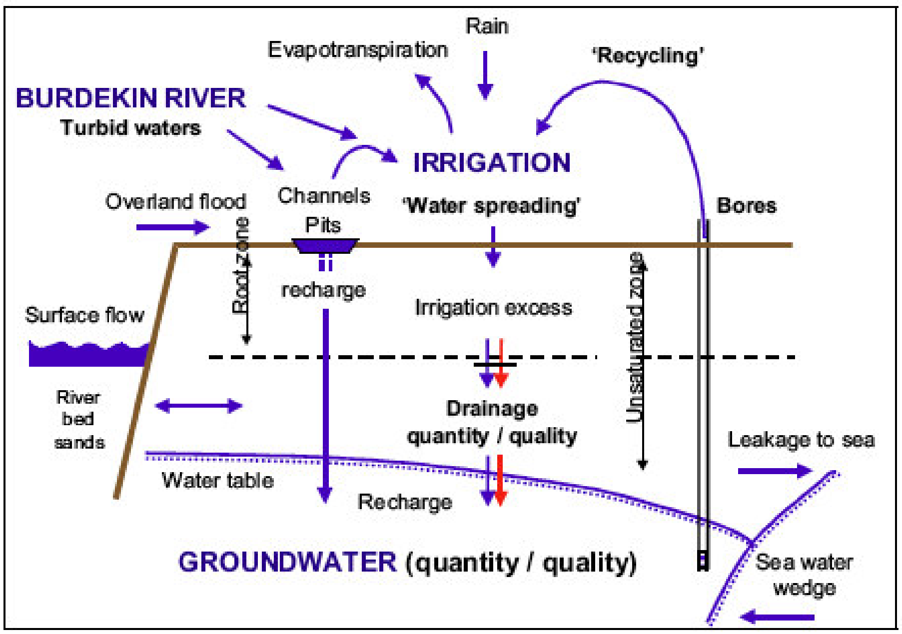


Figure 2: Schematic showing key factors of importance in the Burdekin delta irrigation area

Description

The topography of the Burdekin River Delta is flat to slightly undulating with the general gradient sloping slightly towards the coast. The delta plain is characterized by floodplains, levee banks, coastal sand dunes and mud flats with outcrops of bedrock around the fringes of the delta in the south and southwest. Surface water within the delta comprises the main Burdekin River, a number of natural distributaries, and a network of artificial diversion/distribution channels and recharge facilities. Near the coastal areas, natural lagoons and tidal marshes exist but are mostly beyond the extent of the irrigated area.

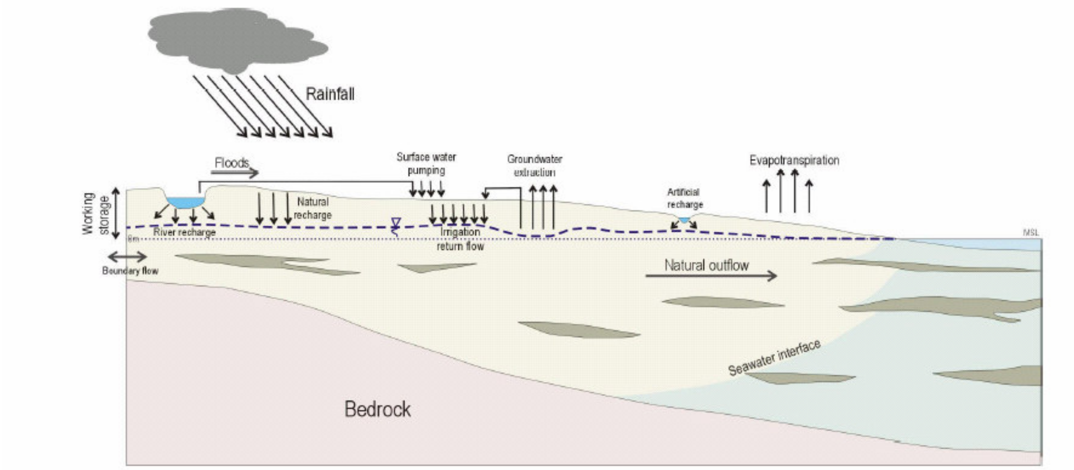
The sediments overlie a basement of granite. The aquifers comprise a complex distribution of clean sands, gravels, silt, clay and organic muds deposited from the Burdekin River. The sediments can be up to 100m thick near the coast. The sediments occur as discontinuous lenses however due to the absence of significant clays are all considered to be part of one heterogeneous aquifer. The aquifer is recharged by leakage from the Burdekin River's bed and banks.

It is estimated that there are approximately 2000 groundwater pumps in the delta area of which at least 1400 are currently in use. Existing water resource development is shown below.

Management Actions

The Water Boards operate a network of artificial recharge facilities comprising pits and channels fed by water from the Burdekin River. This scheme commenced in 1965 and has been expanded to include a series of river pumping stations feeding a network of artificial recharge pits, distribution channels, and natural distributaries. Sand dams have been continuously maintained on the river bed to ensure that water levels remain high enough to maintain pumping throughout dry periods.

Water management practices have evolved over the last few decades in response to local needs. These practices include the use of riverbed sand dams, extraction of river water to distribution channels, natural waterways and large recharge pits to assist with artificial replenishment of the groundwater systems. At this stage the average artificial recharge rate in the Burdekin delta has been estimated as 96,000 ML/yr. Farm water practices such as 'recycling', 'water spreading', and direct pumping from recharge channels have also evolved to play an integral role in the management of the groundwater systems.


Rainfall
Floods
Surface water pumping
Groundwater extraction
Evapotranspiration
Working storage
Natural recharge
Artificial recharge
River recharge
Irrigation return flow
MSL
Boundary flow
Natural outflow
Seawater interface
Bedrock

Ord River Irrigation Area Case Study

The ORIA straddles the border between the WA and NT portions of the Kimberley Region, and is situated on black soil plains associated with the Ord and Keep Rivers. The Ord River Dam impounds Lake Argyle, which supplies the water for the irrigation area. The town of Kununurra is the commercial and administrative centre for the area.

Hydrogeological Typology: Unconsolidated Sediments

Hydrogeological Setting: The Ord River Irrigation Area is characterised by complex topography and geology, resulting in highly variable and localised groundwater conditions.

Groundwater
occurs in the alluvial sediments, bedrock, and weathering profiles beneath the plains. The most important hydrogeological formation is the highly transmissive gravels which directly underlie the irrigation areas. Salinity is also highly variable, ranging from fresh through to saline.

Irrigation Development
In 1963, the completion of the Diversion Dam impounded the Ord River to create Lake Kununurra from which channelled water has supplied irrigated agriculture on the Ivanhoe Plain. In 1972, the formation of Lake Argyle made possible the release for irrigation of up to 13 000 ha of land on the Ivanhoe Plain and 2500 ha on the Packsaddle Plain.

Since 1994 various studies have been undertaken to determine the feasibility of expanding the irrigation area to accommodate an increased demand. There are six main areas promoted for the

Stage 2 development – West Bank of the Ord, Carlton Plain, Mantinea Flats, the Weaber Plain, Keep River Plain and the Knox Creek Plain. The proposed Stage 2 development would cover approximately 46 500 ha, bringing the total amount of irrigable land in the Ord River Irrigation Area to around 62 000 ha.

Management Issues

One of the main concerns, with respect the extension of the irrigation scheme is rising groundwater levels, which has already occurred on the Ivanhoe and Packsaddle Plains. Rising groundwater levels could lead to increased groundwater discharge to the rivers as well as land degradation and could alter groundwater ecosystems within the subsurface environment. Investigations, that are the basis of this Report, enable an assessment to be made of the environmental consequences of changes in the groundwater system.

Management Actions

Since the 1960s, Government agencies from WA and the NT have conducted a series of groundwater drilling investigations, installed piezometers, and constructed test production bores for pumping tests in the ORIA (Table 1). The agencies recognised that an understanding of the geology, groundwater level fluctuations, chemistry, and aquifer hydraulics is required to define the hydrogeology in sufficient detail to plan management for sustainable agriculture. Knowledge of the sub-surface conditions has permitted the modelling of the groundwater regime response to irrigation and has provided the basis to objectively plan and manage irrigation, and assess groundwater management options.

Early investigations included the construction of piezometers to monitor groundwater levels and salinity on the Ivanhoe Plain and Carlton Plain in 1964.65. There was some re-drilling on the Ivanhoe Plain in 1968 and Carlton Plain in 1978. The Weaber Plain saw an extensive piezometer construction program in 1968 with some redrilling in 1970. In 1983, the GSWA supervised a large piezometer installation program on the Ivanhoe Plain and Weaber Plain including Cave Spring Gap (Laws, 1983a,b; McGowan, 1983). The Keep River Plain had a modest spread of piezometers installed in 1966 and 1972. Little documentation is available for early drilling on the Mantinea Flats.

