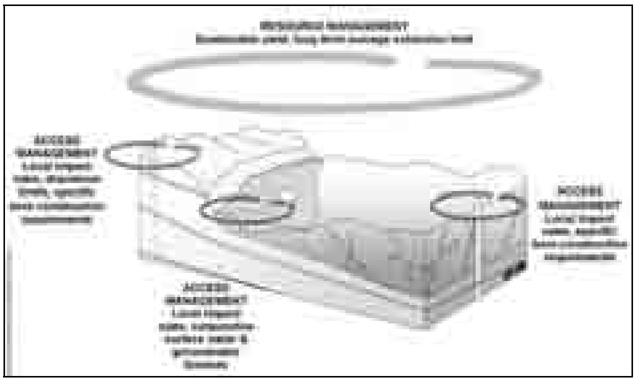
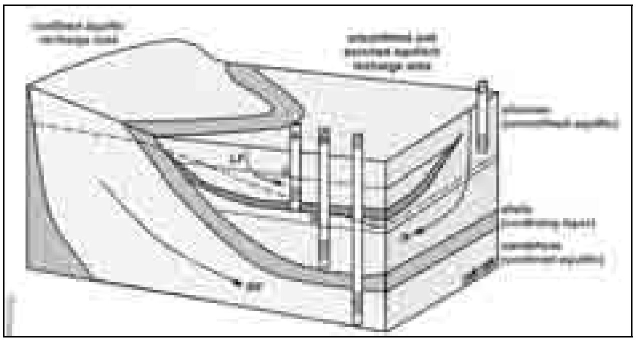
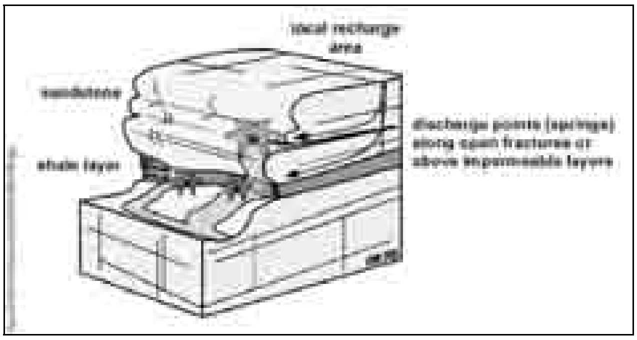
# Groundwater Education Workshop Series

## Workshop Materials

**March 2009**








This project has been assisted by the NSW Government through its Environmental Trust.

## Groundwater Education Workshop Series - Workshop Materials

These materials have been developed by the UNSW Water Research Laboratory in consultation with the project partners of the Groundwater Education Project Steering Committee.

This document contains:

1. Introductory workshop slides
2. Information on groundwater occurrence
3. Information on legislation and management
4. Case study scenarios for the following groundwater issues:
    I. Bore water supply & resource sustainability
    II. Groundwater contamination
    III. Climate change & coastal aquifers
    IV. Urban salinity in western Sydney
    V. Construction & dewatering
    VI. Recharging aquifers with stormwater & treated water
5. Groundwater management information fact sheets

This document is intended to complement the information contained in Sydney Coastal Councils Group Groundwater Management Handbook - A Guide for Local Government, First Edition.
www.sydneycoastalcouncils.com.au/documents/GroundwaterManagementHandbook.pdf



**Disclaimer**

While all care has been taken to report accurately, the Sydney Coastal Councils Group, the UNSW Water Research Laboratory and the Groundwater Education Project Steering do not accept responsibility for any information, whether correct or incorrect, supplied by others for this document, or for any loss or harm arising from the use or misuse of this document.

This project has been assisted by the NSW Government through its Environmental Trust.

More information about the Groundwater Education Project can be found at:
www.sydneycoastalcouncils.com.au/groundwater.htm

# Groundwater Workshops
# - Sydney area

**Wendy Timms, Doug Anderson**

Consulting, Research & Training Services to Industry & Government since 1959

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Thanks to Contributors and Reviewers:

Craig Morrison, Kate Black, Greg Russell, Michael Galloway, Sarah Deards
(SCCG Steering Committee)
Greg Russell (DWE) – groundwater graphics
Richard Green (DWE) – review of DWE parts
WRL client permissions for examples

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## Workshop Objectives

Aims:

- ➢ Increase our knowledge of groundwater systems
- ➢ General principles of groundwater science
- ➢ Build capacity of councils in groundwater management
- ➢ Clarify roles of council, DWE and DECC
- ➢ Practical demonstration of groundwater tank model
- ➢ Fact sheets & CD ROM

Remember:

Your input & local knowledge is needed

This workshop will not cover local details or resource status

*Disclaimer:*

*Workshop materials provide general recommendations only. Formal technical and legal advice should be sought as required for specific cases.*

*UNSW WRL Consulting Projects provides independent expert water services to meet client briefs.*

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## This workshop includes….

- Handouts for each session including scenarios & case examples
- 6 Fact Sheets
  - Water and time
  - Groundwater myths
  - DIY groundwater monitoring
  - Groundwater modelling matters
  - Climate change, sea-level rise and coastal aquifers
  - Urban salinity (WSUD Practice Note 12)
- CD-ROM with workshop materials + articles

**Watch for updated information on:**

**www.sydneycoastalcouncils.com.au**

**www.connectedwaters.unsw.edu.au**

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| Approx. Time | Topic | |
|---|---|---|
| 9:00 to 9:10 | Introductions | |
| 9:10 to 10:00 | Groundwater occurrence & resource sustainability | |
| 10:00 to10:45 | Legislation and management – updates | |
| 10:45 to 11:00 | Morning tea | |
| 11:00 to 11:45 | Bore water supply & sustainability | |
| 11:45 to 12:30 | Scenario – groundwater contamination | |
| 12:30 to 1:30 | Lunch | |
| 1:30 to 2:15 | Hands-on 'experiments' with groundwater tank model | |
| 2:15 to 3:00 | Scenario - construction & dewatering<br>or<br>Scenario - recharging aquifers with stormwater & treated water | |
| 3:00 to 3:15 | Afternoon Tea | |
| 3:15 to 4:00 | Scenario – climate change & coastal aquifers<br>or<br>Scenario – urban salinity in western Sydney | |
| 4:15 or 4:30 | Outcomes & the future | |

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# Role of Councils & State

What? Local groundwater conditions and possible adverse impacts of development
- WRL provides information on technical groundwater issues

How? The environmental management of groundwater is the responsibility of State agencies and/or Councils

Questions to Consider:
- When is a groundwater issue referred?
- When is a groundwater issue mainly council responsibility?
- What is the interaction between different sections of council on groundwater related issues? Who does what? What is overlooked?
- At what stage of approvals are groundwater issues dealt with?

Council responsibility begins with:
- Awareness of local groundwater conditions & possible adverse impacts
- Appreciation of State Policies & Legislation
- Familiarity with groundwater license requirements

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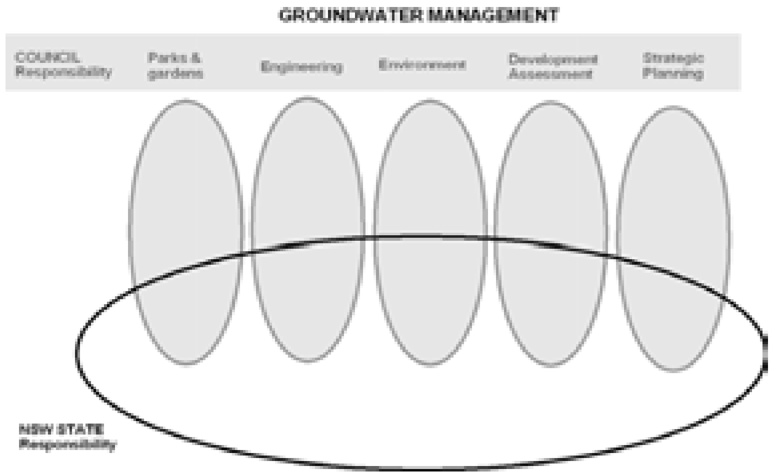
# Role of Councils & State

**An outcome of this workshop aims to clarify who is responsible for which aspects of groundwater management within Councils & State agencies**








# Glossary

**Groundwater terms - See glossary on p145 of SCCG Groundwater Handbook (2006)**

**State environmental planning policy (SEPP) -** is a policy proposed by the Minister and approved by the Governor, which addresses matters of state significance. State Policies relate to such issues as wetland management (SEPP 14) , and land remediation (SEPP 55), coastal protection (SEPP 71).

**Local Environmental Plan (LEP)** - a legal document that controls land use and development at the council level.

**Planning Certificate (149 Certificate)** - issued under section 149 of the Environmental Planning and Assessment Act) contains planning information about a parcel of land including its zoning and any plans or restrictions that apply.

**Development Control Plan (DCP)** - a detailed guideline that includes procedures and development requirements to be followed when preparing and lodging development proposals. It is prepared and adopted by the Council after being advertised for public comment but does not need the Minister's approval. A DCP adds to the controls in the LEP.

**Integrated Development** - those proposals that require development consent plus a particular permit or approval from a state agency. For example, a licence from the Department of Environment and Climate Change because the development is close to a water course.

**Complying Development** - and its development criteria are listed in the Complying Development Control Plan. Complying Development is small scale, low impact development that can be approved without a merit assessment.

**Exempt Development** – and its development criteria are listed in the Exempt Development Control Plan. Exempt development that meets the specified criteria does not require any approvals and includes things such as barbecues and small garden sheds.

**Designated Development -** development that is likely to have significant impact on the environment and, as such, is subject to special regulatory procedures. Examples of designated development include certain marinas, cement works, mines, extractive industries, turf farms and livestock intensive industries.

# Seeking advice?

**Department of Water & Energy**
waterinfo.nsw.gov.au

Water Licensing Unit - Sydney
ph. 02 9895 6263

**Department of Environment & Climate Change**

**Australian Centre for Environmental Law**
www.law.usyd.edu.au/accel

**Australian Drillers Association**
www.adia.com.au

**International Association of Hydrogeologists**
www.iah.org.au

**Australian Contaminated Land Consultants Association**
www.aclca.asn.au

**Centre for Groundwater Studies**
**- technical short courses**
www.groundwater.com.au

(*superseded in 2009 by Centre for Groundwater Research and Training*)

**UNSW Connected Waters Initiative**
**– training & research**
www.connectedwaters.unsw.edu.au

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# Where to find professional support services….

**International Association of Hydrogeologists (IAH – NSW Branch)**

www.iah.org www.iah.org.au

www.connectedwaters.unsw.edu.au/technical/iah/iah.html

**Check qualifications? Groundwater training typically only at Masters level**
**Check relevant experience? Several specialities within hydrogeology**

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## Importance of Groundwater

- 95% of global unfrozen fresh water is groundwater
- 21% of Australia's water use is groundwater
- 15% of groundwater is used in agriculture

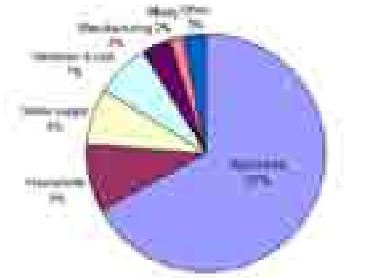

Figure 1: Water uses in Australia (ABS, 2005)

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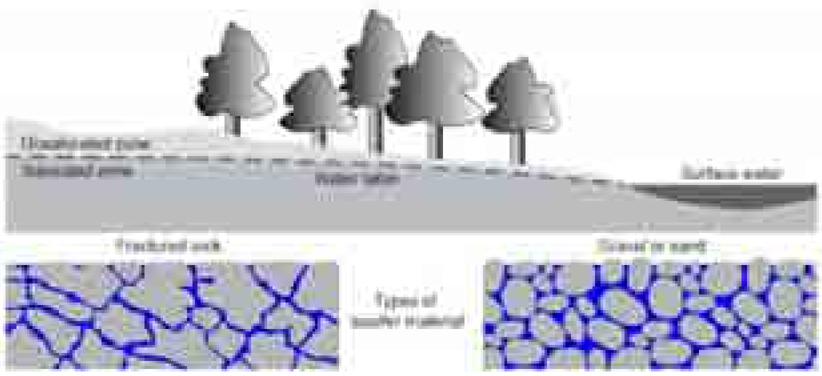
## How is groundwater stored ?

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## How is groundwater stored ?

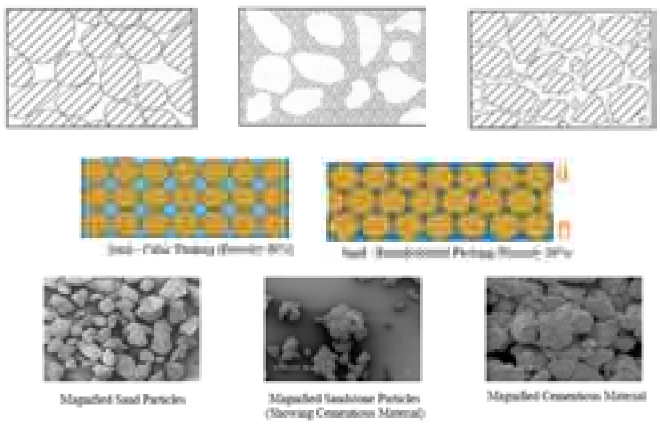



**Figure 4: Factors Contributing to the Porosity of Sedimentary Deposits (Courtesy of Ian Acworth)**



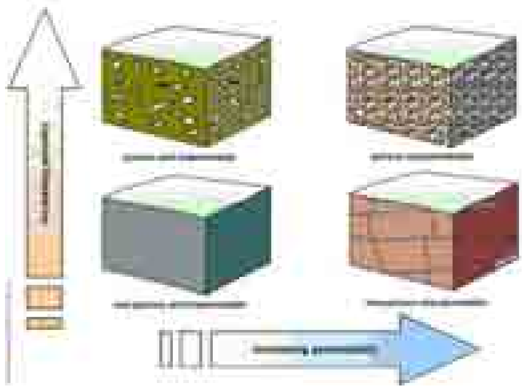


## How is groundwater stored ?

**Permeability and porosity determine how water is stored and moves.**

**Porosity – ratio of volume of void space to total volume of the geological formation**

**Permeability or hydraulic conductivity – degree of interconnected pores that allow water flow**



Source: SCCG Groundwater Handbook

## How is groundwater stored ?

**Table 1**
**Porosity Ranges for Different Materials**

| Classification | Material | Porosity (%) |
|---|---|---|
| Unconsolidated Sediments | Gravel | 25 - 40 |
| | Sand | 25 - 50 |
| | Silt | 35 - 50 |
| | Clay | 40 - 70 |
| Rocks | Fractured basalt | 5 - 50 |
| | Karst Limestone | 5 - 50 |
| | Sandstone | 5 - 30 |
| | Limestone, Dolomite | 0 - 20 |
| | Fractured crystalline rock | 0 - 10 |
| | Dense crystalline rock | 0 - 5 |

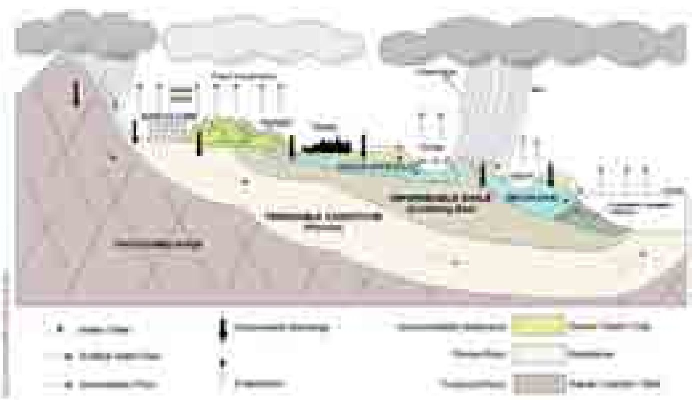




## The Water Cycle

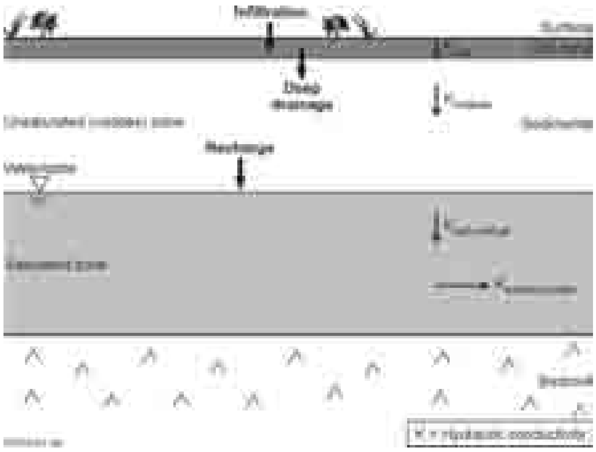
- **Groundwater is an integral part of the water cycle or hydrological cycle**
- **Groundwater moves very slowly – 150 m/year through the Botany sand aquifer, and < 1 m per year through sandstone.**