From 1994 to 1996, the government agencies of WA and the NT undertook a drilling program across the entire ORIA. It included expanding the monitoring network, constructing production bores with monitoring bores and undertaking pumping tests. The GSWA and the Power and Water Authority (PAWA) of the Northern Territory started the program in 1994. The Water and Rivers Commission (WRC) of Western Australia and Department of Lands Planning and Environment (DLPE) of the Northern Territory completed the program in 1996. Details of borehole completions for the 1994.96 program are presented in Humphreys *et al.,* 1995; Nixon (1997a,b,c,d,e,f,g,h), and O.Boy Agriculture Western Australia (AgWA) has also undertaken extensive shallow drilling for irrigation infiltration studies. These studies are at irrigation-bay scale, and piezometers are monitored with continuous data loggers. Bores drilled in WA have generally been numbered with a prefix letter, which in latter years has denoted location (e.g. PS . Packsaddle, KC . Knox Creek). The year of drilling and a sequential number identify piezometers installed by AgWA (e.g. 91/1 is the first bore drilled in 1991). Bores in the NT are identified by a Registered Number (RN) which is sequential in order of drilling (Table 1).

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Shepparton Irrigation Region

The Shepparton Irrigation Region covers more than 500,000 ha in north central Victoria and has a population of about 110,000. Of this 317,000 ha was irrigated in 2000-2001 using 1.5M ML/a. The main primary industries are horticulture, dairying, cropping, viticulture, wool, forestry and grazing. The Shepparton Irrigation Region contributes 25 % of Victoria's export earnings with production in 2000-2001 totalling about $6 billion.

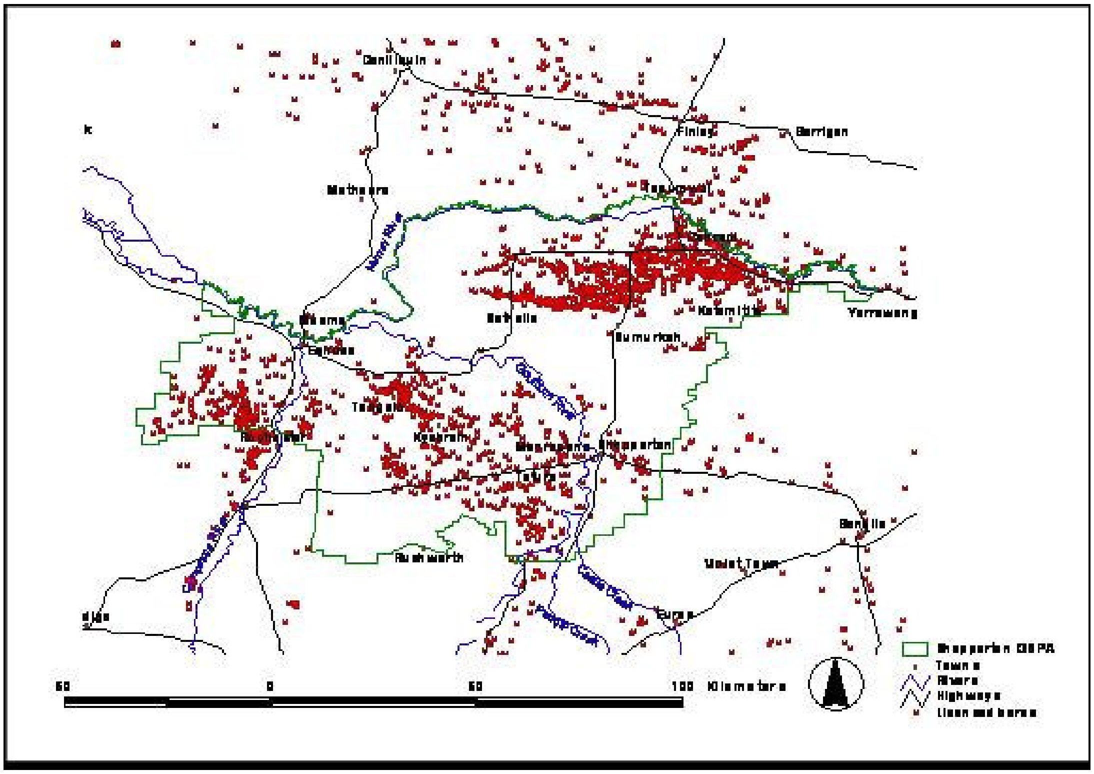
This community is dependent on the sustainable development of its water resources for irrigation. Management of water resources is undertaken by a number of agencies. Irrigation water is extracted from both rivers and water-bearing horizons in the ground (aquifers). Each has different impacts on the natural environment.

The Shepparton Groundwater Supply Protection Area applies to water supply bores in the Shepparton Formation excluding those used solely for stock and domestic purposes.

Hydrogeological Setting

Shepparton lies in a regionally extensive multi-layered sedimentary basin. There are three major aquifer systems in this area but only two are used for irrigation. The uppermost aquifer system is the Shepparton Formation aquifer. This unit has lenses of silt, sand and gravel in clay. Irrigation supplies are extracted from the lenses of sand and gravel. Water enters this aquifer (it is recharged) from the infiltration of rainfall and surface water. If there is a pathway to the surface through interconnected sand lenses then the water in the lens is likely to be fresh, otherwise it will be saline. Better quality supplies are commonly found close to creeks and lakes. To obtain enough water for an irrigation supply a number of shallow bores are connected and pumped together. This is known as a spear point system.

The deeper parts of the Shepparton Formation gradually become sandier until there are lenses of clay in an aquifer that is mainly sand. The unit that lies under the Shepparton Formation is the Calivil Formation. This unit comprises sand and gravel. The unit below this is the Upper Renmark Formation. This unit also comprises sand. These three units together form one aquifer. Because of the high sand and gravel content very large supplies of good quality water are available. The map below shows the location of licensed irrigation bores in this area.

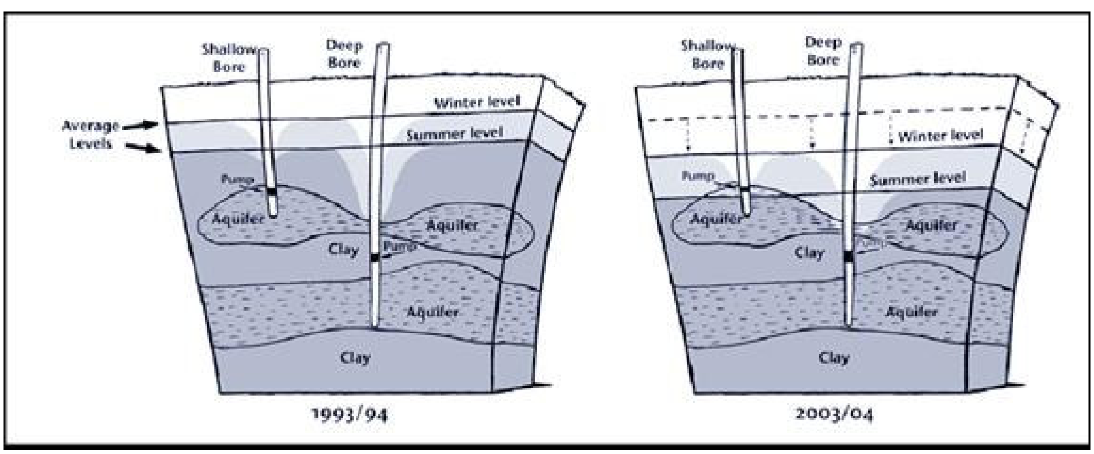


Surface Water Supplies

Surface water supplies are distributed through a network of channels and drains that criss-cross the irrigation region. Irrigators are licensed for a certain volume of water however in dry years when the total amount of water available for irrigation is lower the allocation may be significantly reduced.

Management Issues

1. In many areas, water levels in major aquifers have been declining and over the last ten years non-sustainable extraction has resulted in many bores going dry. This results partly from increasing extraction by irrigators and partly due to a decrease in rainfall and surface water flows which recharge the aquifers.



Source: Goulburn-Murray Water, Newsletter No 5 May 2004

2. Mounding of the watertable beneath irrigation areas irrigated by surface water occurs particularly where the Shepparton Formation is clayey. This has not been as significant an

issue since the start of the drought but it is expected that when the current drought is over that this will become a significant issue once more.