**See Fact Sheet "Water & time"**



Source: SCCG Groundwater Handbook

## Infiltration, deep drainage and recharge

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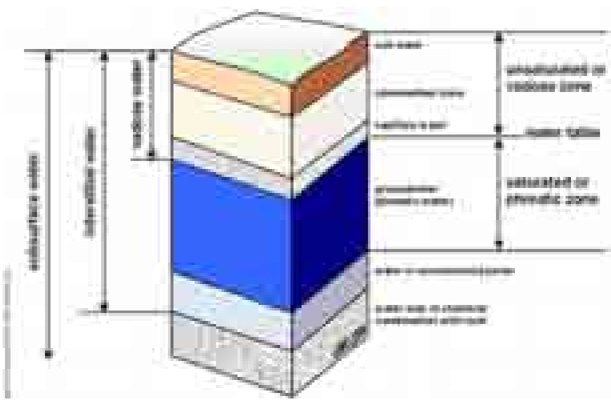
## Water in the Subsurface

- Vadose water
- Soil water
- Unsaturated zone
- Water table
- Capillary zone
- Saturated zone



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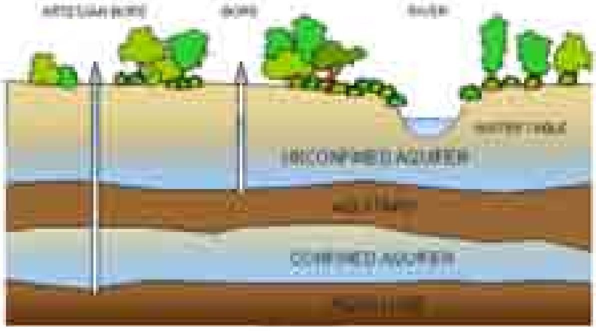
Source: SCCG Groundwater Handbook

## Groundwater terms

**Aquifer – saturated sediments or rock from which groundwater can be extacted**
**Aquitard – saturated sediment or rock of low permeability which water can flow slowly**
**Aquiclude – impermeable sediment or rock through which water cannot flow**

**Artesian – bore with a pressure surface above the ground allowing water to flow without pumping**

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## Types of Aquifers

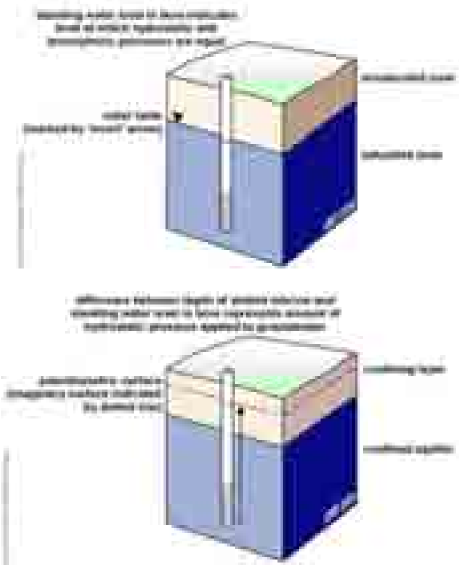
**Unconfined aquifer**

- **Watertable defines boundary between unsaturated and saturated zone at which pressure is atmospheric**

**Confined aquifer**

- **Groundwater rises in a bore above the top of the aquifer as a pressure or "potentiometric" level**

**Perched aquifers**



Source: SCCG Groundwater Handbook

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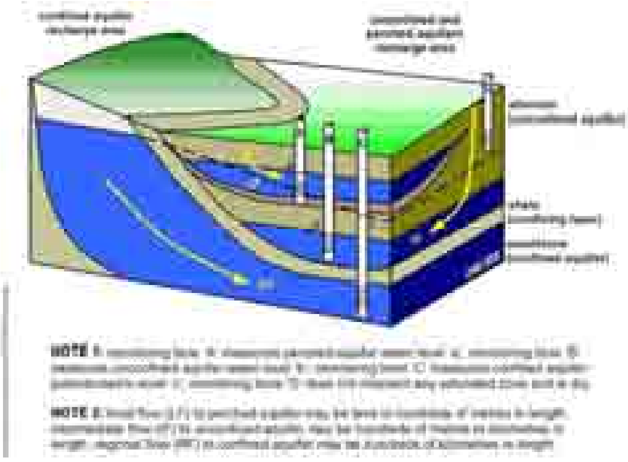
# Groundwater Flow

**The direction and rate of groundwater flow is determined by the hydraulic gradient applied, through differences in water level or pressure**

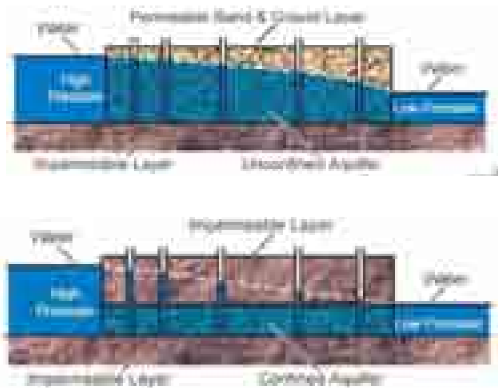


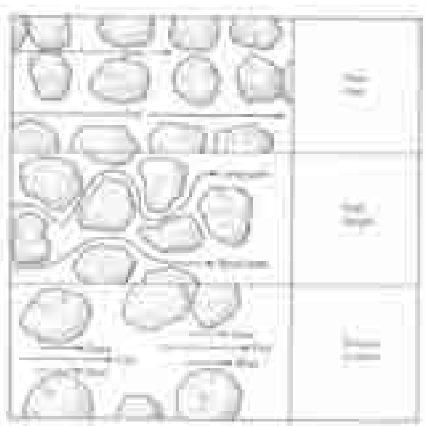


Source: SCCG Groundwater Handbook



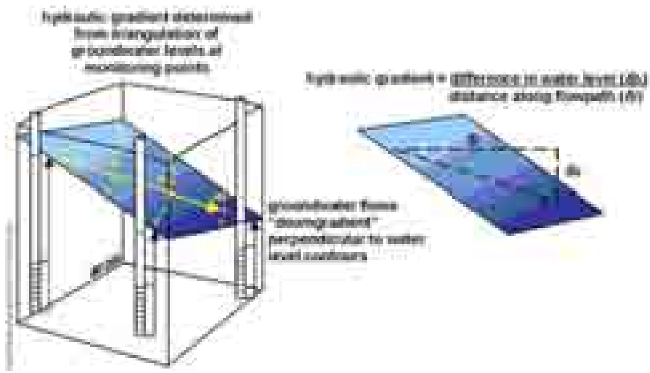
# How does groundwater flow?





# Hydraulic Gradient

**For small areas, the hydraulic gradient (dH/dL) is generally assumed to be a planar surface between monitoring points.**




Source: SCCG Groundwater Handbook



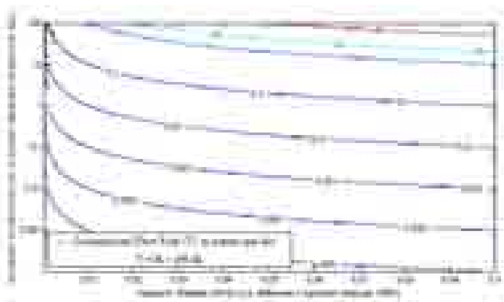
# How fast can groundwater flow ?

**Groundwater flow rate is estimated by multiplying the hydraulic gradient (dH/dL) by the permeability (K).**

**This graph shows flow rates from <0.0001 m/day to 5 m/day for typical hydraulic gradients and permeabilities**

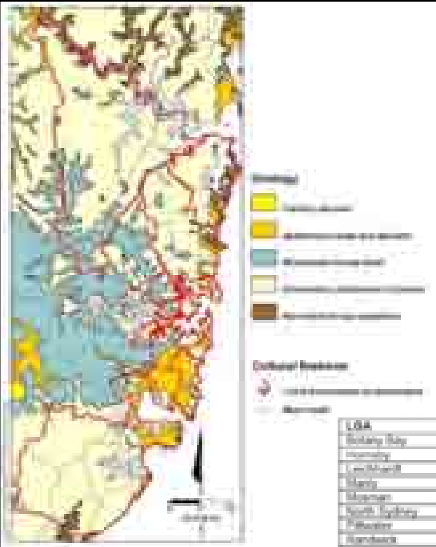
Groundwater Flow Rate (V) in metres per day

V = K × dH/dL



**Note that groundwater velocity differs from groundwater flow rate**

# Local Geological Units



| LGA | Major geological unit | Secondary geological unit | Minor geological unit |
|---|---|---|---|
| Botany Bay | Coastal sand beds | | |
| Hornsby | Hawkesbury Sandstone | | Wianamatta Group shale |
| Leichhardt | Hawkesbury Sandstone | | Wianamatta Group shale |
| Manly | Hawkesbury Sandstone | Coastal sand beds | |
| Mosman | Hawkesbury Sandstone | | |
| North Sydney | Hawkesbury Sandstone | | Wianamatta Group shale |
| Pittwater | Hawkesbury Sandstone | Coastal sand beds | |
| Randwick | Coastal sand beds | Hawkesbury Sandstone | |
| Rockdale | Coastal sand beds | Hawkesbury Sandstone | Wianamatta Group shale |
| Sutherland | Hawkesbury Sandstone | Coastal sand beds | |
| City of Sydney | Coastal sand beds | Hawkesbury Sandstone | Wianamatta Group shale |
| Warringah | Hawkesbury Sandstone | | Wianamatta Group shale |
| Waverley | Hawkesbury Sandstone | Coastal sand beds | |
| Willoughby | Hawkesbury Sandstone | | Wianamatta Group shale |
| Woollahra | Hawkesbury Sandstone | Coastal sand beds | |

Source: SCCG Groundwater Handbook





# Unconsolidated sediments

**Coastal sand beds (eg Botany sand aquifer)**

- **Contain significant groundwater resources because of porous and permeable sands.**
- **Readily recharge by direct rainfall infiltration**
- **Relatively shallow water table within a few metres of surface**
- **Vulnerable to contamination**
- **Significant groundwater dependent ecosystems (GDEs)**

Courtesy – Dynamic Graphics

**Alluvial aquifers**

- **Sediments deposited by rivers and creeks**
- **Of generally limited extent in SCCG area**
- **Clayey and silty materials with low yield**

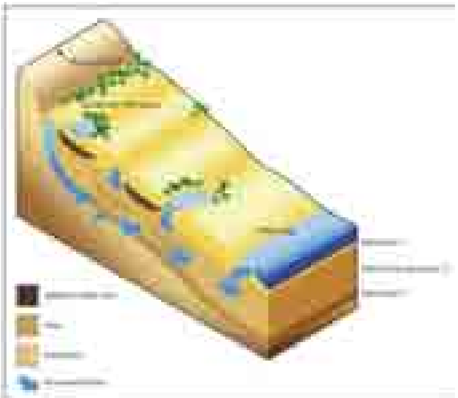
Source: SCCG Groundwater Handbook

## The Botany aquifer

- Hydraulic connection is one-way towards south & south-west
- Groundwater levels in north-east of aquifer are **~40 m above** levels at Botany Bay
- Water moves through sand aquifer at about **150 metres per year**
- ~**60 years** travel time over **~8 km** from Centennial Park recharge area to Botany Bay over
- excessive groundwater pumping can cause minor northwards flow

  Zones 1  major contaminated area

  Zones 2-4  point contamination



*(Source: Modified from Sydney Morning Herald, 26/8/2006)*

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## The Botany aquifer

The Botany Aquifer Management Strategy - initiated in 2005

Groundwater Status report for the Botany aquifer - 2000

August 2003 – Groundwater Embargo Area (Zone 1)

August 2006 - All domestic groundwater use banned in Zones 2, 3 and 4.

10 July 2007 – The Botany aquifer embargo was extended to encompass the entire Botany sand aquifer. Precludes new groundwater bores, except for private domestic purposes, urban water supply purposes, dewatering, monitoring, test and remediation bores and replacement bores.

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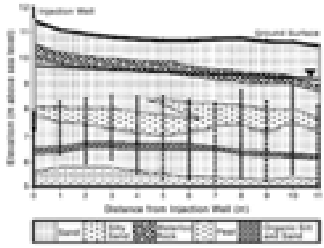
# Groundwater in the northeastern Botany aquifer

**Sandy aquifer**, partially confined by clay/peat in some areas

Watertable ~ 3-8 m depth
Aquifer thickness ~ 15-60 m
Hydraulic conductivity ~10-50 m/day
Recharge factor ~30% of rainfall
Driving head of about 40 m over 8 km

**Groundwater flow rates near Allison road**
~ 3 ML/day natural
~ 5 ML/day ? enhanced



**Groundwater storage in 1 km$^2$ is worth $10 million !**
9000 million L/ km$^2$ @$1.10/KL

But….not all groundwater storage is accessible

Jankowski & Beck 2000

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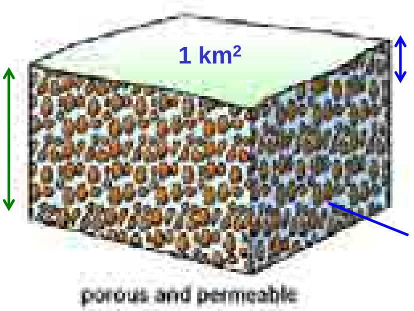
# What is the value of Botany aquifer groundwater ?