3. Water loss in open channels occurs through evaporation and also due to the water soaking through the base of the channel. Where the channel crosses a sandy lens of the Shepparton Formation these losses can be as high as 59-68%.
4. Salinity in adjacent highland areas has resulted from a change in land use from tree covered slopes to cleared land. This means that less water is being used by vegetation leaving more to soak into the ground increasing aquifer recharge. Consequently water levels have risen bringing the watertable closer to the surface. Where the groundwater is salty this causes dryland salinity. It is estimated that 260,000 tonnes of salt flows to the Murray River each year.
5. Surface water quality and river health is impacted by contaminants including salt, nutrients from irrigation drainage, sewerage treatment plants, sediment mobilisation, urban stormwater and intensive animal industries. Flow patterns in waterways have been altered impacting aquatic biodiversity, water quality and the waterway environment.

Management Initiatives

1. Groundwater management areas have been established to monitor groundwater usage in irrigation areas and to cap usage in areas where the extractions exceed current estimates of recharge. In some cases minimum groundwater levels are specified in Groundwater Management Plans
2. An extensive network of monitoring bores and a regular monitoring program have been in place since the 1980's to monitor the status of groundwater mounds.
3. Water authorities are closing inefficient channels and moves are underway to pipe other channels where losses are high. The introduction of water trading has allowed water managers to effectively move water usage to more appropriate locations.
4. The dryland salinity issue is being addressed by research and development, together with on-ground works undertaken by the Farm, Sub-surface Drainage and Community Surface Water Management programs.
5. A wide range of programs and partnerships have been established to address the various components of the surface water quality and rive health issues.

Loxton Irrigation District (SA)

Location: The town of Loxton is located on the River Murray in South Australias Riverland region. It comprises the irrigation sub-districts of Loxton, Media, Rilli and Sherwood.

Hydrogeological Typology: Sedimentary Basin.

Hydrogeological Setting: Regionally extensive multi-layered sedimentary basin, highly saline groundwater, irrigation with imported surface water (River Murray). Three major aquifer systems have been identified in the Loxton irrigation area; the unconfined Upper Loxton Sands below the irrigated highlands, the confined Murray Group Limestone system and the Alluvial Monoman Formation (or floodplain sands).

The hydrogeology of the Loxton area is documented in detail in AWE (2002).

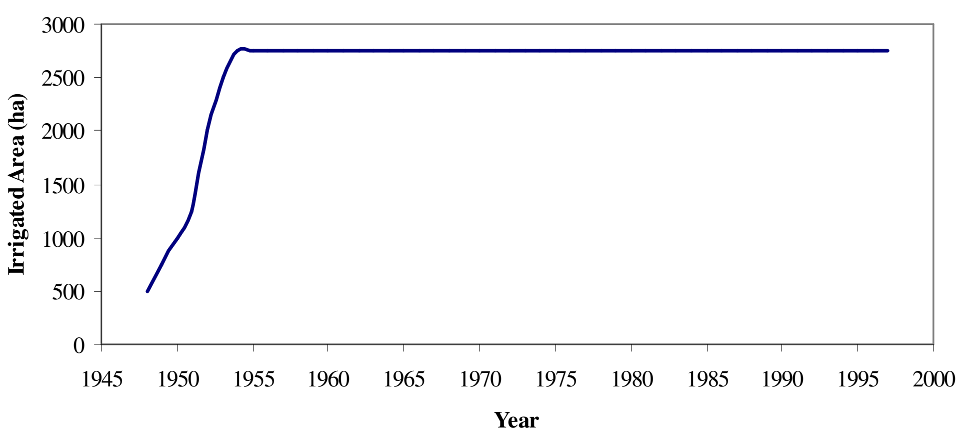
Irrigation Development

The Commonwealth Government established the Loxton Irrigation Area in the 1940's as a War Service Land Settlement Scheme. A brief chronological history of events related to irrigation and drainage developments in the Loxton Irrigation Area are presented in Table 1.

Table 1: Chronology of Irrigation and Drainage Developments at Loxton (PPK, 1997)

Year	Event
1945	Land Surveys for the Loxton Irrigation Area commence
1946	Construction of the irrigation scheme commences
1948	First 50 properties settled – irrigation commences
1952	Perched water tables result in waterlogging and salinisation of root zones Seepage shafts sunk – tile drain systems installed with connection to shafts
1955	Irrigation headworks completed – final settlement of 260 properties Drilling of drainage bores reaching to deeper aquifers commences
1964	Construction of comprehensive drainage scheme delivering to Katarapko Island Disposal Basin supersedes seepage shafts and drainage bores
1983	Media Irrigation Area landholding connected to CDS under agreement with SA Water – additional landholding included in 1989

The estimated growth in irrigated area for Loxton is shown in Figure 1 below.



Currently more than 32 GL/yr of River Murray water is allocated for diversion for the irrigation of over 3,000 ha of horticulture within the Loxton, Media, Rilli and Sherwood irrigation areas.

Management Issues

Accessions of irrigation drainage water below the root zone have resulted in the formation of a large groundwater mound below the irrigated areas, which extends to more than 15 m above the adjacent Murray River pool level. Historically, these accessions have comprised drainage water that was not intercepted by the Comprehensive Drainage Scheme (CDS), leakage from the open channels that delivered irrigation water to individual properties and overflow of unused water from the channels. The CSDS delivers water to a series of ancient ox-bow lake depression on Katarapko Island, across the river from Loxton (Figure 2, from AWE 2003). The interactions between irrigation, drainage and the hydrogeology at Loxton are shown on the salt and water balance block diagram (Figure 3, from AWE 2002).

As the groundwater mound grew, problems arose including waterlogging of irrigable land, seepage and salinisation of the adjacent river floodplain (including Rilli, Thiele and Loxton floodplains) and increasing River Murray salinity levels in the Loxton reach due to the displacement of high salinity native groundwater in the underlying aquifers. The disposal of drainage water to Katarapko Island may also be contributing to the increased river salinity levels.

River salinity surveys have indicated the salt load increase in the Loxton reach (approximately 20 km) can exceed 130 tonnes/day.

Management Actions

Management of the off-site issues of irrigation at Loxton need to focus on minimising drainage water accessions and the interception of the flow of saline groundwater to the river and floodplain environment.

The recent completion of the rehabilitation of the water delivery system from open channels to a pressurised pipe system was recently completed, and it is expected that this will result in a significant decrease in the overall volume of drainage water recharge to the aquifers. It is estimated that the drainage water volumes could decline by around 25% as a result of rehabilitation (Smith 1997).

The South Australian Department for Water Land and biodiversity Conservation are currently investigating and designing a groundwater pumping scheme (Salt Interception scheme) to address the measured high salt load discharges to the River Murray. The Murray-Darling Basin Commission requires an approval submission prior to funding the investigation, design and construction of SISs, and this is documented in MDBC (2003).

References

Australian Water Environments (2002). *Loxton LWMP Investigations Preliminary Salt and Water Balance for the 1999 / 2000 Year*. Loxton to Bookpurnong LAP, September 2002.

Australian Water Environments (2003). *Loxton, Media, Rilli and Sherwood Preliminary land and Water Management Plan – Summary Document*. Loxton to Bookpurnong LAP.

PPK (1997). *Assessment of the Impact of the Loxton Irrigation District on Floodplain Health and Implications for Future Options*. Loxton Irrigation Advisory Board, September 1997.

Smith, K. (1997). *Drainage Report Loxton Irrigation District for the Loxton Irrigation Advisory Board and South Australian Water Corporation.* Ken Smith Technical Services, 1997.

Murray-Darling Basin Commission (2003). *Approval Submission for the Loxton and Bookpurnong Salt Interception Schemes.* MDBC, 2003.