**Dynamic volume = 1500 ML per km$^2$** **~$2 million per km$^2$ @ $1.25 /KL**

**+ Environmental Values for Groundwater Dependent Ecosystems**
**+ Social Values such as amenity of Centennial Park**

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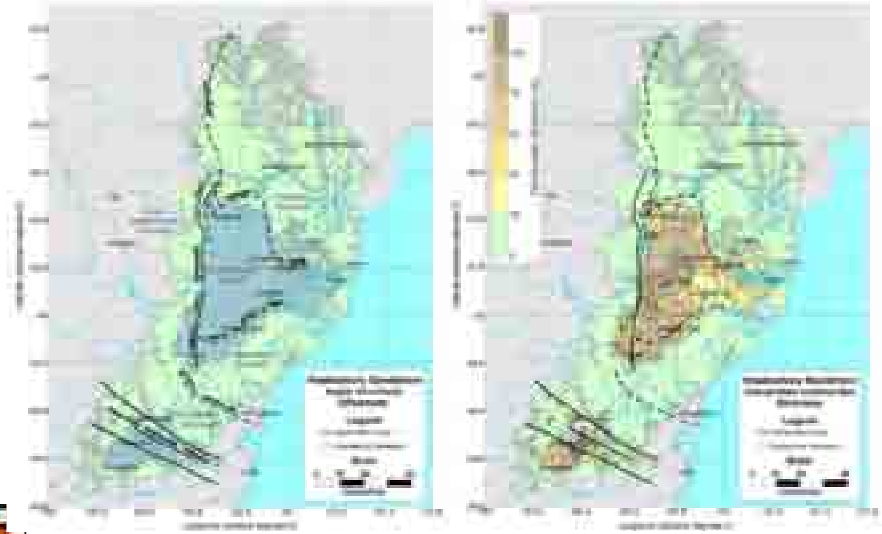
# Hawkesbury Sandstone – Geological Influences



Source: G Russell (2007) Dept. Water & Energy

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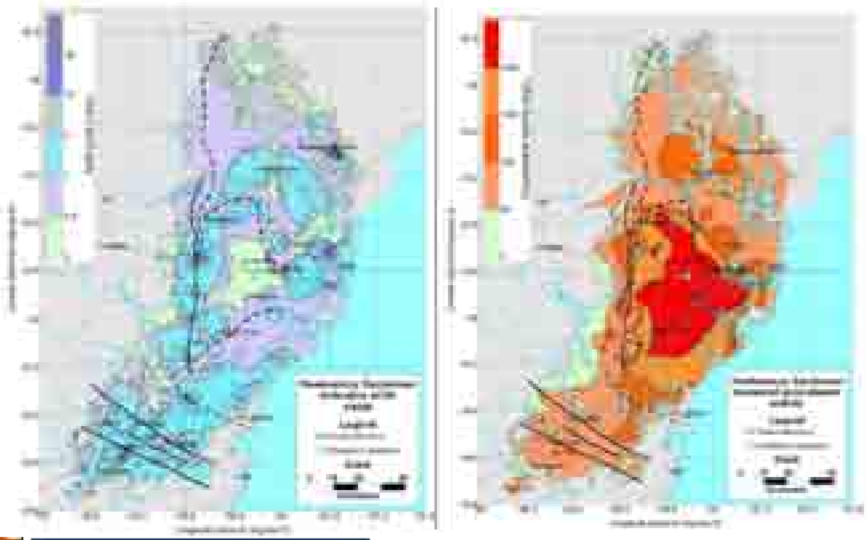
# Hawkesbury Sandstone - Groundwater Attributes



Source: G Russell (2007) Dept. Water & Energy

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# Drought groundwater supplies - SCA

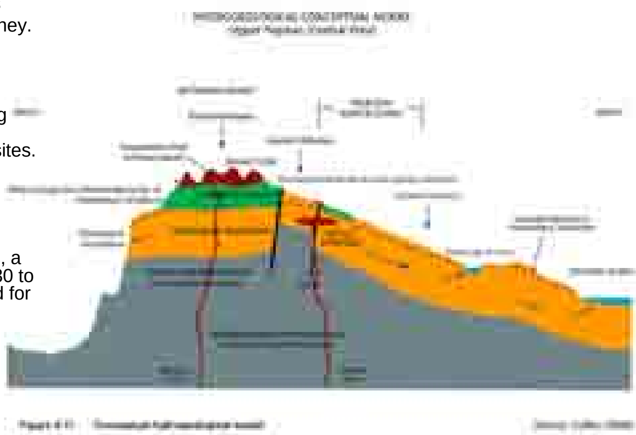
**Proposed bore fields**
Kangaloon in the Southern Highlands
Leonay and Wallacia in Western Sydney.

**How deep is the groundwater?**

Hawkesbury Sandstone water bearing zones range in depth from 90 to 300 metres, across the various borefield sites.

**How much groundwater could be pumped from all borefield sites?**

It is estimated that from all three sites, a total of around 30 to 45 billion litres (30 to 45 gigalitres) a year could be pumped for two to three years during a drought pumping cycle.



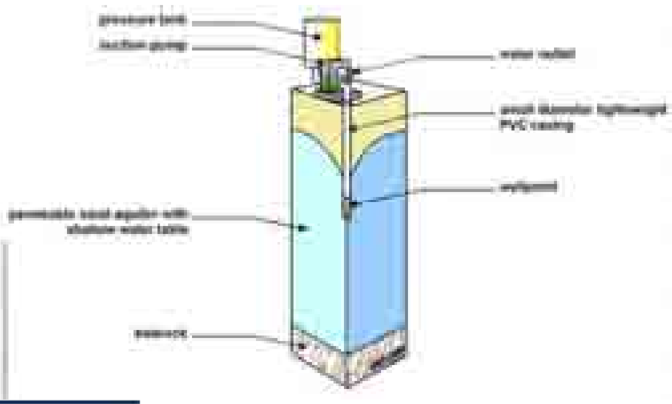
Source: Sydney Catchment authority, http://www.sca.nsw.gov.au/dams-and-water/metropolitan-water-plan/groundwater-investigations-community-consultation/frequently-asked-questions-groundwater





# Spearpoints

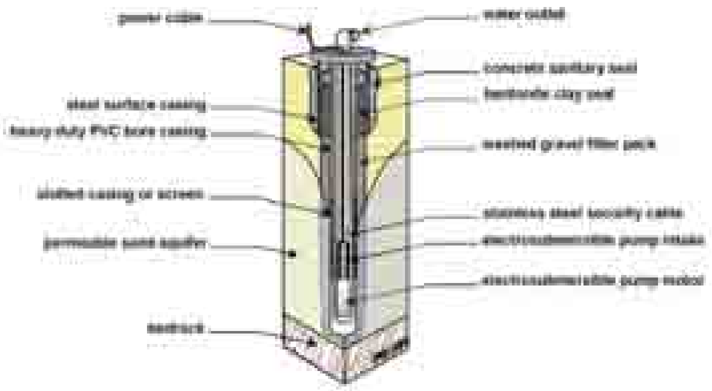
- Shallow, < 6 m depth
- Suitable for soft sediments
- Pushed or jetted into the ground
- Low yields 0.3 to 0.5 L/second



Source: SCCG Groundwater Management Handbook

# Bores

- Shallow to deep installations
- Soft sediments or hard rock
- Yield 0.5 to 40 L/second
- Heavy duty PVC casing and stainless steel screens






Source: SCCG Groundwater Management Handbook

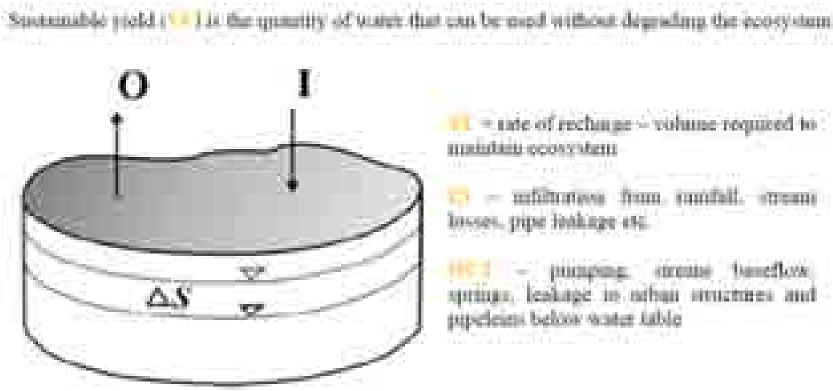


# GROUNDWATER RESOURCE SUSTAINABILITY



Source: Kalf & Woolley 2005

# Groundwater balance






Source: Kalf & Woolley 2005



# Sustainable yield

- Sustainable yield of an aquifer is different from yield of a bore !
- The **sustainable yield** of an aquifer is defined as:

  "*The groundwater extraction regime, measured over a specific planning timeframe, that allows acceptable levels of stress and protects dependent economic, social and environmental values.*"

- The *NSW State Groundwater Dependent Ecosystems Policy* (NSW Government 2002) defined a default value for sustainable yield of 70% of the **average long-term annual recharge** to a groundwater system (the remaining 30% being an environmental water provision).

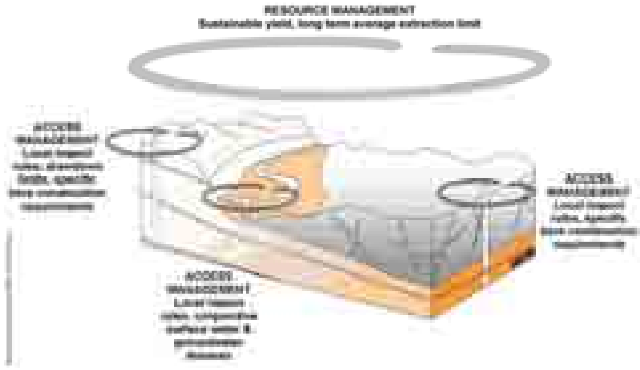
- In order to define the sustainable yield for an aquifer (or Groundwater Management Area, GWMA), there is a need to determine the average annual recharge to the system.



Source: SCCG Groundwater Management Handbook

## Access and resource management

- **Resource management –** determination of sustainable yield and it's application to the total groundwater development allowed for an aquifer
- **Access management** – applies at a local scale and involves the protection of dependent ecosystems, prevention of pumping interference and preservation of groundwater quality

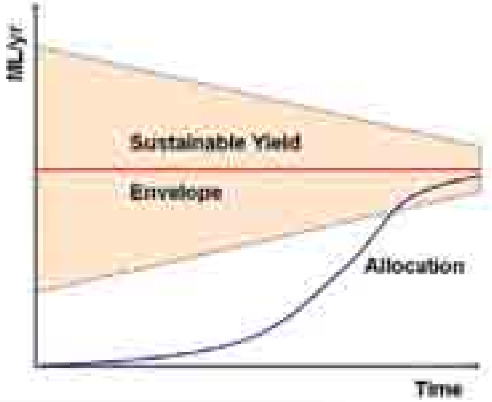



Source: SCCG Groundwater Management Handbook



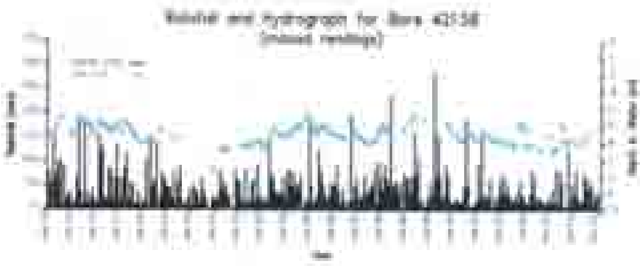
## The Future – overall aims

- Continued delivery of groundwater resources in 10 yrs & 100 yrs – sustainability
- Equitable access for groundwater users including rivers & environment
- Improved science to reduce uncertainty




Brodie, 2004

# Groundwater levels

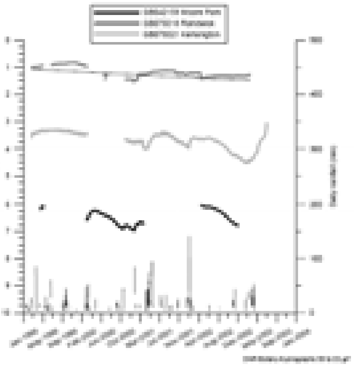


**A basic measure of sustainability !**

**Groundwater levels - balance between recharge and discharge (or usage)**

- Dynamic equilibrium in N.E. Botany aquifer
- Stable levels indicate sustainable usage

- Cost effective to monitor with automated loggers



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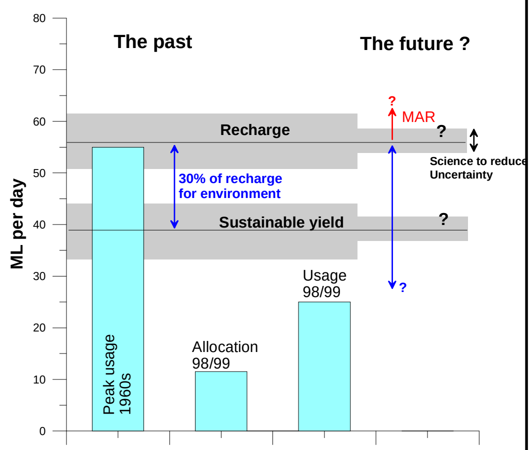
# Sustainable groundwater yield – Botany aquifer

Default NSW policy that 30% of recharge is reserved for environmental flows, currently under review for Botany aquifer

July 2007 – New embargo precluding new groundwater bores across entire Botany aquifer (with exceptions…)

**MAR can boost sustainable yield**

**Needs further scientific assessment**
- updated hydrographs & status report
- improved groundwater flow models
- environmental flow requirements
- independent recharge studies (physical & chemical isotope methods)




**Botany aquifer status (DNR, 2000)**
GWMA018 north of Botany Bay

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## Uncertainty in sustainable yield estimates

- **Groundwater science is inexact – natural subsurface variability**
- **Sustainable yield uncertainty depends on data availability – can be improved**
- **"In the ball park" estimates be used for prudent resource management**

| **Estimated accuracy*** | **Groundwater quantity assessment** |
|---|---|
| ±10% | Based on reliable data and investigations that have required little or no extrapolation or interpolation |
| ±10% to 25% | Based on approximate analysis and limited investigations. Some measured data and some interpolation/extrapolation to derive the dataset |
| ±25% to 50% | Little measured data, based on reconnaissance information. |
| >±50% | Derived without investigation data. Figures estimated from data in nearby catchments, or extrapolated/interpolated from any available data |

**NLWRA, 2001**

**See *Irrigation Australia* article by Timms – on CD ROM**

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## Groundwater is not always the best option

**There are many options for water supply:**
- Dams & river transfers
- Rainwater harvesting
- Stormwater harvesting
- Recycling
- Desalination
- Groundwater

**Water quality needs to be fit-for-purpose**

**Water from any source should be used wisely**

**The most appropriate water source for a specific site and/or application depends on many factors:**
- Cost ($/kL), energy use (kWhrs/kL), proximity, water quality that is fit-for-purpose, sustainability, life-cycle costs, environmental impacts, matching peak supply & demand, storage requirements etc.

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# Properties of water

Water Properties
- Heavy, 1 tonne=1 kl
- High heat capacity
  - $c_p$=1.2kWhr/*kl*/°C
  - $\Delta H_v$=630kWhr/*kl*
- Viscous/turbulent
  - $\mu=10^{-3}$Pa.s

Energy implications
- Gravity flow where possible!
- Moving 100km
  0.3 kWhr/kl ($0.06/kl)
- Lifting water 1000m
  2.8 kWhr/kl ($0.56/kl)
- Evaporating water
  730 kWhr/kl (80) ($146.00/kl)
- Heating 15→50°C
  41 kWhr/kl ($8.20/kl)

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# Energy costs for water supply

- Need to consider full LCA (life-cycle assessment) including costs of investigation, capital, operating expenses and design life.

| **Location** | **Water supply** | **kWh per kilolitre** |
|---|---|---|
| Sydney | Deep groundwater<br>(fractured sandstone, 60 m head, 25 ML/day) | ~0.4 |
| | Shallow groundwater (sand aquifer) | <0.1 |
| | Desalination | 4.9* |
| | Shoalhaven transfers | 1.9 |
| | Recycling purified wastewater | 1.0 |
| | Deep storage in Warragamba dam | <0.14 |
| | Stormwater harvesting | ? |
| Orange County, US | Desalination | 3.5 – 4.0 |
| | Colorado River transfers | 1.8 |
| | Managed aquifer recharge system | 1.2 |

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* For ~125 ML/day plant    Sources: Sydney water website, Greg Leslie UNSW (2005), WRL data

# Costs and fit-for-purpose for water supply options

Some Sydney examples….

| Water supply | Total cost ($ per kilolitre) | Fit-for-purpose (typical quality)* | Issues |
|---|---|---|---|
| Deep groundwater (fractured sandstone) | $2-10 | Drinking water | Power supply in remote areas, iron-biofouling of bores, very slow recharge rates, low yields except in major fractured areas |
| Shallow groundwater (sand aquifer) | <$1 | Irrigation | Vulnerable to contamination, low yield from spear-points, lower watertables during drought, iron-biofouling of bores. |
| Stormwater harvesting | ~$10 ($0.5 - $40)* | Irrigation | High nutrients, pathogens and metal concentrations, storage required |
| Desalination | | Drinking water | Energy, brine |
| Shoalhaven transfers | | Drinking water | Energy, environment |

Sources: Sydney water website, WRL data, *DEC (2006)

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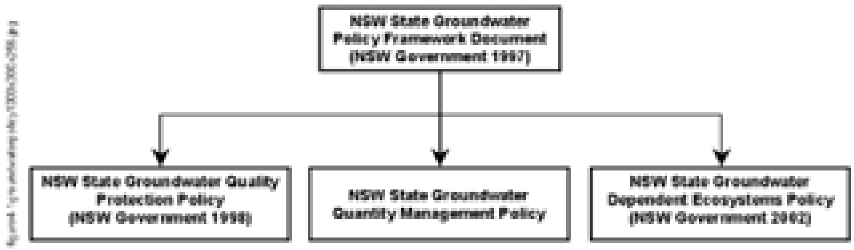
# Groundwater legislation & management

**Planning approval and management of developments should aim to minimise adverse impacts on groundwater resources and dependent ecosystems by:**

- **Maintaining, where possible, natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems.**
- **Not polluting or causing adverse changes in groundwater quality.**
- **Rehabilitating groundwater systems where practical.**