Figure 2: Irrigation Network and CDS

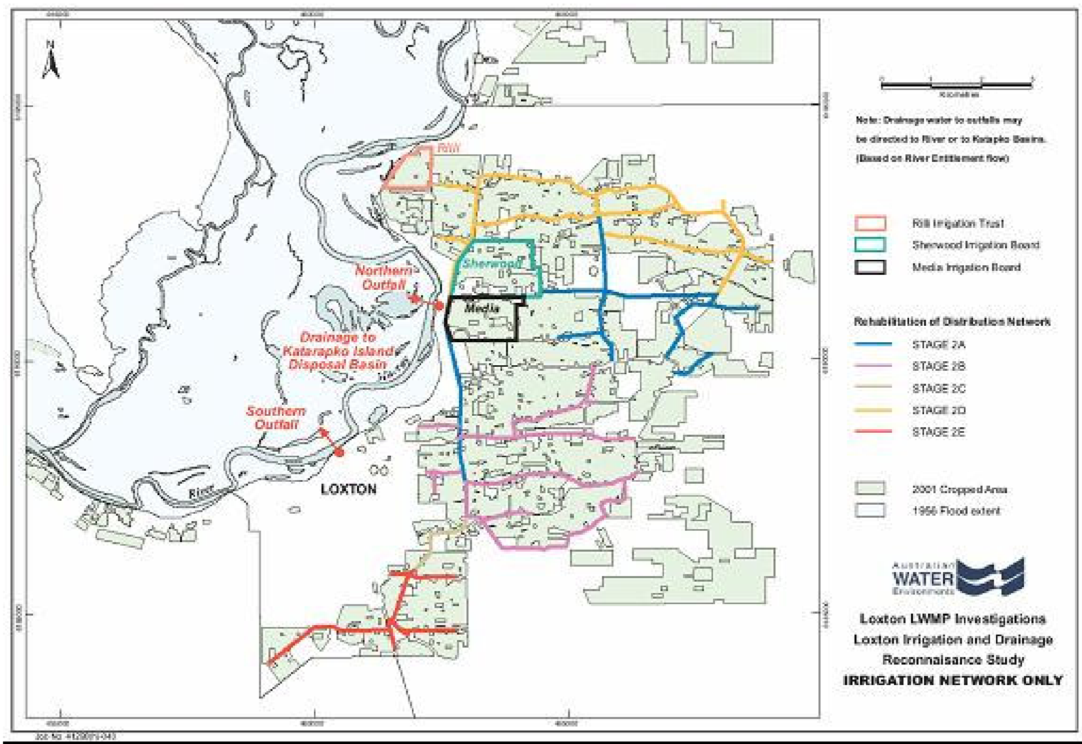
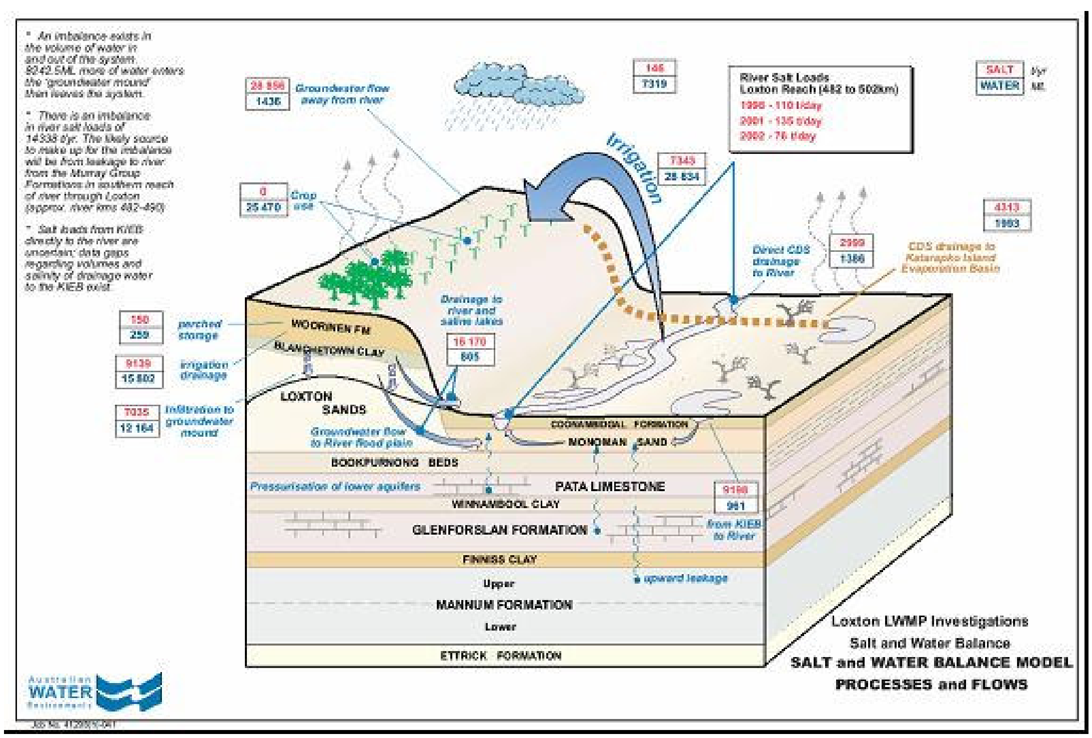
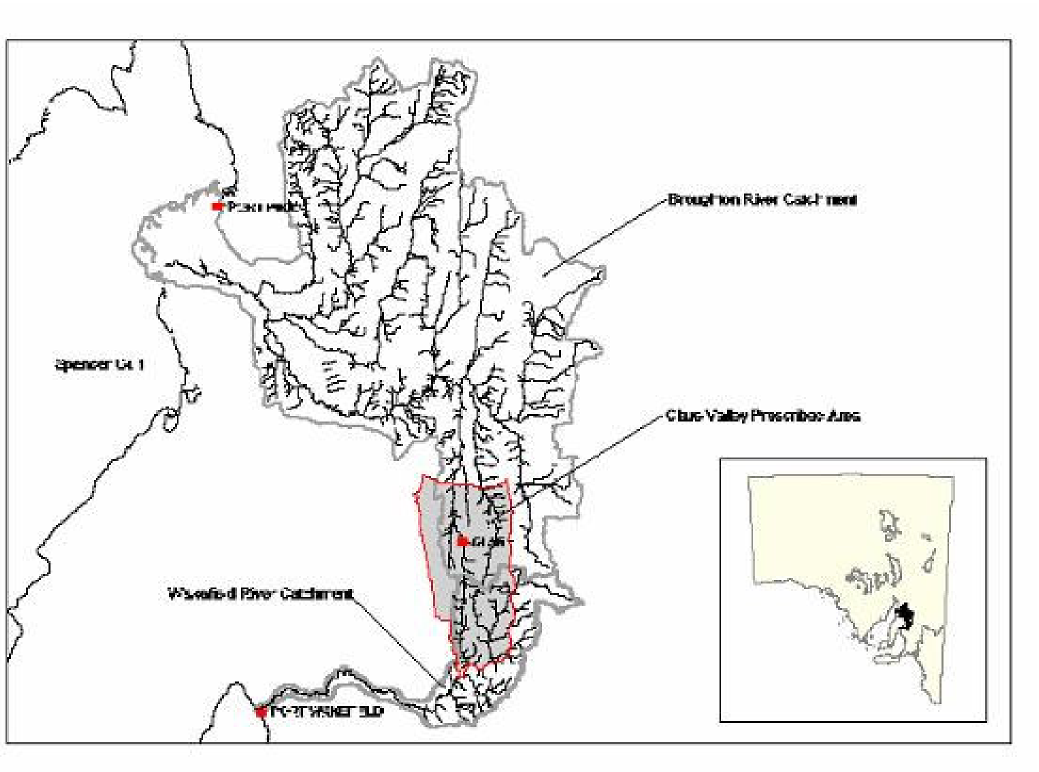


Figure 3: Block Diagram of Salt and Water Balance



Clare Valley Prescribed Wells Area (SA)

Location: The Clare Valley is located some 100 km to the north of Adelaide within the Mt Lofty Ranges (Figure 1).



Hydrogeological Typology: Fractured Rock.

Hydrogeological Setting: This description of the hydrogeological setting in the Clare Valley is transcribed from the Clare Valley prescribed Water Resources Area Water Allocation Plan. There are two water bearing aquifers in the Clare Valley

1. A fractured rock aquifer which is a consolidated rock with the voids provided by cracks or fractures (figure 5). Groundwater flows within the fractures while the majority of water is stored in the low porosity matrix. A variety of different materials including slate, shale, dolomite and quartzite form the fractured rock aquifers. The majority of the ground water resources used in the Clare Valley are sourced from fractured rock aquifers. The aquifers have a low capacity to store water due to their low percentage of pore spaces in the rock matrix, and therefore the available resource is significantly affected by seasonal conditions. Recharge to underground water occurs regionally throughout the Clare Valley and occurs when the soil moisture increases to such levels that the water infiltrates into the ground. In some cases, underground water recharge can occur directly where the fractured rock is exposed. Some recharge, particularly to alluvial aquifers, occurs through the bed of a watercourse.

2. Sedimentary aquifers in the Clare Valley have been formed through the deposition of unconsolidated gravel, sand and silt particles by rivers. Water is stored and travels through

interconnected voids in these unconsolidated sediments with relatively high porosities Geographically these aquifers form in the middle of the valley and interact closely with the surface watercourses that pass over them. Sedimentary aquifers are not extensive in the Clare Valley area, and provide only a small portion of the underground water resource.