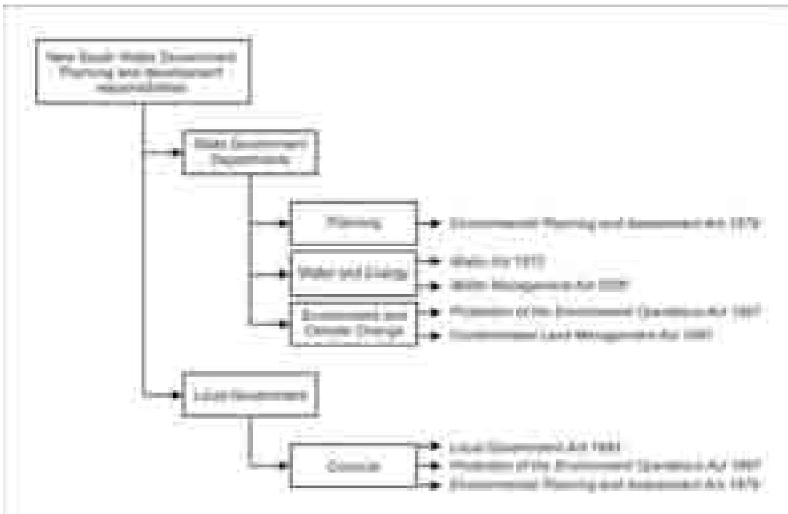



Source: SCCG Groundwater Handbook



Groundwater Workshop

# Groundwater legislation & management



Source: Revised after SCCG Groundwater Handbook

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# Regulation and management of groundwater in NSW

Policies for the protection, sustainable management, enhancement and preservation of groundwater resources

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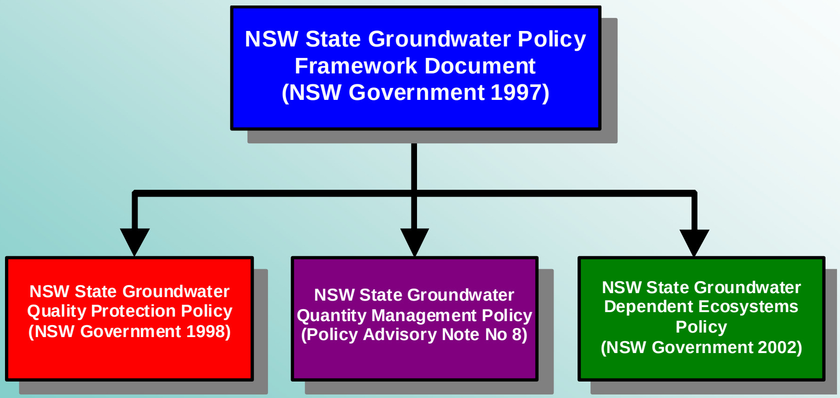
# Policy components




NSW Government
Department of Water & Energy

# Framework Document

- Establishes the framework for the ecologically sustainable management of the State's groundwater resources
- Places stewardship obligations on all users
- Encourages the replacement of unsustainable activity with sustainable options
- Highlights the need to protect valuable resources and restore degraded areas
- Promotes adaptive management that is integrated, as far as possible, with other resource management policies, controls or instruments.

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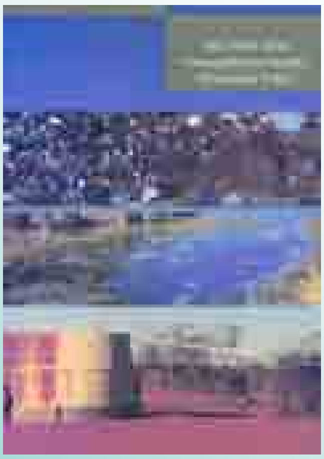
Department of Water & Energy

# Groundwater Quality Protection Policy

- Specifies management principles designed to protect the quality attributes of groundwater resources
- Identifies potential hazards to groundwater quality and the need to maintain beneficial uses
- Emphasises the requirement to specifically protect Town Water Supplies from contamination
- Encourages the prevention of pollution
- Imparts responsibility for using groundwater suitable for the end purpose on licensees
- Highlights the need for consideration of cumulative impacts
- Promotes the protection of groundwater dependent ecosystems and restoration of degraded areas



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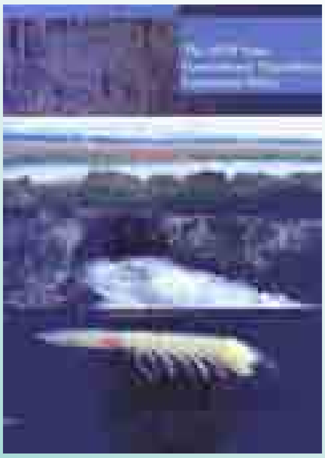
Department of Water & Energy

# Groundwater Dependent Ecosystems Policy

- Defines groundwater dependent ecosystems (GDEs).
- Specifies management principles designed to protect GDEs.
- Identifies areas of research required to achieve appropriate levels of protection.
- Outlines a required ongoing process to identify and value GDEs
- Highlights the need to implement measures to prevent degradation of existing groundwater attributes where GDEs are exposed to threatening processes
- Emphasises the requirement to scrutinise development proposals to identify potential GDE impacts and ensure mitigation measures are built in to the project



NSW Government Department of Water & Energy

# Groundwater Quantity Management Policy

- Describes types of aquifer settings and defines 'sustainable yield'.
- Specifies management principles designed to equitably share groundwater resources between users, as well as the environment.
- Promotes protection of GDEs
- Requires local impacts to be minimised or avoided
- Establishes basic right for stock and domestic use and a priority of access to a groundwater source
- Identifies the granting of entitlement according to demonstrated current need
- Considers business flexibility through allowing transfers of entitlement
- Establishes a requirement to manage aquifer interference activities

NSW Government Department of Water & Energy

## Application of policy

- All project proposals are assessed against NSW State Groundwater Policy objectives and principles.
- Impacts of proposed activities considered with regard to the quantity and quality of the groundwater resource (in particular with respect to other users and the type of activity proposed) and dependent ecosystems in the vicinity.

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Department of Water & Energy

## Conclusion

*It is essential that all levels of Government, when planning for future growth, ensure that valuable groundwater resources are protected and preserved, so that their beneficial uses, particularly for village and town water supplies, are maintained for future generations*

NSW Government
Department of Water & Energy

# Regulation and management of groundwater in NSW

Licensing of extraction to maintain sustainable stewardship of groundwater resources

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# Rights to access groundwater are often misunderstood

**Article from the Daily Telegraph 18 October 2006: ‘Toffs boring for liquid gold: MP’**

‘*Liberal Pat Farmer, the Government’s Western Sydney Spokesman said artesian water should be pooled for the use of all Sydney residents.* **(Landholders have basic right to access groundwater)**

*“My argument is that water’s like oxygen in the air: it doesn’t belong to anyone in particular, so why should that water be used for a rich few instead of the betterment of many?” he said.* **(Ownership of water legally vested in the State)**

*Mr Farmer called for a permit system to monitor the use of bore water, perhaps similar to mining licences*’. **(Licensing system established in 1912 and expanded in 1955)**


Daily Telegraph

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Department of Water & Energy

## Council issues

- Contaminated sites (e.g. petrol stations, industrial areas, landfills)
- Dewatering for construction (e.g. basement car parks)
- Groundwater for water supply (e.g. cooling tower supply, green space watering)
- Waterlogging (e.g. inundation of low lying areas due to urban development)
- Aquifer recharge (e.g. stormwater infiltration basins)

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## Ownership of water resources

- Water owned by the Crown
- Rights to control, manage and use groundwater vested in the Minister responsible for water resources
- Access to groundwater allowed through legislated framework of authorisations (licences and approvals)

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# Legislative authorisation for access to a groundwater source

- Water Act 1912 (non-Water Sharing Plan Areas)
  - Part 5 – Artesian wells
- Water Management Act 2000 (Water Sharing Plan areas)
  - Chapter 3 Part 1 – Basic landholder rights
  - Chapter 3 Part 2 – Access licences
  - Chapter 3 Part 3 – Approvals

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# *Water Act 1912* long title

- *“an Act to consolidate the Acts relating to water rights, water and drainage, drainage promotion, and artesian wells”*

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## Definition of ‘bore’

- “Any bore or well or any excavation or other work connected or proposed to be connected with sources of sub-surface water and used or proposed to be used or capable of being used to obtain supplies of such water whether the water flows naturally at all times or has to be raised either wholly or at times by pumping or other artificial means” (s105 *Water Act 1912*).


## *Water Management Act 2000* long title

- “*an Act to provide for the protection, conservation and ecologically sustainable development of the water sources of the State, and for other purposes*”

## Definition of 'water bore'

- "water bore means a bore that is used: (a) for the purpose of finding an aquifer, or (b) for the purpose of testing the production capacity or water quality of an aquifer, or (c) for the purpose of taking water from, or discharging anything into, an aquifer, or (d) for any other purpose prescribed by the regulations, being a bore that has been artificially created, widened, lengthened or modified by means of drilling, boring, augering, digging or jetting" (*Water Management Act 2000*).

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Department of Water & Energy

## Drillers required to be licensed

- Water bore drilling contractors must hold a current drillers licence of the appropriate class
- Drillers licences issued by the NSW Department of Water and Energy

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Department of Water & Energy

# Bores required to be licensed

- Any bore, well, excavation, shaft, trench, collector system, spearpoint or artesian bore, including test bores for investigation purposes, monitoring wells and construction dewatering systems

- Trigger for licensing is the intersection of the water table ("connection with source of sub-surface water")

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Department of Water & Energy

# Bore licence conditions

- Conditions applied to <u>all</u> bore licences

- Standard conditions relating to property location, bore decommissioning, etc.

- Special (non-standard) conditions may apply in certain areas to protect the environment (e.g. dewatering licences are valid only for a specified period)

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Department of Water & Energy

# Summary

- Greater Sydney area still subject to *Water Act 1912* provisions regarding licensing
- Landholder must hold Bore Licence prior to any drilling
- Driller must hold current NSW Driller's Licence
- Conditions applied to Bore Licence must be complied with

*The NSW Department of Water and Energy's aim is to achieve the ecologically sustainable management of the State's groundwater resources. This aim is embodied in the provisions of the Water Management Act 2000 and the Water Act 1912, which are the primary mechanisms for managing groundwater in NSW.*

# Licensing contacts

Water Licensing Unit - Sydney area

**t** 02 9895 6263

**f** 02 9895 7255

**a** Level 11, 10 Valentine Avenue
Parramatta NSW 2150

**p** PO Box 3720 Parramatta NSW 2124

# Case Study Scenarios for Groundwater Issues

# Scenario 1 – Bore water supply

*A development application for an irrigation extraction bore has been opposed by community groups who are concerned over sustainability of a nearby wetland. The feasibility of using bore water instead of drinking water to irrigate the local park is questioned.*

- Information from the SCCG *Groundwater Management Handbook*
- Additional information
  - New Fact Sheet "DIY Groundwater Monitoring"
  - Best Practice for Bores & Pump Testing
  - Optimising bore water supplies (WRL Solutions Sheet)
- Case example
  - Feasibility of groundwater supplies in council area, SCA GDE studies
- Questions to consider





# Information from the SCCG *Groundwater Management Handbook*

Ch4 Legislation, Policy and Other Instruments

Ch2 Accessing Groundwater
- p24-25 Types of installations
- p28 FAQ
- p32 Bore water quality

Ch6 Groundwater Management
- p83 sustainable yields & local impacts

Ch8 GDEs
- p111-113 Types of GDEs?

## Groundwater is not always the best option

**There are many options for water supply:**
- Dams & river transfers
- Rainwater harvesting
- Stormwater harvesting
- Recycling
- Desalination
- Groundwater

**Water quality needs to be fit-for-purpose**

**Water from any source should be used wisely**

**The most appropriate water source for a specific site and/or application depends on many factors:**
- Cost ($/kL), energy use (kWhrs/kL), proximity, fit-for-purpose, sustainability, life-cycle costs, environmental impacts, matching peak supply & demand, storage requirements etc.

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## How much water is needed?

Groundwater is not recommended in Sydney for drinking water or watering vegetable gardens etc. Groundwater is generally fit-for-purpose for irrigation.

Rule of thumb for irrigation requirements of Sydney parks:

0.4 kL/m²/year (0.033 kL/m²/month)

| | |
|---|---|
| **For a playing field area** | **17,000 m²** |
| **Estimated demand** | **6732 kL/year less rainfall inputs** |

| Sporting facility | kL/m²/year |
|---|---|
| Golf green | 0.60 |
| Bowling green | 0.22 |
| Sporting field, eastern-central Sydney | 0.22 |
| Sporting field, western Sydney | 0.13 |
| Golf course – greens and trees combined | 0.5 |
| Golf course fairways, western Sydney | 0.12 |

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Source: Sydney Water 2008

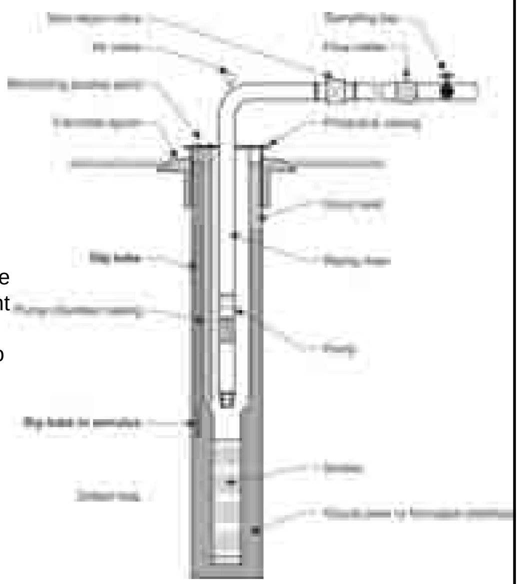
# Best practice – water bores

**ADIA 2003 Minimum construction requirements for water bores in Australia**

www.nrw.qld.gov.au/water/management/bores/aust_standards.html

1. Sealing & grouting (pressure cementing) during bore construction to prevent leakage of saline water – very important through shales in Sydney!
2. Protective bore monuments to prevent seepage down bores
3. Water usage meters
4. Sampling tap
5. Dip tube within casing to enable water level monitoring

Decommissioning old bores – sealing with grout to prevent mixing of saline water

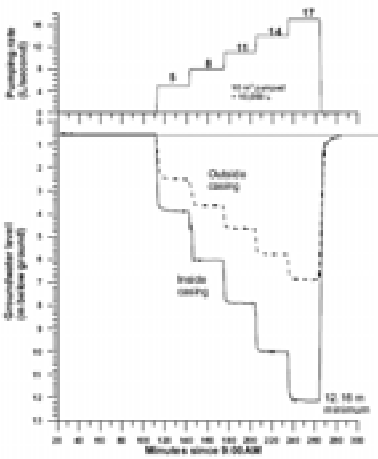


Source: Fact Sheet – DIY Groundwater Monitoring



## Australian Standard 2368-1990
## Test pumping of water wells

- **Air lift testing** – rough yield estimates over several minutes typically carried out by the driller during development (or cleaning) of new bores
- **Step testing** – controlled flow rate testing of a bore over several hours, with increasing steps or flow rates with water level monitoring to identify the optimal pumping rate of a bore under different pumping regimes. Recommended for all new water supply bores, except small spearpoints.
- **Constant rate testing** – pumping of a bore at the optimal rate typically over at least 24 hours to confirm the most suitable pump and optimal intake depth (Australian Standard AS 2368-1990). Recommended for all new water supply bores, except small spearpoints.
- **Aquifer system testing** – pumping of a test bore with detailed monitoring in nearby bores to determine the hydraulic properties of the groundwater system. The test bore and monitoring bores are specifically designed to enable calculation of aquifer transmissivity, storativity and the presence, type and distance of any hydraulic boundaries.



# Bore & pump efficiency considerations

- Energy costs over 25 year design life can be 70% of total bore costs
- 40% of bores suffer from efficiency problems
- Need to monitor yield performance
- Bore/pump cleanout required when specific capacity of pumping falls by 10%

**TECHNICAL**
- Maximum groundwater yield
- Required groundwater yield
- Required pumping period

**PRACTICAL**
- Accessibility
- Proximity to power supplies
- Corrosive nature of water
- Maintenance period

**FINANCIAL**
- Capital cost of pumps
- Capital cost of power supply
- Pump life expectancy
- Pumping and operational costs
- Repairs and maintenance costs

SKM (2001)

$$\text{Gross power Required (kW)} = \frac{\text{Flow rate (litres/sec) x Total Pumping Head (metres)}}{\text{102 x Pump Efficiency (\%) x Derating (\%)}}$$



Source: Timms (2004) Irrigation Australia Article on CD



How to optimise groundwater supplies & increase confidence that drilling will provide sufficient yields of good quality groundwater

Source: WRL Solutions Sheet 3100

# Case example

Feasibility of groundwater supplies in a council areas scope included:

- How much water is needed to irrigate a park?
- Mapping local geology and hydrogeology
- Local issues eg. salinity, landfills, acid sulphate soils
- Opportunities and constraints for groundwater use
- Costs of groundwater supply development & monitoring
- Groundwater quality
- Risks & environmental considerations

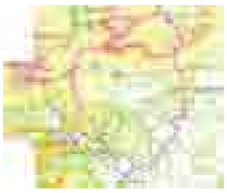


Source: Courtesy Marrickville Council

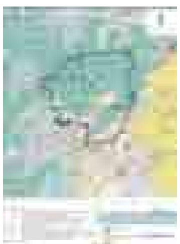


# Case example

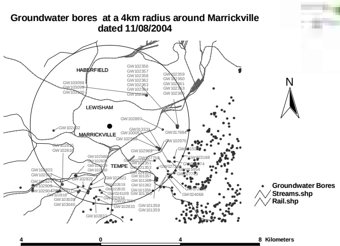
Topography & drainage



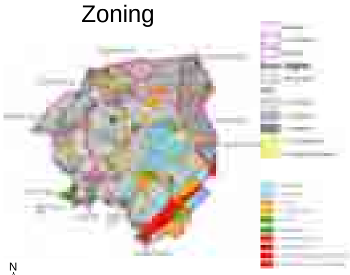
Geology



Bores




Zoning



Soils



Source: WRL project for Marrickville Council

# Case example

Acid sulphate soil testing



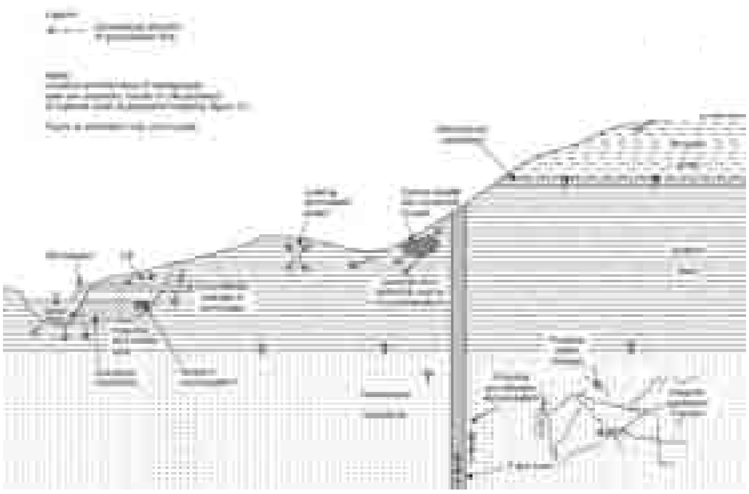
**Part 7: Environmental Management Provisions**
**Section 57: Development involving acid sulfate soils**
Development must not be carried out without development consent on land identified as being subject to acid sulfate soil risk, which is shown edged heavy black on the acid sulfate soils map, if it will involve works at or below the groundwater level or it could lower the groundwater table….
**Acid sulfate soils map means the series of maps marked "Marrickville Local** Environmental Plan 2001-Acid Sulfate Soils Planning Maps".
**Actual acid sulfate soils** means soils containing highly acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulfides or primarily pyrite. The soil material has a pH of less than 4 when measured in dry seasonal conditions.
**Potential acid sulfate soils** means soil material which is waterlogged and contains oxidisable sulphur compounds and that has a field pH of 4 or more but will become severely acid when oxidised.



Source: WRL project for Marrickville Council



# Case example





Source: WRL projects & Courtesy of Marrickville Council

# Case example

**Currently few operating bores in Hawkesbury sandstone around Sydney**

- mostly low yield ~0.5 L/s
- iron bio-fouling management req.
- bore stability issues

**Relatively expensive source**

- cost about $80,000 plus $5,000 per year in ongoing monitoring and assessment
- pay back period of 10 yrs if 18.3 kL/day (0.2 L/s) bore and water value of $1.25 /kL
- cost of supply is $3-6.60/kL over 5 years, or $1.15 to 1.90 over 30 year life with above assumptions

| Tasks | Indicative costs in 2006* (ex GST) |
|---|---|
| **Preparation for drilling**<br>•Application for test bore licence<br>•Prepare drilling schedule<br>•Engage suitable drilling subcontractor<br>•Services search & dial-before-you-dig | $5,000 |
| **Drilling and bore installation**<br>• Deep bore to about 200-230 m in Unit A & C of Hawkesbury sandstone. | ~$50,000 |
| **Bore testing & water quality assessment**<br>•Step testing and constant rate testing according to AS/NSZ 2368-1990 using a temporary pump to determine yield and other tasks. | ~$10,000 depending on depth, bore yield and length of pumping test required. |
| **Installation and commissioning of pumping system**<br>•Provision of electrical power supplies (possibly 3 phase), pump, and dosing system to control iron biofouling. | ~$10,000 Assumes existing storage tank. |
| **Ongoing monitoring and assessment**<br>•Supply and configuration of automated water level sensor and logger, Annual hydrogeological assessment of any trends in groundwater levels and water quality. | ~$5,000 per year (indicative) |

Source: WRL projects



# RESOURCE SUSTAINABILITY
# &
# Groundwater dependent ecosystems

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## Groundwater dependent ecosystems

**GDEs are ecosystems** consisting of plant and animal species that are reliant on groundwater during their life cycle.

**GDEs are important** for many reasons including biodiversity and ecosystem services provided for maintaining clean water and air.

**Stygofauna** are a new classification of animals that live within groundwater systems. Insects, gastropods and worms are stygofauna. The ecology, life-cycle and significance of stygofuana is an area of active research.

Obligate GDEs – completely dependent on groundwater
Facultative GDEs – partially dependent on groundwater when available

Guidelines for GDE assessment (SKM 2001, NSW DLWC 2002, Land and Water Australia 2007).

GDEs are relatively new area – science is yet to catch up with policy

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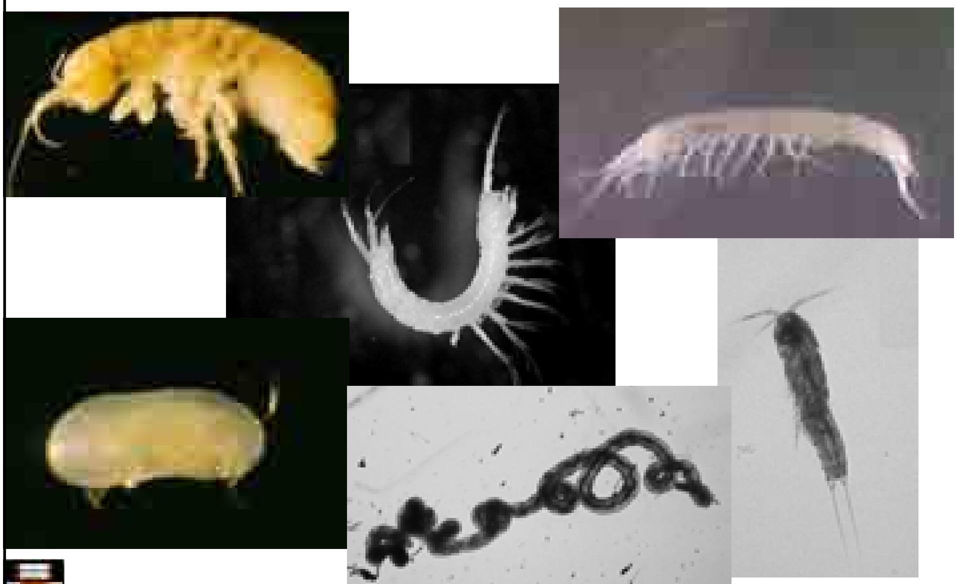
## Stygofauna from the region



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# GDEs – stygofauna from Kangaloon groundwater

• Stygofauna collected – found in shallow water bearing zones, not deep rock.

• Two species, both belong to Crustacea – a Syncarida and Copepoda
• Stygofauna found is regarded as macrofauna since >1000 um in size
• Tree roots within bores are a known food source for some stygofauna

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SMEC 2006 for Sydney Catchment Authority

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# GDEs – wetlands


SMEC 2006 for Sydney Catchment Authority

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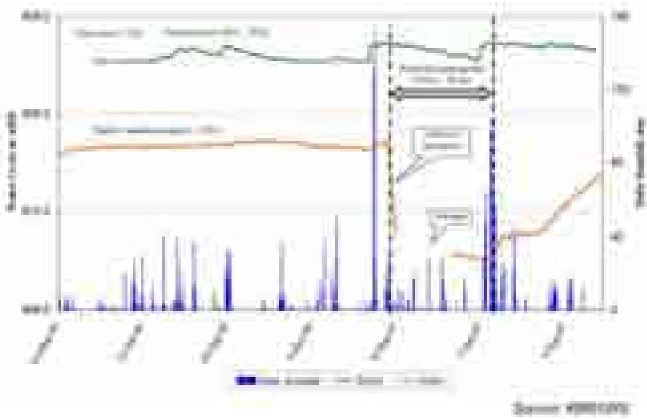
## GDEs - wetlands

- Detailed groundwater pumping test in deep fractured Hawkesbury Sandstone provided evidence that Butlers Swamp is perched and not connected to underlying aquifers.
- Minor drawdown during the pump test observed at Butlers Swamp was attributed to gradual draining after rainfall, and was comparable with water level response recorded in Stockyard Swamp, outside the zone of pumping influence.



KBR 2008 for Sydney Catchment Authority



## GDEs – ecological communities

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# GDEs – threatened fauna

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# Frequently Asked Questions: Bore water supplies

- Do I need a licence to access and use groundwater?
- Where can I get a bore licence application?
- Why do I need a licence?
- How much does it cost to get a licence?
- If I move, can I use the licence on the property I have just purchased?
- Who can I get to install a bore for me?
- What else should I do before having a bore drilled?

Some Councils require a Development Application to be lodged that covers the construction of a bore.

Refer to Bore or Spearpoint Installation Checklist in SCCG Handbook p28-29

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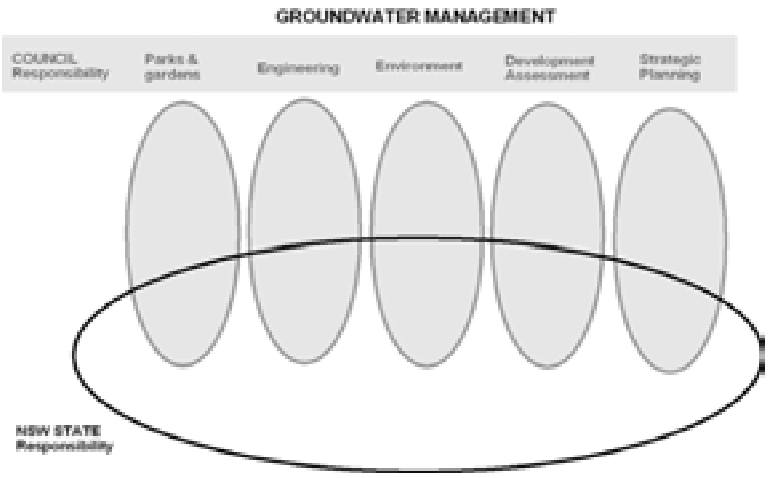
Source: SCCG Groundwater Management Handbook

# Role of Councils & State

**An outcome of this workshop aims to clarify who is responsible for which aspects of groundwater management within Councils & State agencies**



# Scenario 2 – Groundwater Quality and Contamination

*Group A:*
*Patrons of a shopping complex have just reported that they can smell fumes in the car park basement and lifts. Approximately 100m away at a public park, residents have been complaining for several months that they can smell rotten egg gas. The park is irrigated with groundwater and contains a series of inter-linked groundwater dependent ponds…*

*Group B:*
*Groundwater is being used for irrigation of open space, basic landowner rights and water supply for primary contact (i.e. swimming pools). Over the last ten years groundwater quality has been gradually declining due to increasing nutrient and pesticide concentrations. If current trends continue the beneficial use of the groundwater will be lost…*



Groundwater Workshop – S2

# Questions for group discussion

- What are the responsibilities of council?
- What is the interaction between different sections of council? Who does what? What is overlooked?
- Who can council consult for assistance?
- Can the issue be referred to a state government agency, and if so to which agency or agencies and after what process?
- What planning instruments, policies and guidelines are available to help council manage the groundwater issue now and in the future?

**Instructions:**
Nominate a member of your group to present your answers.
Summarise the answers to each question on a piece of paper.
Prepare the following post-it notes to be attached to the board:

Post-it Note #1: *Scenario Name (i.e. 2A or 2B), Type of contamination (i.e. Point Source or Diffuse), Ultimate Responsibility (Council or State (which ones)), At what stage is responsibility referred?*

A post-it note for each section of council involved in the issue listing the: *Scenario Name (i.e. 2A or 2B), responsibility of council section, applicable planning instruments, policies and guidelines, and assistance sought.*

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## Ecologically Sustainable Development

Ecologically Sustainable Development (ESD) is development 'that meets the needs of the present without compromising the ability of future generations to meet their own needs' (*Our Common Future*, Brundtland Report, 1987, p.8).

ESD is commonly associated with the principles of sustainable development and inter-generational equity:

- The precautionary principle - if there are threats of serious or irreversible environmental damage, lack of full scientific uncertainty should not be used as a reason for postponing measures to prevent environmental degradation.
- Inter-generational equity – the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.





## Ecologically Sustainable Development

- In 1992, the Intergovernmental Agreement on the Environment committed all Australian governments to the concept of ESD in the assessment of natural resources, land-use decisions and approval processes (Schedule 2).
- The Local Government Act 1993 requires councils, councillors and council employees to have regard for the principles of ecologically sustainable development as spelled out in the Protection of the Environment Administration Act in carrying out their responsibilities (LGA 1993 s.7(e)).
- Each council's charter includes a responsibility 'to properly manage, protect, restore and enhance and conserve the environment of the area for which it is responsible, in a manner that is consistent with and promotes the principles of ecologically sustainable development'. A council must pursue its charter in the exercise of its functions, however the charter is not legally enforceable (LGA 1993 s.8(2)).
- A council has the power to 'provide goods, services and facilities, and carry out activities, appropriate to the current and future needs within its local community and of the wide public, subject to this Act, the regulations and any other law' (LGA 1993 s.24). Chapter 6 of the LGA makes it clear that service functions include 'environmental conservation, protection and improvements of services and facilities'.