Figure 1: Schematic of Fractured Rock Aquifer

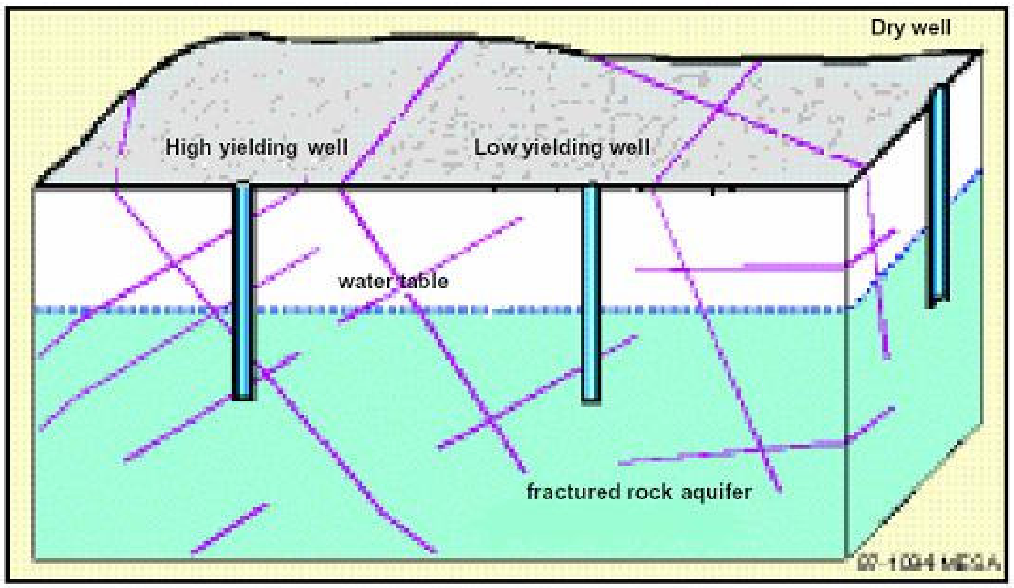
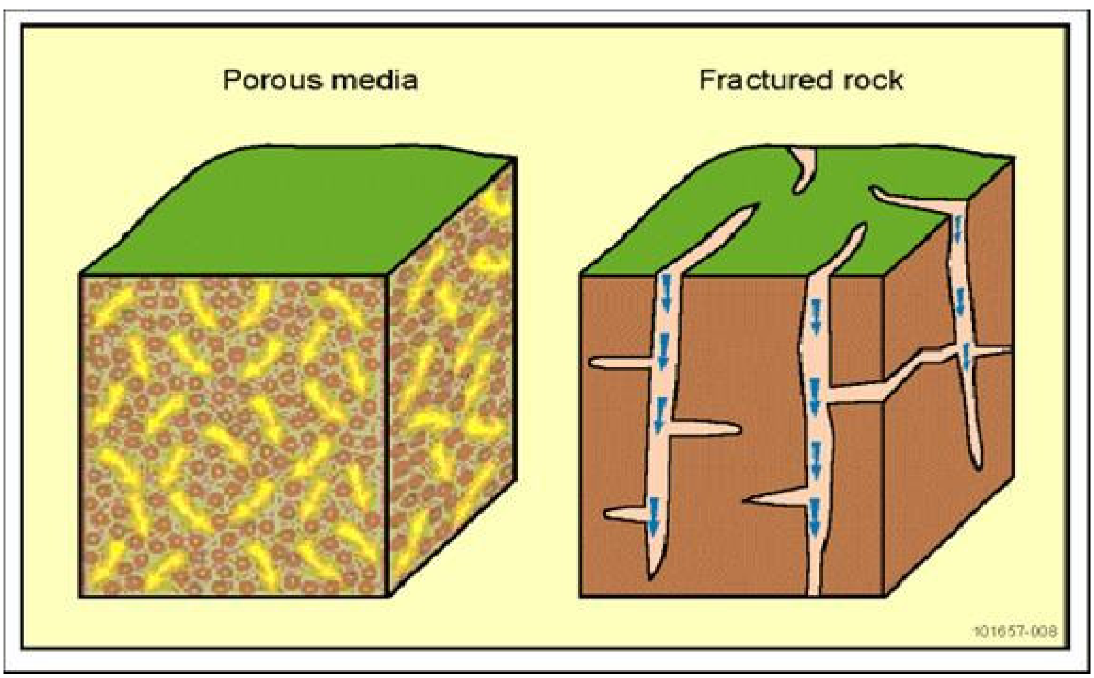


Figure 2: Comparison of Porous Media and Fractured Rock Aquifer Texture



Irrigation Development

There are 4 200 ha of vines in the Clare Valley, a large increase compared to the 2 000 ha of vines existing in 1995. Not all vines are irrigated and some are only partly irrigated. Approximately 1 500 ML of surface water and water from watercourses and 2 700 ML of underground water is allocated (or the equivalent in hectares and maximum irrigation rates).

Management Issues

Due to the nature of the fractured rock aquifers, the volume of good quality underground water is unknown and it is difficult to predict the long-term sustainability of the underground water resource. An extensive groundwater monitoring program has been undertaken in the Clare Valley since 1987/88 to monitor the depth and salinity of the underground water. The results to date indicate that:

- large drawdowns in water table levels during the summer are recorded but these have been shown to recover during an average rainfall winter.
- some wells show a large seasonal variation in salinity. When water levels drop, some wells show an increase in salinity.

Although there are large seasonal variations in the depth of the water table and salinity, the monitoring does not show any clear deterioration in the quality or volume of the groundwater resource.

The Clare Valley groundwater resource has a limited capacity for further development, given its nature and size and the requirements for ecosystems and downstream users.

There are localised problems with demand approaching and/or exceeding the capacity of the resource, particularly after a series of below average rainfall years.

Management Actions

Water Allocation Planning policy in the Clare Valley recognises that a workable limit to the capacity of the resource can be determined in terms of a zone of influence around each licensed well or group of wells. New licensed wells can not be established within an existing zone of influence, because this would exceed the local capacity of the groundwater resource.

Imported water, brought in via the SA Water pipelines from the River Murray, can provide extra capacity in the Clare Valley Prescribed Water Resources Area. The amount of water and the locations where it will be used depend on the effect of the use of imported water on the receiving prescribed water resources and the productive capacity of the land.

Further development can also be accommodated if the efficiency of water use is increased. For example, the evaporation losses from dams are considerable and cause efficiency losses.

References

Department for Water Resources (2000). *Water Allocation Plan for the Clare Valley Prescribed Wells Area*. Department for Water Resources, December 2000.

Northern Adelaide Plains Prescribed Wells Area (SA)

Location: The Northern Adelaide Plains extend over an area of approximately 800 km2 and centred 30 km to the North of Adelaide. It extends from the Mt Lofty Ranges in the east to Gulf St Vincent in the west.

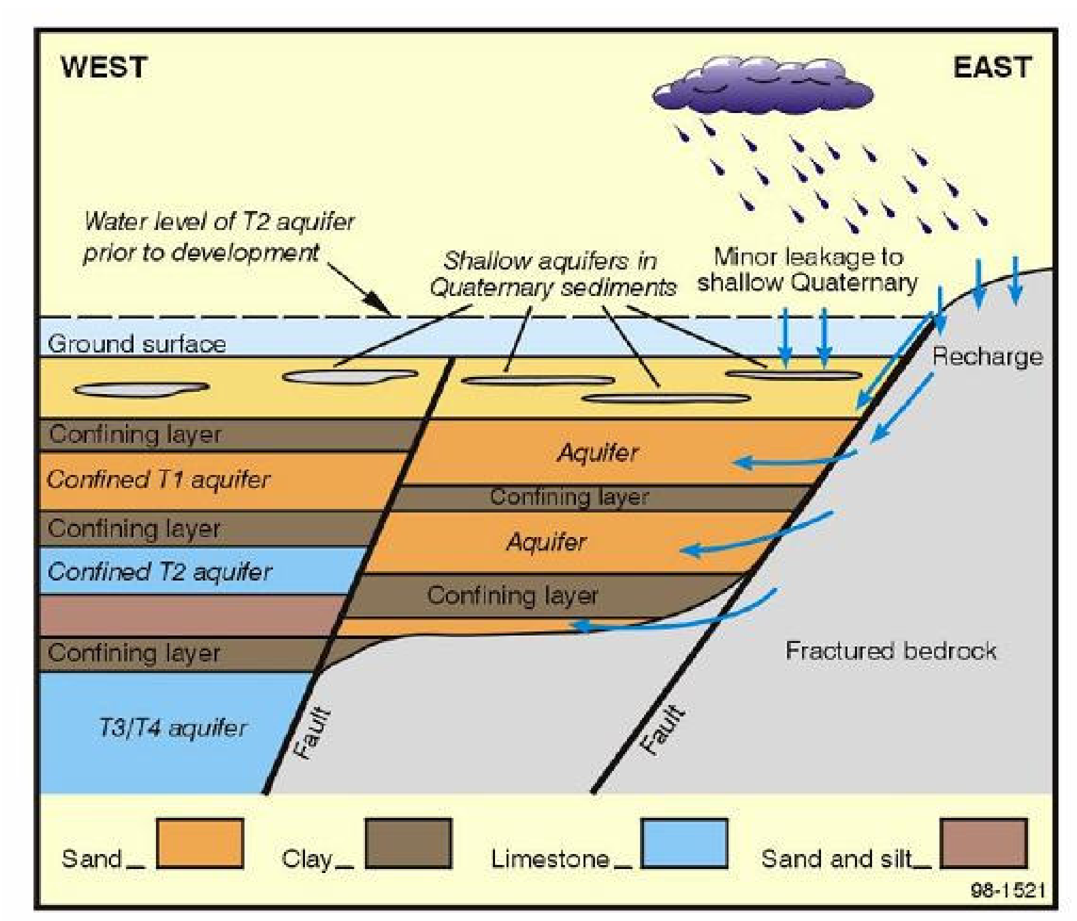
Hydrogeological Typology: Sedimentary Basin.