## Information from the SCCG *Groundwater Management Handbook*

Ch4 Legislation, Policy and Other Instruments (addressed in morning session)

Ch7 Groundwater Quality and Contamination
- p90-93 Typical Groundwater Quality Characteristics
- p94 Beneficial Uses of Groundwater
- p95-97 Groundwater Contamination
- p98 Acid Sulphate Soils
- p100-103 Groundwater Sampling and Monitoring
- p103-104 Contaminated site investigations
- p104-105 Assessment of groundwater quality

Ch8 GDEs (addressed in Scenario 1)

Ch9 Hydrogeological Mapping

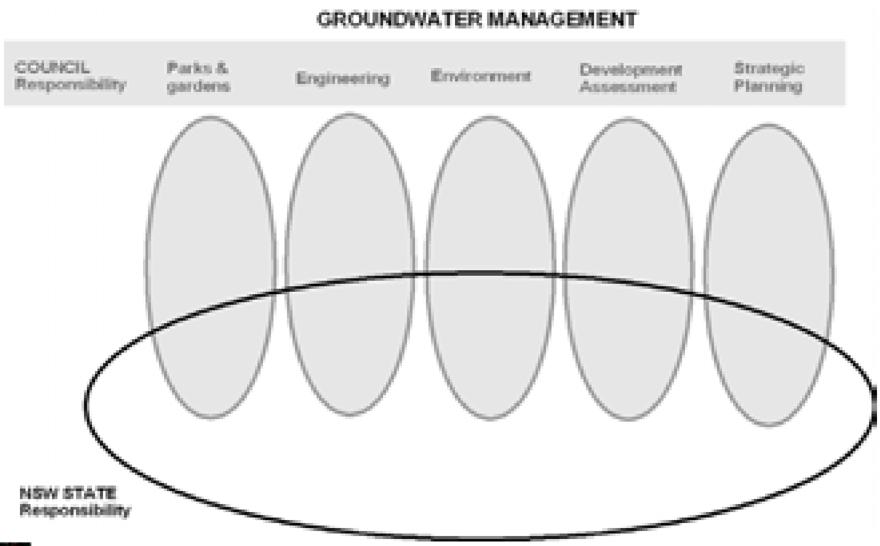
Additional information
- Typical water quality characteristics
- DIY Monitoring Fact Sheet

Case example
- Centre Cinema, Canberra (February 1977)





# Scenario Questions to Consider



# Why is Groundwater Quality Important?

Groundwater supports a range of beneficial uses. Contamination of groundwater can:

- result in major economic and social disruption, and
- be impossible or very expensive to remove.

Example: Walkerton, Ontario, Canada, May 2000

During a heavy rainfall event cattle manure washed from a paddock to the recharge zone of a fractured rock aquifer containing municipal water supply bores. The town water supply became contaminated with a highly dangerous strain of bacteria (*E. coli* O157) and 2,300 people became ill, 65 people were hospitalised, 7 people died and 27 people developed serious kidney disorders. There was a major economic impact on the community with disruption of businesses and schools over several months.

Example: ORICA, Botany

During former operations at the Botany site, contamination of soil and groundwater occurred as a result of manufacturing activities when environmental standards, regulations, and understanding were not of today's standards. Clean-up costs are well in excess of $170 M

(For more information see: http://www.oricabotanytransformation.com/)



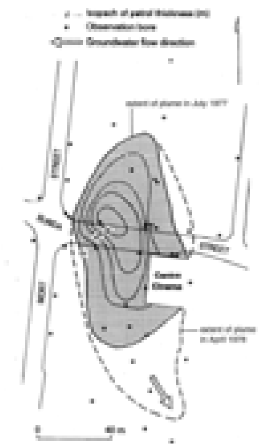


# Case example: Centre Cinema, Canberra

In February 1977 an explosion occurred in the lift shaft of the Centre Cinema in Canberra. The site was located partly below the water table. The explosion was ignited using welding equipment in an attempt to install fans to disperse petrol fumes that had been reported by the patrons. The workman was killed and the cinema was out of commission for many months.

In response to the explosion, a large number of boreholes were drilled to determine the extent of the suspected contaminant plume. It was eventually determined that a nearby service station had 'lost' 30,000 L of petrol when installing new underground tanks.

Fortunately the spill occurred in a low permeability fractured rock aquifer. Had the spill occurred in a more permeable aquifer (i.e. the Botany Sands) the extent of contamination would have been significant.



Source: Smith (1988)

# Beneficial Uses of Groundwater

Beneficial Use: The intuitive value of the groundwater in supporting a variety of economic purposes and environmental attributes

The beneficial use categories defined within the NSW State Groundwater Quality Protection Policy (NSW Government 1998) for application within New South Wales are:

- Ecosystem protection
- Recreation and aesthetics
- Raw water for drinking water supply
- Agricultural water
- Industrial water

Sustainability: Groundwater is a shared resource and its highest beneficial use should be maintained. Activities should not degrade the resource. Groundwater should be fit-for-use (i.e. groundwater should not be used if a more economic and sustainable source of water exists)



Source: SCC Groundwater Handbook



# Potential Contaminants in Urban Environments

- Industrial effluent and manufacturing wastes (e.g. Hexachlorobenzene, HCB).
- Leachate generated from landfills, stockpiles, cemeteries or contaminated soils.
- Nutrients and salts from Sewage Treatment Plant (STP) effluent irrigation activities.
- Saline groundwater arising from over-pumping in coastal areas (saltwater intrusion).
- Hydrocarbons from leaking underground storage tanks (USTs) beneath existing or closed service station sites or petrol company depots.
- Stormwater runoff from urban areas.
- Emergency response wastes during and after chemical fires.
- Nutrients, chemicals and microbiological organisms from leaking underground pipelines and sewers.
- Fertilisers and pesticides leached from open space areas such as golf courses or parks.
- Acidic waters and elevated metals concentrations from the disturbance of acid sulphate soils in coastal areas.
- Sulphur compounds and other chemicals from the deposition and infiltration of atmospheric pollutants.
- Nutrients and salts from widespread domestic wastewater irrigation in inappropriate hydrogeologic settings.
- Leaks of stored organic chemical compounds used in industrial or commercial processes.



Source: SCC Groundwater Handbook

# Likely Sources and Indicators of Contamination

| Recharge source | Importance | Water Quality | Pollution indicators |
|---|---|---|---|
| Leaking water mains | major | good | generally no obvious indicators |
| On-site sanitation systems | major | poor | nitrogen (ammonium, nitrate), boron, chloride (salinity), faecal coliforms |
| Leaking sewers | minor | poor | nitrogen (ammonium, nitrate), boron, chloride (salinity), faecal coliforms, sulphate, industrial chemicals |
| Surface soakaway drainage | minor to major | good to poor | nitrogen (ammonium, nitrate), chloride (salinity), faecal coliforms, hydrocarbons, dissolved organic carbon (organic load), industrial chemicals |
| Seepage from canals and rivers | minor to major | moderate to poor | nitrogen (ammonium, nitrate), boron, chloride (salinity), sulphate, faecal coliforms, dissolved organic carbon (organic load), industrial chemicals |

Source: Foster, et. al. 1998

Indicators may be:

- Extremes in pH (e.g. low pH might coincide with acid sulphate soils)
- Salt scalds or saline seeps
- Elevated levels of nitrate (e.g. contamination by fertilizer)
- Fumes (e.g. hydrocarbons or other volatile organics)
- Red stains at groundwater discharge points or fish kills in creeks and estuaries (acid sulphate soils have been exposed to oxygen or pesticides in soils may have leached to surface waters)

Any urban site is likely to be affected by contamination in some way.



Source: SCC Groundwater Handbook



# Assessment of Groundwater Quality for Use

There are no guidelines for groundwater quality (quality is variable)

Guidelines are broadly based on beneficial use classifications:

- Australian Drinking Water Guidelines 2004: http://www.nhmrc.gov.au/publications/synopses/eh19syn.htm
- ANZECC Guidelines for Fresh and Marine Water Quality: http://www.mincos.gov.au/publications/australian_and_new_zealand_guidelines_for_fresh_and_marine_water_quality

To assess suitability of groundwater for use it is necessary to consider:

- Frequency of sampling to detect varying groundwater processes
- Nearby potential contamination sources
- Ambient / Natural groundwater quality
- Surface characteristics at groundwater discharge point
- Quality requirements and treatments for end use



Source: SCC Groundwater Handbook

# Groundwater Sampling

- Groundwater quality can change with time → Sampling programs need to be carefully designed
- Water quality samples can change rapidly during and after collection → Sample collection, handling and preservation procedures are important.
- Sampling and monitoring of groundwater quality should be carried out by suitably qualified and experienced environmental personnel.
- The following general suite of parameters is recommended for all groundwater quality samples:

| | |
|---|---|
| **Physical parameters** | Alkalinity, electrical conductivity (EC), pH, redox potential (Eh), total dissolved solids (TDS), total hardness |
| **Major anions** | Sulphate ($SO_4^{2-}$), chloride ($Cl^-$), bicarbonate ($HCO_3^-$) |
| **Major cations** | Calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), sodium ($Na^+$), potassium ($K^+$) |
| **Inorganics and heavy metals** | Aluminium (Al), antimony (Sb), arsenic (As), barium (Ba), boron (B), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), lithium (Li), manganese (Mn), mercury (Hg), nickel (Ni), selenium (Se), silver (Ag), zinc (Zn) |
| **Nutrients** | Ammonia ($NH_3$), nitrate ($NO_3$), total nitrogen (N), total phosphorus (P) |
| **Microbiological organisms** | Faecal coliforms, faecal streptococci, *Escherichia coli* |
| **Organic compounds** | Benzene, toluene, ethylbenzene, xylene (BTEX), semi-volatile chlorinated hydrocarbons, volatile chlorinated hydrocarbons, chlorinated aliphatics, pesticides, phenols, polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPH) |

All samples should be collected and transported in accordance with **Australian Standards AS/NZS 5667.1:1998 : Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples** and **AS/NZS 5667.11:1998 : Water quality - Sampling - Guidance on sampling of groundwaters**. Sample analysis should be undertaken by a National Association of Testing Authorities (NATA) accredited laboratory under appropriate Quality Assurance and Quality Control (QA/QC) protocols. All sampling procedures and results are to be clearly documented and reported.

A hydrogeologist can provide advice if sampling needs to be targetted or optimised

Source: SCC Groundwater Handbook





# Is groundwater safe to use ?

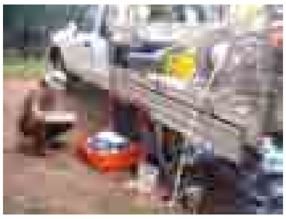
**Groundwater quality is generally excellent in the north-eastern Botany aquifer**

- fit-for-purpose depending on treatment
  - eg. irrigation, toilet flushing, cooling towers
- mostly complies with drinking water guidelines if disinfected and iron/manganese is removed. Nitrate treatment required in some areas.

- some areas of lower quality groundwater
  - near old landfills
  - near leaking sewers
  - near top of watertable (eg. trace metals, salt)
  - in pockets of stagnant groundwater

**Comprehensive assessment for a wider range of parameters is required, and strategic monitoring**

| Parameter | Pump bore* | Sydney Water supply | Drinking water guidelines# |
|---|---|---|---|
| pH | 5.5-6.3 | 8 | 6.5-8.5 |
| TDS | 100 | 110 | <500 |
| Iron | 10 | 0.016 | <0.3 |
| Nitrate as N | 0.2 | 0.3 | 11.3 |
| E.Coli | mostly ND | ND in 99% | ND in 98% |
| Total P | 0.05 | | |
| Zinc | 0.02 | | |
| Cu, Pb, Ni, Cr | ND | | |
| ND = not detected | | | |



## Typical Water Quality Characteristics

Groundwater in the Sydney region typically exhibits the following attributes:

- variable salinity
  - typically below 500 mg/L in coastal sands
  - Typically 500 mg/L to more than 1,500 mg/L in sandstone
  - In Western Sydney potentially in excess of 5,000 mg/L
- low pH (typically below 7 if conditions are reducing)
- elevated concentrations of Manganese or Iron (especially in porous and fracture rock aquifers or acid sulphate soil areas)
- a degree of hardness
- nitrates: variable (concentrations above 11 mg/L unsafe for drinking)
- nitrites: variable (concentrations above 3 mg/L unsafe for drinking)

An indication of likely water quality in an area (salinity) can be obtained from the NSW Natural Resource Atlas.



Source: SCC Groundwater Handbook



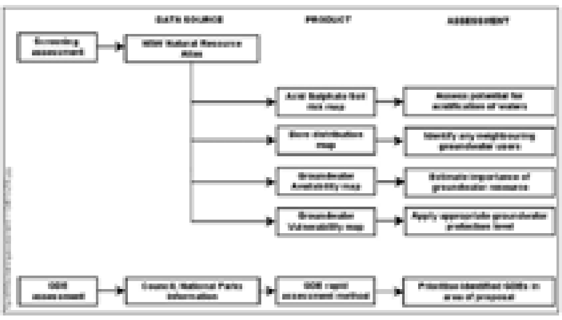
## Groundwater Mapping

Groundwater mapping with the NSW Natural Resource Atlas can be used to find existing bores near a site and for the rapid initial assessment of likely:

- presence or absence of acid sulphate soils (potential for acidification)
- groundwater availability (quality and yield – importance of resource)
- groundwater vulnerability (pollution potential – level of protection required)

The use of this resource is described in Section 9 of the Groundwater Management Handbook.

If registered bores exists near a site it may be possible to obtain groundwater level data from DWE to assess depth to groundwater, trends and flow directions





Source: Groundwater Management Handbook (Section 9)

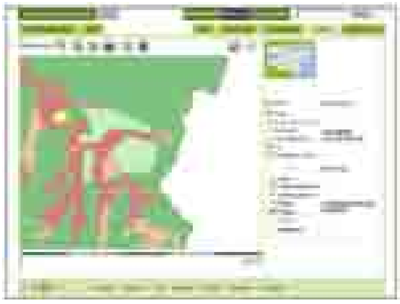
# Groundwater Vulnerability Mapping

Groundwater vulnerability is determined by consideration of:

- Depth to water, Recharge, Aquifer media, Soil media, Topography, Impact of unsaturated zone, Conductivity (Hydraulic) of aquifer media.

Indicative groundwater vulnerability classifications for SCCG region aquifers:

| Aquifer type | Indicative vulnerability category |
|---|---|
| Unconsolidated sediments (alluvium) | High |
| Unconsolidated sediments (coastal sands) | High |
| Porous rocks | Moderate to Moderately high |
| Fractured rocks | Low to Moderate |





Source: Groundwater Management Handbook (Section 9)



# Salinity (Cations and Anions)

- Groundwater salinity is typically sodium chloride type
- Can be measured or expressed as parts per million, Total Dissolved Solids (mg/L), Electrical Conductivity (µS/cm)

Sources of salinity

- Rocks (connate salts) and weathering of rocks
- Rainfall recharge, especially in coastal areas (cyclic salts)
- Saline Intrusion (especially from pumping)
- Wind blown salts (Aeolian)

| Descriptor | Indicative range | Aesthetic guideline (ADWG 1996) | Palatability range (ADWG 2004) | Palatability (ADWG 2004) |
|---|---|---|---|---|
| "Fresh", "good", "sweet" | "0 - 500 ppm" | Good quality drinking water based on taste | < 80 mg/L<br>80 - 500 mg/L | "Excellent"<br>"Good" |
| "Slightly salty" | "501 - 1000 ppm" | Acceptable drinking water based on taste | 500 - 800 mg/L<br>800 - 1000 mg/L | "Fair"<br>"Poor" |
| "Brackish" | "1001 - 3000 ppm" | Excessive scaling, corrosion and unsatisfactory taste | > 1000 mg/L | "Unacceptable" |
| "Salty", "poor" | "> 3000 ppm" | Excessive scaling, corrosion and unsatisfactory taste | | |

Note: 1 ppm ~ 1 mg/L. ADWG 1996 refers to the Australian *Drinking Water Guidelines 1996* (NHMRC / ARMCANZ 1996); ADWG 2004 refers to the Australian *Drinking Water Guidelines 2004* (NHMRC / NRMMC 2004)



Source: SCC Groundwater Handbook

# Groundwater Sampling Recommendations

- Sampling and monitoring of groundwater quality be carried out by suitably qualified and experienced environmental personnel.
- Where groundwater contamination may be of concern, personnel undertaking the sampling have adequate Personal Protective Equipment (PPE) and be trained in its use.
- Quality assurance and quality control checks of laboratory data be included and addressed in any sampling and monitoring program.
- Monitoring be undertaken using appropriately designed bores of sound construction and with adequate security to prevent tampering.
- Laboratory samples are interpreted by a hydrogeologist
- If groundwater contamination is suspected, the local Council or DEC should be contacted for further assistance and guidance.
- Councils ensure that a suitable environmental management plan is provided as part of any Development Application involving groundwater, that is commensurate with the vulnerability and protection levels applied to the aquifer.