Hydrogeological Setting: The Northern Adelaide Plains is a multi-layered sedimentary basin, with high quality groundwater resources which are utilised for irrigation. It is underlain by Tertiary and Quaternary sediments up to 600 metres thick which contain numerous aquifer systems. The sediments are of deltaic origin formed by the accumulation of sediments from the surrounding hills. Figure 1 shows a typical cross-section of the resource showing the Tertiary and Quaternary aquifers and the flow of water in those aquifers.

The main source of recharge for the Tertiary aquifers of the Northern Adelaide Plains is from the rainfall-fed fractured rock aquifers in the Mt Lofty Ranges to the east of the prescribed area. The higher elevation of the Mt Lofty Ranges acts to pressurise water, which flows laterally in a westerly direction through the fractured rock aquifers of the ranges into the Tertiary aquifers of the Plains.

The hydrogeology of the Northern Adelaide Plains is summarised in the Water Allocation Plan for the Northern Adelaide Plains Prescribed Wells Area (Northern Adelaide and Barossa CWMB, 2000). This case study description is largely transcribed from this document, and from the Catchment Water Management Plan.

Figure 1: Schematic Hydrogeological Cross Section of the Northern Adelaide Plains



Irrigation Development

It contains relatively fertile soils underlain by a series of sand, gravel and limestone aquifers which are used as a source of irrigation water. Market gardens were established during the 1860s.

Management Issues

Water users in the Northern Adelaide Plains Prescribed Wells Area rely heavily on the extraction of underground water from the Tertiary aquifers for industrial use and crop irrigation purposes. The bulk of the extractions occur from the T1 and T2 aquifers. The average use over the last 10 years is 18,000 ML per year which is pumped from over 1,200 wells spread throughout the region, and the extraction rate has been fairly constant for the last decade.

In their natural state the main aquifers were sufficiently pressurised to ensure that most wells in the western part of the NAP were free flowing (artesian) approximately 10 to 15 metres above ground level. However, levels began to decline dramatically in the 1930s due to increasing irrigation activity. By the 1940s the major aquifers were no longer artesian and by the 1960s intensive pumping had resulted in the formation of a large cone of depression.

Recent hydrogeological investigations have continued to identify two major problems associated with the current level of groundwater use in the region - water level decline and increasing salinity levels.

The water level recorded in T1 aquifer has declined by 10 to 30 m in an area where a steep cone of depression has developed, mostly as a result of intensive irrigation (Figure 3). The decline is in response to a number of factors including the intensity of pumping during summer. The water level does not recover completely during winter, partly as a

result of pumping during the winter period.

Over the last 30 years, the average salinity recorded in the Tertiary aquifers of the Northern Adelaide Plains has increased by 200mg/L in some parts of the T2 aquifer and up to 800mg/L in the T1 aquifer.

The capacity of the resource is presently insufficient to meet the current demands for water use in the Northern Adelaide Plains Prescribed Wells Area without causing detrimental impacts on the underground water resources of the area. The current level of underground water use in the Northern Adelaide Plains Prescribed Wells Area is therefore in excess of what is considered to be an acceptable safe yield.

The unacceptable impacts could include increases in underground water salinity, losses of elastic storage, reduction in pressure and water level decline to an unconfined situation.

Management Actions

Many years of investigation have been incorporated into the current NAP Water Allocation Plan. This document provides the rules and principles to achieve the following objectives:

1. Allocation and use of underground water in a sustainable manner.
2. Allocation expressed as a volume of water that may be taken and used.
3. Efficient use of water.
4. Maintenance of water quality.
5. Maintenance of underground water dependent ecosystems.
6. Maintenance of the integrity of the aquifers.

Additional water sources potentially include treated wastewater from the Bolivar treatment works and the use of Aquifer Storage and Recovery to harvest stormwater.

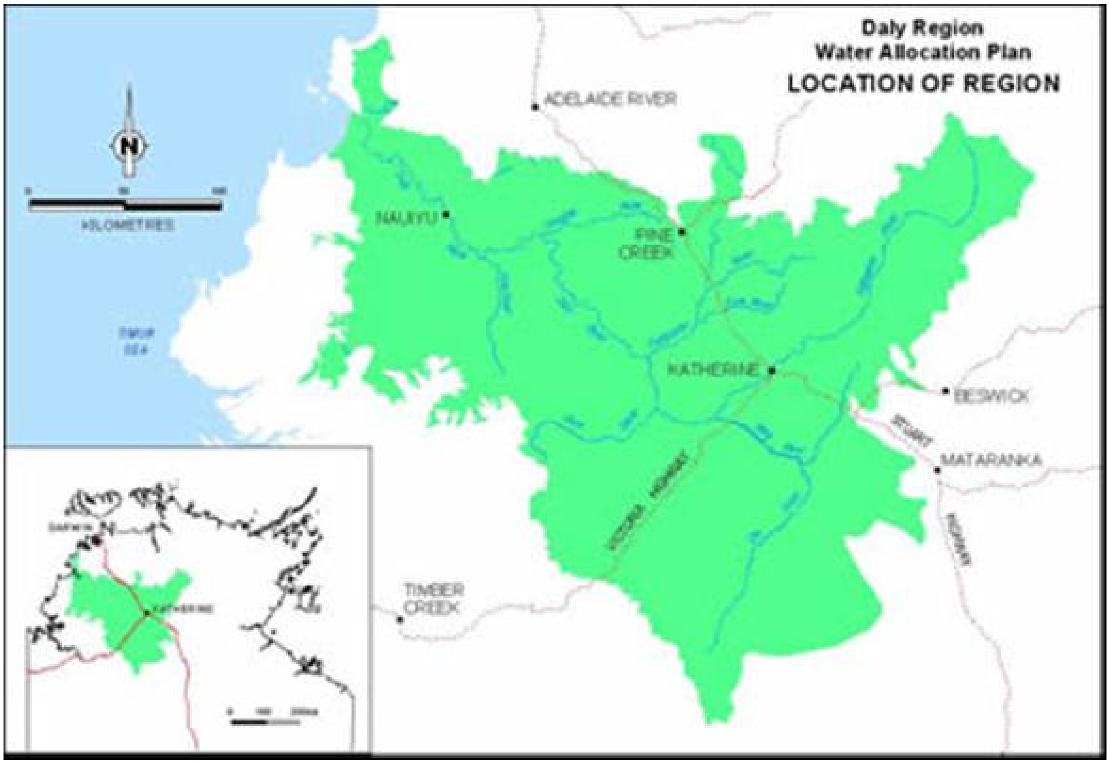
References

Northern Adelaide and Barossa Catchment Water Management Board (2000). *Water Allocation Plan Northern Adelaide Plains Prescribed Wells Area*. Prepared with the assistance of the Northern Adelaide Plains Catchment Committee, December 2000.

SKM / Hassell (2001). *Catchment Water Management Plan – VOLUME 1, Northern Adelaide and Barossa Catchment Area*. Northern Adelaide and Barossa Catchment Water Management Board.

Daly Region (NT)

Location: The location and extent of the Daly Region is shown on Figure 1.



Hydrogeological Typology: Limestone (karstic).

Hydrogeological Setting: This description of the hydrogeological setting concentrates on the karstic limestone unit within the Daly Region, the Oolloo Dolostone. The text is transcribed from Tickell (2002).

The Oolloo Dolostone, is the uppermost formation of the Daly Basin and hosts an extensive high transmissivity fractured and cavernous rock aquifer. The aquifer is overlain by up to 100m of Cretaceous clay and sand over a considerable proportion of its extent, which acts to reduce recharge except where the basal Cretaceous sand is thickly developed and outcropping. Recharge occurs in areas where the formation is exposed. The recharge mechanism in those areas is likely to be a combination of diffuse recharge and point recharge via sinkholes

Aquifer discharge occurs via springs in the Daly River. Spring locations are controlled by faulting, stratigraphy and topography. Late Dry season spring-flows to the river from the Oolloo aquifer range from 5 to 15cumecs, depending on the rainfall of the preceding series of years. The downstream portion of the Daly River relies on discharge from the aquifer for the bulk of its dry season flows for five or more months of the year.