Source: SCC Groundwater Handbook



# Groundwater Contamination

**Suggested groundwater contamination assessment framework**

The following process is suggested as a framework that Councils should require applicants to follow in the assessment of groundwater contamination:

- Desk top study. This study should include as a minimum a site history review (e.g. identify all past and present potentially contaminating activities; identify potential contamination types); an assessment of the condition of the site and surrounding environment; documentation of the geology and hydrogeology of the property; and verification with Council and DEC of any information from the contaminated sites register.
- Preliminary sampling and analysis program. Where contaminating activities are suspected or known to have occurred, the need for a detailed site investigation must be assessed. Preliminary sampling and analysis should be undertaken in accordance with 'best practice' procedures and following accepted guidelines relating to environmental site assessments (e.g. NEPC 1999a). Any such program should be undertaken by suitably qualified and experienced consultants.
- Detailed site investigations. If the levels of contamination exceed water quality criteria (or objectives), further investigation will need to be undertaken to determine the course of remedial actions. These should be carried out by suitably qualified and experienced consultants (more specific experience may be required than for preliminary assessments) following appropriate guidelines (e.g. NEPC 1999a).

Further guidance on the investigations required to assess groundwater contamination will need to be obtained on a site-specific basis. Councils should confirm with DEC any requirements that might be needed for particular areas.



Source: SCC Groundwater Handbook pg97

# Contaminated Site Investigation

Contaminated site investigation reports should include:

- Clearly documented links to relevant legislation
- Details and relevance of the water quality criteria used
- Ambient groundwater quality in vicinity of the site
- Proof of appropriate groundwater sampling and assessment
- A tabulation and map of potential 'at risk' groundwater users
- Suggested methods of clean up to restore the beneficial use
- Any other details of the contamination or site that could have a bearing on the groundwater system.

Point Source Contamination issues should be referred to DECC

How does Council manage contamination from diffuse sources?



Source: SCC Groundwater Handbook pg103-104

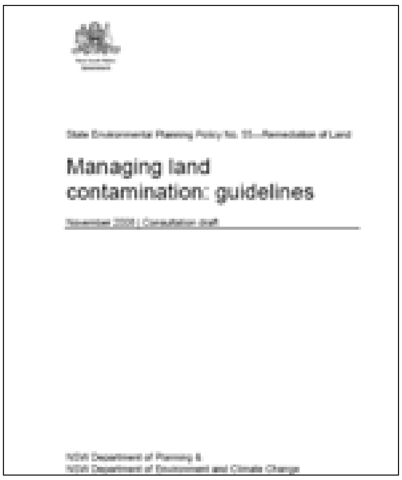
Groundwater Workshop – S2

# NSW DECC – new guidelines

**Check new guidelines – consultation draft issued Nov 2008**

**www.planning.nsw.gov.au/asp/pdf/draft_documents/draft_managing_land_contamination_guidelines_nov08.pdf**

**www.environment.nsw.gov.au/clm**

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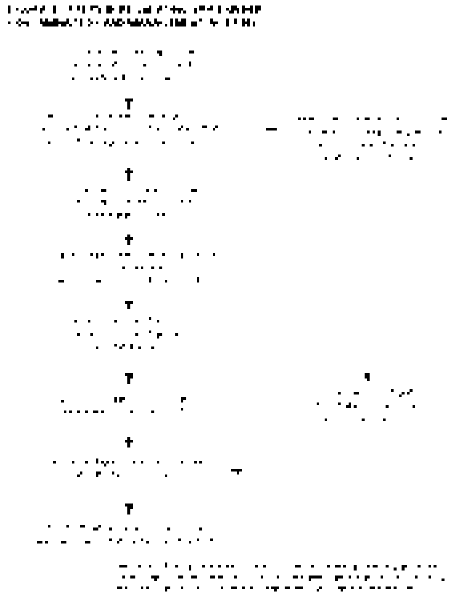
## Steps in Regulating Sites

**NSW DECC under the CLM Act**

**Contamination is Council responsibility if no significant risk of harm**

**Contamination is DECC responsibility if there is significant risk of harm**





Source: NSW DECC

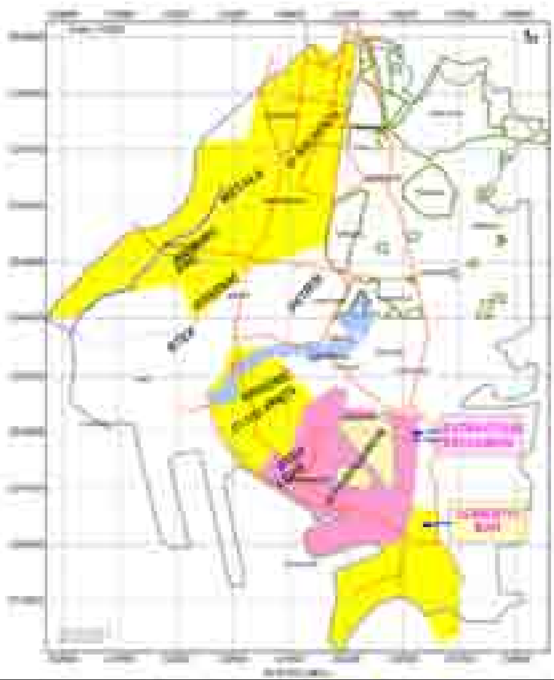


## Case Example: Botany aquifer contaminated areas

EPA notice sites

Courtesy of N. Merrick

2006



# Scenario 3 – Climate change & coastal aquifers

*A development proposed close to the beach includes plans to use an irrigation bore to source water for irrigation.*

Information from the SCCG *Groundwater Management Handbook*

- Additional information – new Fact Sheet
- Case example
  - Desktop assessment for council in Tasmania
- Questions to consider





# Scenario Questions to Consider

What stages of approval does council follow?

- Initial discussion
- Formal DA
- Re-submitted DA
- Public exhibition
- Consent conditions
- What other stages might occur?

What should council be seeking in the DA to prevent significant saline intrusion now, or at some time in the future (ie. climate change)?

## Information from the SCCG *Groundwater Management Handbook*

Ch4 Legislation, Policy and Other Instruments

Ch2 Accessing Groundwater
- p24-25 Types of installations

Ch6.5.1 Dewatering (covered in S5)

Ch7.3.1 Groundwater salinity (covered in S2 or S4)

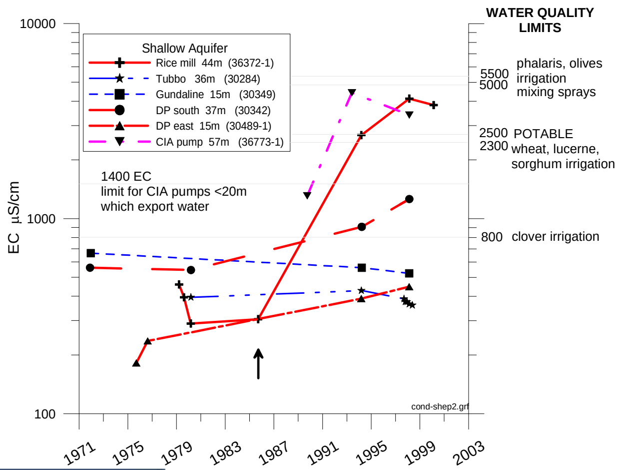




## Why is this issue important?

Increased salinity of strategic water supplies

Impact of high watertables on infrastructure



# The Value of Coastal Aquifers

Table 1. Summary of a GIS-based analysis of irrigation areas and coastal proximity

| State | Total Irrigation Area | Major Land-use | Area at 0-5 m AHD | Area at 0-10 m AHD |
|---|---|---|---|---|
| NSW | 2 867,516 ha | Cropping | 7,663 ha | 10,198 ha |
| NT | 29,899 ha | Tree fruits | 136 ha | 402 ha |
| QLD | 1 1,080,787 ha | Sugar | 15,706 ha | 84,749 ha |
| SA | 271,319 ha | Sown grasses | 9,481 ha | 16,839 ha |
| TAS | 128,795 ha | Cropping | 2,922 ha | 6,837 ha |
| VIC | 3 837,886 ha | Modified pasture | 9,624 ha | 23,018 ha |
| WA | 55,789 ha | Vine fruits | 528 ha | 2,814 ha |
| Total | 3,271,991 ha | Cropping | 46,060 ha | 144,858 ha |

Werner et al., 2008

- Coastal groundwater uses:
  - Town water supplies
  - Irrigation of crops
  - Baseflow to coastal creeks

- Freshwater contaminated by ~5% of seawater is no longer suitable for many beneficial uses

- Serious potential losses




# Saline intrusion – Botany aquifer

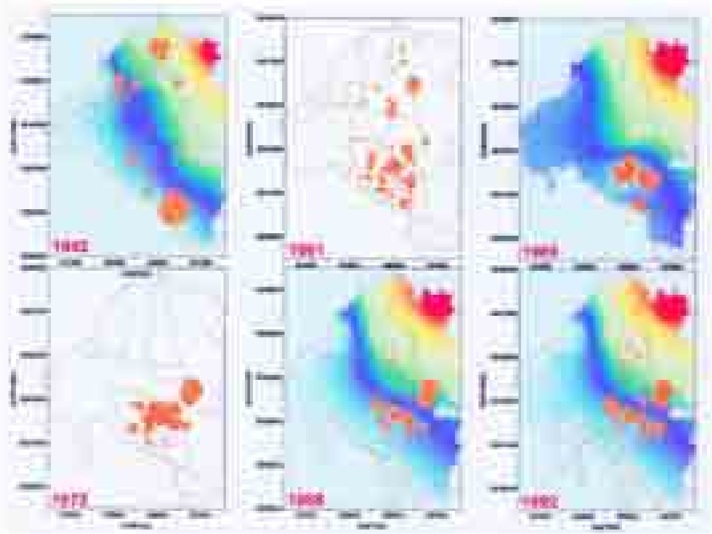
1970-1974
saline intrusion near Botany Bay

Courtesy of Noel Merrick

## History of bore usage – Botany aquifer

Usage moved away from Botany shoreline due partly to saline intrusion

Courtesy of Noel Merrick



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## The Value of Tomago aquifer

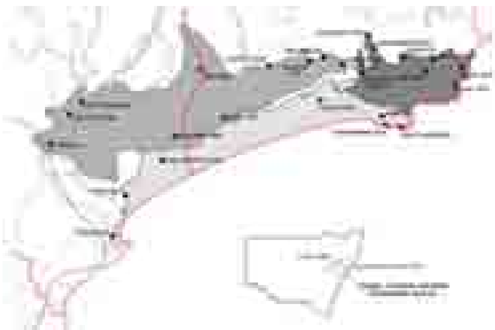
- ~13 % of Hunter Region supply
- population of 500,000

~50 ML/day extracted
~200 ML/day extraction limit

18,000 ML/year @ $1.27/kL

$23 million/year worth of groundwater!

Basic monitoring required by license



Hunter Water 2006 ESD Report

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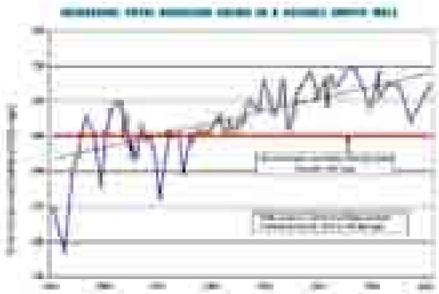
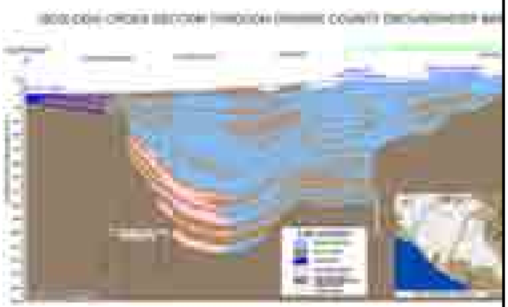
## Saline intrusion



**eg. Saline intrusion below Los Angeles due to increasing groundwater use since 1960's**



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## Adaptive management – Los Angeles

**Recharge ponds**

**Injection bore barrier**

**Managed aquifer recharge**
- Stormwater recharge through ponds
- Injection of treated wastewater to form barrier
- First started in 1970's
- New generation wastewater reclamation plant for injection was commissioned Jan 2008

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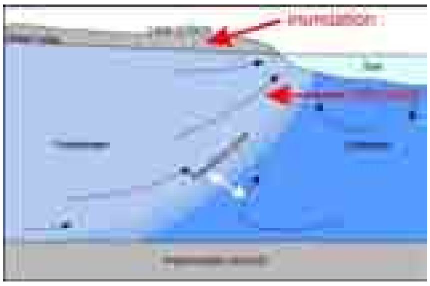
## Groundwater Equilibrium

The equilibrium boundary between fresh and saline water below coastlines can be disturbed by changing sea level & climate, with saline groundwater migrating inland and displacing fresh groundwater near the surface.



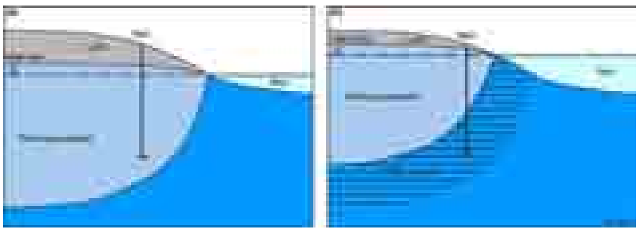

Inundation event (high tide + rainfall)
Clarence Coast, Tasmania, 1974

Source: Carley et al. 2008 WRL Projects





## Groundwater Equilibrium



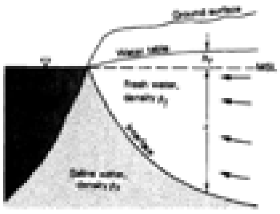
www.ozcoasts.org.au

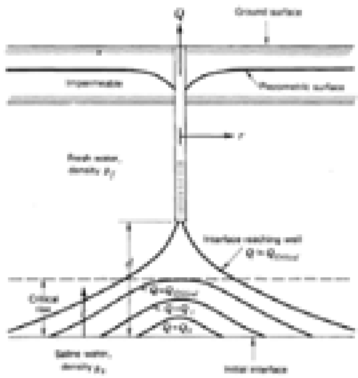
www.connectedwaters.unsw.edu.au/resources/articles/coastal_aquifers.html

## Classic groundwater theories

The Ghyben-Herzberg ratio states, for every 1m of fresh water in an unconfined aquifer above sea level, there will be 40m of fresh water in the aquifer below sea level.

It is analytical solution to approximate the intrusion behaviour, with actual cases more complex and better suited to numerical modelling.



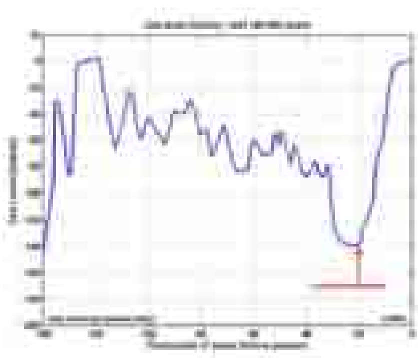


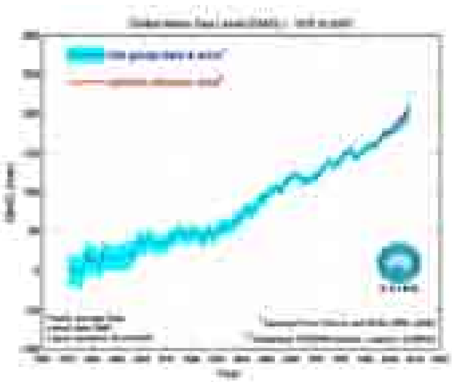




## Sea-level rise will increase saline intrusion

•Sea-level rise has been measured around the world for many years, providing evidence that the rate of rise is increasing. For example, the average sea-level rise that is evident in tide gauges around Australia is 1.2 mm/year (BOM). Global sea-levels have risen on average about 2 mm/year with a total rise of about 0.2 m over the last century.