Figure 1: Plan of Geology (from Tickell 2002)

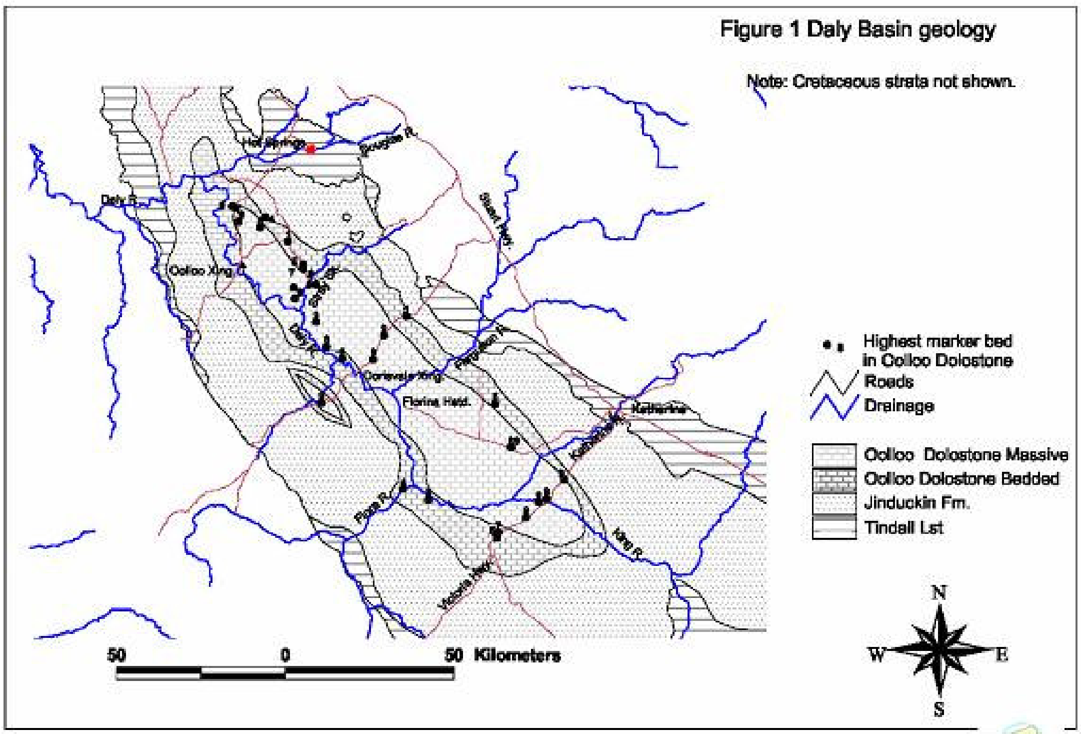
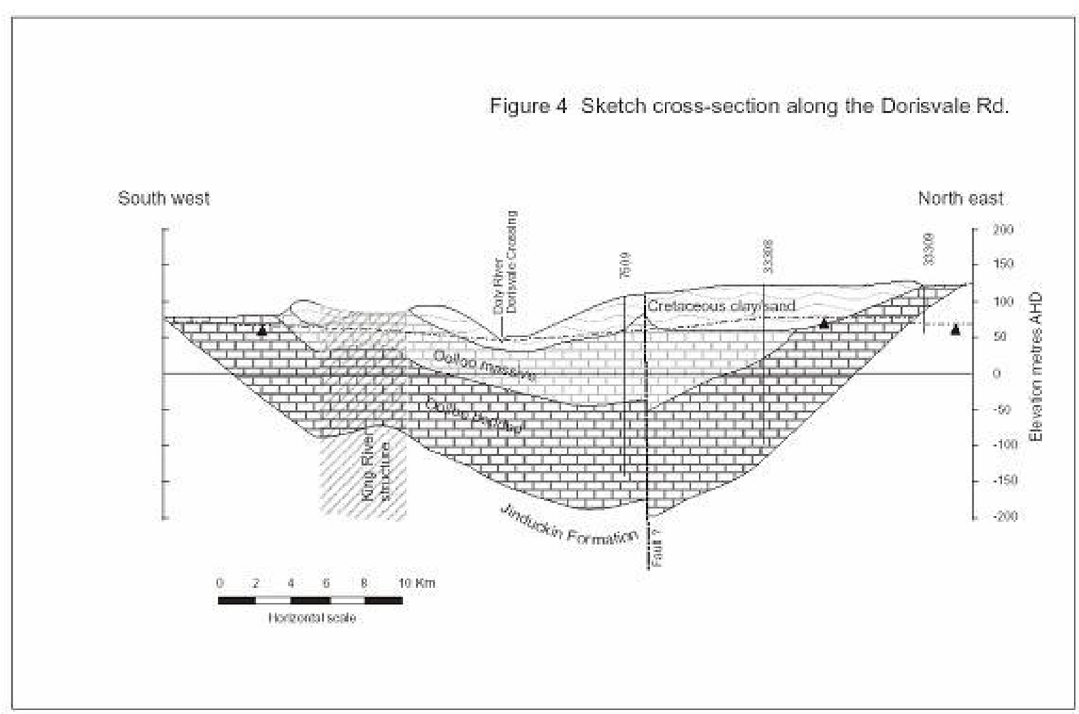


Figure 2: Typical Cross Section (from Tickell 2002)



Irrigation Development

At this stage there is only limited development of the groundwater resource for irrigation use on mangos and fodder crops.

Management Issues

It is recognised that groundwater in the Daly Region will need to be allocated to competing needs, and that the water resources will be shared within sustainable limits, which conserve environmental and cultural needs, while at the same time meeting consumptive uses. The Olloo Dolostone aquifer is important for the provision of dry season base flow to the Daly River.

Management Actions

The following information was sourced from a Water Allocation Plan discussion paper developed by the Department of Infrastructure, Planning and Environment.

A Water Allocation Plan is currently being developed for the Daly Region. The plan will summarise the current knowledge on rainfall, rivers, groundwater aquifers and how they interact through the use of water balance models. The plan will identify both non-consumptive (e.g. environmental and cultural uses) and consumptive (e.g. public water supply, rural stock and domestic, agriculture, industry and aquaculture) uses of water.

The Water Allocation Plan will aim to improve the sustainable use of water resources through:

- Improvements to licensing processes.
- Monitoring of large production bores and river pumps to improve our knowledge of water use and to refine the water balances.
- Monitoring and reporting systems will be improved in order to refine the water balance.
- Managing increased water demand and targeting problem areas or 'hot spots'.
- Environmentally and economically sustainable development and use of water.

References

DIPE (2004). *Discussion Paper – Daly Region Water Allocation Plan*. Department of Infrastructure, Planning and Environment, March 2004.

Tickell, S.J. (2002). *Groundwater Resources of the Oolloo Dolostone*. Department of Infrastructure, Planning and Environment, Natural Resources Division, Report 17/2002, December 2002.

Irrigation of dairy effluent on karst systems in northern Tasmania

NB map of karst near Mole Creek not provided but is available.

Isolated areas of concern exist where dairy effluent is irrigated over karst systems. In comparison to other groundwater environments, flow through karst systems is often rapid due to the presence of conduits such as caves. These can provide efficient pathways for the movement of water from one part of the karst to another, with little purification if the water is contaminated. If water entering the karst system is polluted, this may spread rapidly to a much wider area.

Information on karst aquifers can be found at:

http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/JMUY-63Z4UB?open

Issues associated with irrigation of dairy effluent on karst systems include:

- The impacts on groundwater of:
  - Increased nutrient concentrations
  - Increased pathogens
  - Decreased oxygen levels
  - Impacts on groundwater-dependent ecosystems
- Build up of nutrients (particularly potassium) in soil to toxic levels
- Poor areal distribution of available nutrients
- Application of irrigation to saturated soils (due to lack of winter/spring storage)

In Tasmania, the majority of our understanding of groundwater dependent ecosystems, being a relatively new area of research, is confined to those found in karst environments. Aquatic ecosystems in karst environments support a specialised fauna that is often distinct from that of surface waters. Species that live solely in these environments have curious morphologies including the degeneration or loss of eyes and body pigment, elongated antennae and legs, and enhanced sensory structures.

Information on groundwater dependent ecosystems can be found at:

http://www.dpiwe.tas.gov.au/inter.nsf/WebPages/RPIO-4YA8VK?open

Sink holes on a dairy farm overlying a karst system in Tasmania

A sink holes in a karst system in Tasmania

Irrigation of dairy effluent on drained swampland in northwest Tasmania

An effluent irrigator

Centre pivot irrigator used un intensive vegetable production in Tasmania

Appendix 7

Indicative Quotation on Hardcopy Book

CL Creations Pty Ltd
PO Box 1136 Lane Cove 1595
T: 2 9906 3633
F: 2 9437 0299
E: carolen@clcreations.com.au
ACN 003 610 366

25 February 2005
By email (pages 2)

Mr David Fuller
URS
25 North Terrace
Hackney SA 5069

Dear David,

Thank you for inviting CL Creations to provide a quote for the production of a book for the 'Sustainable Irrigation Study'.

The cost includes:

Specification	Requirement
Design and artwork of all edited text, tables, diagrams, charts 2 design concepts supplied	Design of all text and information for diagrams, etc supplied
Photo research	CL Creations will liaise with the organisations for appropriate images and captions (the price does not include the cost of purchasing images)
Printing	Pages 96 plus cover Print run: 1,000 copies **a)** Specifications as per *Water Innovation: A New Era for Australia* (printed Asia) **b)** Soft cover 350gsm art, A4 size, four colour process throughout (printed Australia)
Final sign-off and approval	PDFs will be emailed for review and changes One colour mock-up supplied for final changes and sign-off
Delivery	One address in Australia
TOTAL COST (incl GST)	**a)** $55,000 **b)** $50,000

CL CREATIONS

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F: 2 9437 0299
E: carolen@clcreations.com.au
ACN 003 610 366

Additional costs

Appointment of writer to research, contact appropriate stakeholders and write manuscript based on 15,000 words as well as technical editing of all text supplied. Depending on the amount of research required, will determine the final cost.	$25,000 (approx)
If only technical editing is required (the manuscript supplied)	$4,000
Design of additional pages over 96 pages allocated	$150 per page
Additional colour mock-up of 96 pages	$1,000
Any changes made to printer's proofs	Invoiced directly by printer
Photo library images and search fees (if required)	Invoiced by photo library
Courier fees	At market rate

Schedule
Please allow 4-5 weeks for design and final approval and 7- 9 weeks for printing overseas (printing in Australia about 3 weeks).

Thank you again David for this opportunity. If there is any further information you require, please do not hesitate to contact me. I look forward to speaking with you soon or meeting with you when I will be Adelaide sometime March or April.

Yours sincerely
Carolen Barripp
Publisher

Appendix 8

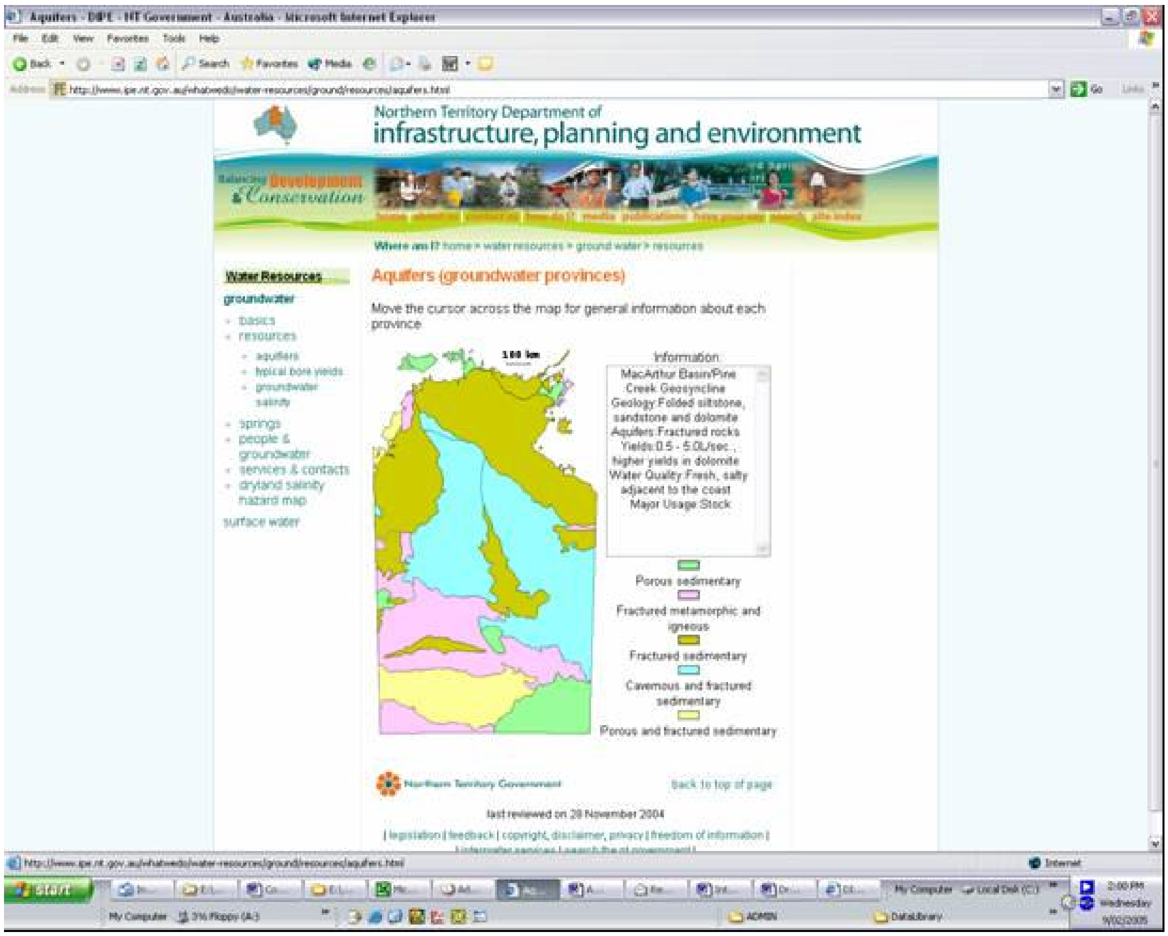
Some Examples of Agency Web Information

Appendix 8: Examples of Agency Web Information

NT Department of Infrastructure, Planning and Environment

Aquifer type map – note description window for area under hover

http://www.ipe.nt.gov.au/whatwedo/water-resources/ground/resources/aquifers.html

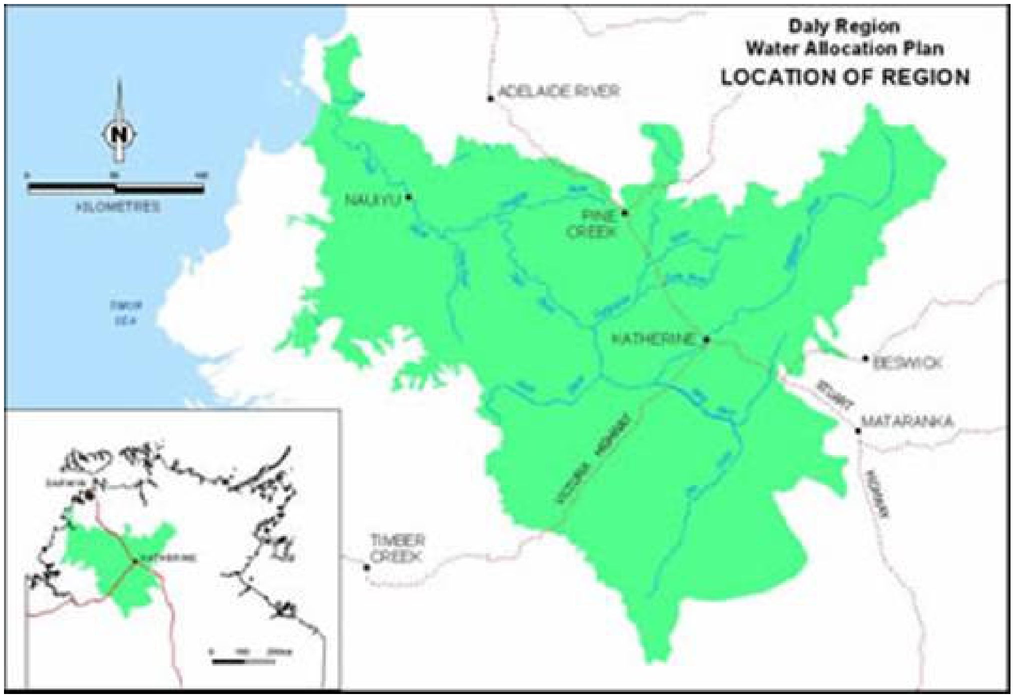


Daly Region WAP Discussion Paper

http://www.ipe.nt.gov.au/whatwedo/dalyregion/waterplan/index.html

SA Department for Water, Land and Biodiversity Conservation

A map of the groundwater resources of the state obtained from the DWLBC web site is shown on **Error! Reference source not found.**.



WA Department of Environment

Formerly the Waters and Rivers Commission, this Departments web site has many useful links to a variety of information levels. An example is included as **Error! Reference source not found.**, obtained from the following link:

http://www.wrc.wa.gov.au/public/waterfacts/8_groundwater/climatic.html#ground

Appendix 8: Examples of Agency Web Information

Groundwater Resources of South Australia

Groundwater Flow Systems information for Tasmania (draft in confidence)