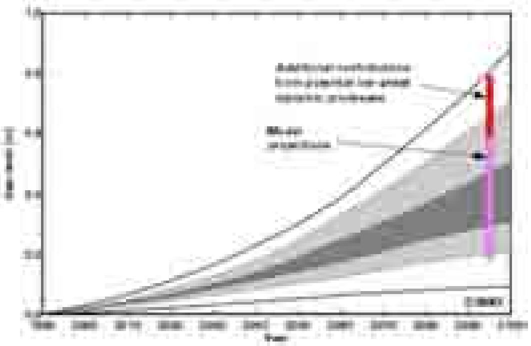




http://www.cmar.csiro.au/sealevel

# Projected sea-level rise

- There are also various scenarios of sea-level rise in the future based on current understanding and models of the many factors and feedback processes that contribute to sea-level rise.
- Currently best estimates (IPCC 2007) indicate sea-level increase of 0.2 to 0.5 m by 2050 and 0.5 to 0.9 m by 2100.
- Current coastal management and construction guidelines around Australia allow for up to 1.0 m of sea-level rise by 2100 (NCCOE, 2004).
- Plus sea-level rise due to possible melting of the and Greenland icesheets (+7 m) and Artic, Antarctic icesheets

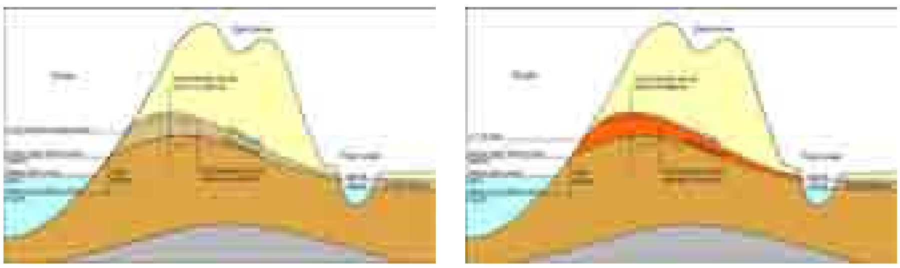


http://www.cmar.csiro.au/sealevel





# Groundwater-ocean boundary



**Increased mean sea-level could further increase groundwater mounding and change discharge dynamics**

It is commonly, but wrongly assumed that groundwater continuously discharges at mean sea level & that groundwater level is at mean sea level. In reality, the action of waves cause mounding of groundwater at the coast meaning that the watertable is at about mean high tide level.

Wind & wave climate also important as a groundwater driver, particularly for storm events.

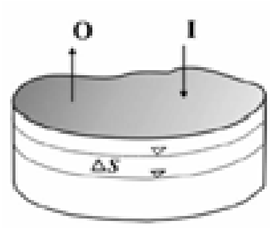
Turner et al. 1997

# Potential consequences for coastal groundwater

**Potential and actual impacts have been reported in several coastal aquifer systems:**

- Seawater intrusion and lateral migration of the fresh-saline interface
- Seawater flooding and inundation of unconfined aquifers
- Flooding and saline contamination of bore heads

- Changing groundwater balance
  - Changing recharge due to variable rainfall and evapotranspiration
  - Increased groundwater extraction and decreased groundwater levels
  - Changing discharge patterns that may impact on aquatic and wetland ecosystems




Kalf & Woolley, 2005

- Subsidence of land surface – if clays, peats etc.

- High watertable impacts on structures
  - ingress to sewer & septic systems, discharge to basements, upwards pressure on tanks & pools





# Desktop assessment

**Depends on information available:**

- Geology and hydrogeology maps
- Hydrology & catchment topography data
- Bore survey data, screen depth & stratigraphy

- Groundwater level variation – spatially, with aquifer depth & over time
- Groundwater quality – EC, pH, T and major ions at a minimum

- Groundwater usage volumes & dependence
- Aquifer status relative to sustainable groundwater yield assessments

→ If possible, determine if hydraulic head dependent or flow dependant coastal boundary

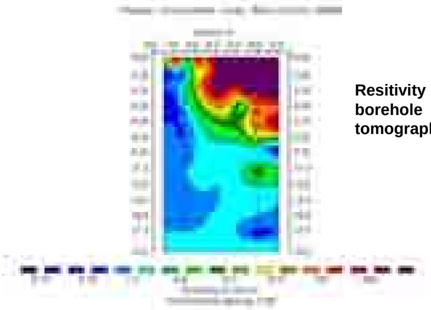
→ Identify potential impact ranking for more detailed assessment if required

| Potential impact | Desktop assessment |
|---|---|
| Seawater intrusion and lateral migration of the fresh-saline interface | **Assessment for each potential impact:**<br>**• High**<br>**• Moderate**<br>**• Low**<br>**• Unknown** |
| Seawater flooding and inundation of unconfined aquifers | |
| Flooding and saline contamination of bore heads | |
| Changing recharge in the aquifer catchment due to variable rainfall and evapotranspiration | |
| Increased groundwater extraction and decreased groundwater levels. | |
| Changing discharge patterns that may impact on surface waters and groundwater dependent ecosystems | |
| Waterlogging of infrastructure, ingress of salt water | |
| Subsidence of land surface | |

## Detecting the fresh-saline interface

**Geophysical methods**
- Electro techniques
  - needs truthing – values depend on porewater salinity & lithology (clay content etc.)
  - airborne EM –large areas
  - resistivity imaging – 2D sections useful
  - downhole EM – can detect changes over time in porewater surrounding borehole

- Downhole gamma – identify confining sedim
- Ground penetrating radar (2D Sections)
  - estimate depth of sandy aquifers
  - not always successful



Resitivity by borehole tomography

WRL 2007
*Lakes Beach*

Acworth & Dasey 2003 *Hydrogeology J.*



2. Consequences for coastal aquifers

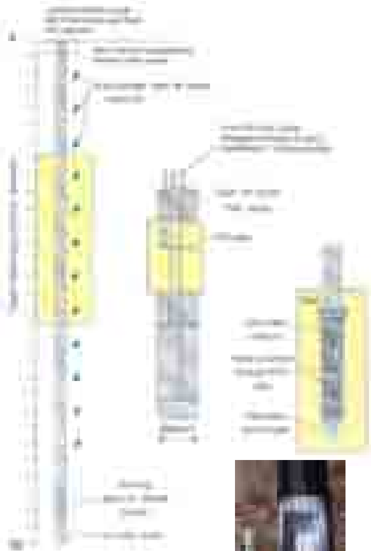
## Detecting the fresh-saline interface 2

**Time series groundwater level & EC data:**
- cost effective automated groundwater loggers
- download manually or telemetry
- online hydrographs for real time management

**Piezometer is a monitoring bores with short intake screen.** Ideally obtain data at <1 m depth increments.

| Screen length | Monitoring Effectiveness |
|---|---|
| Long (>5 m) | Poor |
| Short (~1 m) | Good* |
| Mini (~5 cm) | Excellent |

***Best if 'nested' by installing shallow & deep screens in separate holes.**



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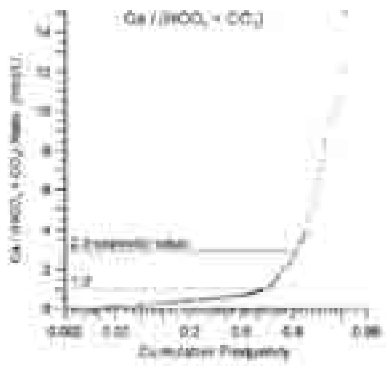
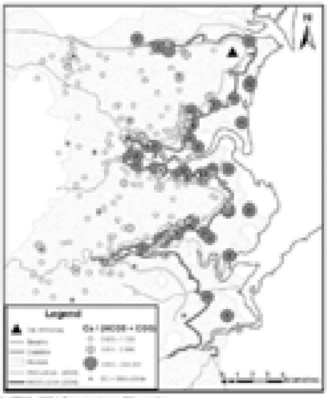
## Geochemical warnings of saline intrusion

**Pioneer Valley aquifer (Mackay Qld) – intrusion of seawater is advancing, although must be distinguished from other salinisation processes due to agriculture, dissolution of rocks and relict seawater pockets.**



Werner & Gallagher 2006 *Hydrogeology J.*





## Scenario Questions to Consider

What stages of approval does council follow?

- Initial discussion
- Formal or re-submitted DA
- After public exhibition
- Consent conditions
- Approvals other than DA's?
- What other stages might occur?

What should council be seeking in the DA to prevent significant saline intrusion now, or at some time in the future (ie. climate change)?

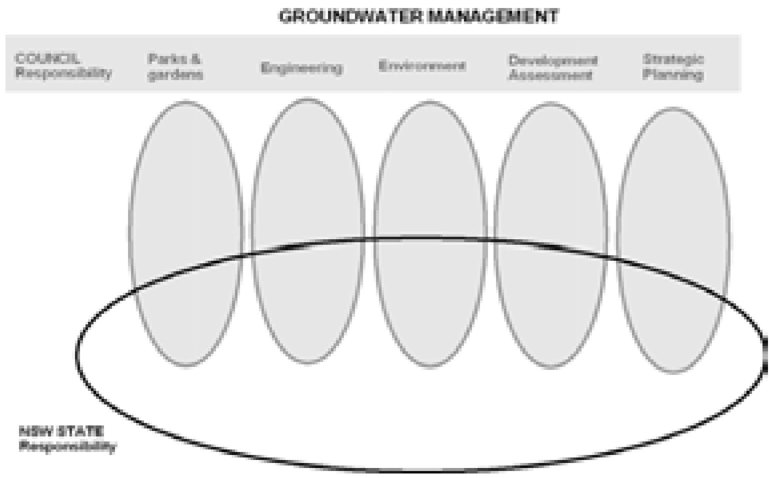
At what stage does council require:

- Feasibility of irrigation bore (eg. depth, pumping rate, aquifer characteristics)
- Detailed predictions of water level drawdown & EC & movement of saline interface
- Monitoring reports including interpretation & assessment – for pumping history, water levels & water quality

Contingency plans if issues emerge

# Role of Councils & State

**An outcome of this workshop aims to clarify who is responsible for which aspects of groundwater management within Councils & State agencies**



## Scenario 4 – Urban Salinity in Western Sydney

*Salt scalds and seeps have been observed…*
*A development is proposed in a high risk salinity area…*

Information from the SCCG *Groundwater Management Handbook*

•Additional information
- Introduction to urban salinity in Western Sydney
- Urban salinity (WSUD Practice Note 12)
- Monitoring and Prevention Strategies

•Case example

•Questions to consider





## Information from the SCCG *Groundwater Management Handbook*

- p91
- p93
- p96
- p104
- p112
- p134

## What is Salinity?

Salinity is the presence of dissolved salts in soil or water

High salinity in soils, rivers and groundwater can have natural and anthropogenic causes:

- dissolution of connate salts or the weathering of the soils and rocks through which water flows
- recharge or saltwater intrusion from the ocean
- rainfall and windblown aerosols from the coast

The following can exacerbate salinity:

- Changes in vegetation type (i.e. removal of deep rooted vegetation)
- Pumping of groundwater (i.e. saline intrusion or aquifer leakage)
- Irrigation or leaking pipes (salts may accumulate in the soil)
- Erosion or removal of soil for construction (may expose saline soils which may further erode and cause downstream salinity issues)
- Altering groundwater flow (i.e. construction below water table

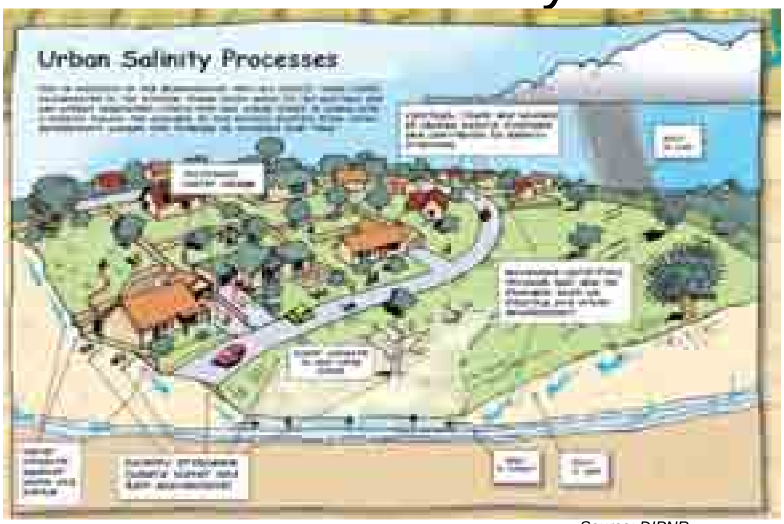
The impacts of salinity may be gradual or immediate



Sources: Holmick *et al*, 2007, Nicolson, 2003

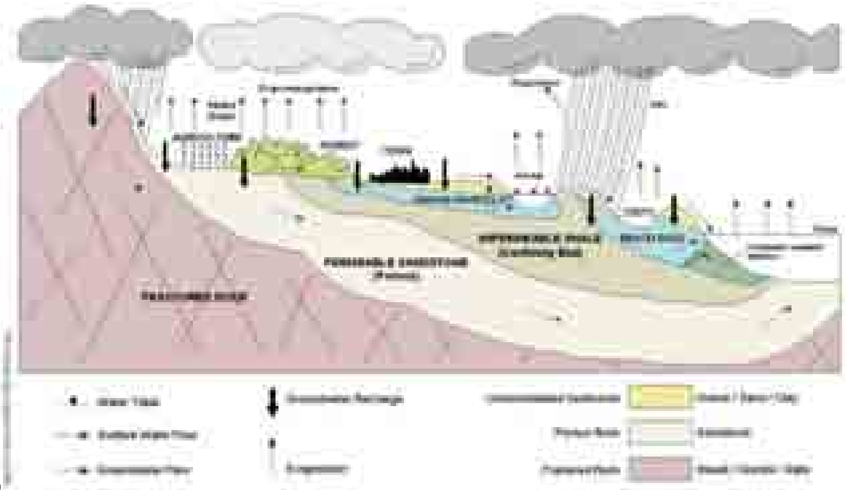


# Urban Salinity




*Source: DIPNR*

# The Water Cycle



*Source: NSW Government (1998)*

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## Where is Salinity a Problem?

Salinity has long been recognised as a problem in Western Sydney:
- saline groundwater and brackish creeks observed from 1800s
- salt tolerant species frequent ecosystems in the area

→ Naturally high levels of salt in soils or groundwater
→ Groundwater may be close to the surface in some areas

Salt in Western Sydney likely to be a function of geology and climate:
- Wianamatta Shales (marine in origin) have high fossil salt content
- Groundwater in fractured shales may contain 5,000 – 50,000 mg/L of salt and this water is known to feed Second Ponds and South Creeks
- Windblown coastal aerosols may deposit 20-200kg salt/ha/year
- Soil B horizon may contain 30-50 tonnes salt/ha
- Groundwater flowing through the soil B horizon mobilises some salts

The salinity potential of Western Sydney was mapped by DIPNR in 2002

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Sources: McNally, 2004 , Nicolson, 2003

# Where is Salinity a Problem?


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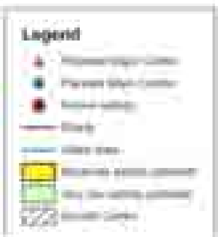
Water Research Laboratory

# Where is Salinity a Problem?

**Salinity Potential in Western Sydney (DIPNR, 2002)**

**Compared with Metro Strategy urban growth areas**

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# What are the impacts of Salinity?

As salinity increases in soils, soils may become sodic (dominantly sodium ions attached to cation exchange sites on soils)

Sodic soils are highly dispersive, therefore more susceptible to erosion and more impermeable, thus causing waterlogging

http://www.anra.gov.au/topics/salinity/impacts/index.html

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

*Source: WSUD in Sydney (2003), Nicolson (2003)*

Groundwater Workshop – S4

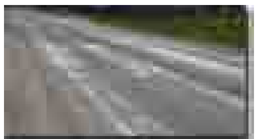
# What are the impacts of Salinity?

Salts may accumulate in buildings founded on damp, salty soils. Accumulation of salt can cause:

- crumbling of brickwork,
- concrete corrosion and cracking,
- corrosion of steel reinforcement (of concrete)

Pipework, stormwater infrastructure, pavements and roads may undergo similar damage and eventual failure

Salt tolerances among plants vary widely and slight increases in salinity may cause the death of some plants, while others remain unaffected



http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/urban_salinity_road_assets

www.regional.org.au/au/gia/06/185hazell.htm

UNSW - School of Civil and Environmental Engineering
Water Research Laboratory

*Source: WSUD in Sydney (2003), Nicolson (2003)*

## What are the impacts of Salinity?

High salinity in soils or irrigation water may cause:
- salt scalds (i.e. new housing estates in St. Mary's)
- reduced productivity or death of vegetation,
- damage to soil structure and damage to buildings.

Micrograph of mortar between bricks showing little binding capacity



Sources: McNally, 2004 , Nicolson, 2003, *WSUD in Sydney (2003)*



## Costs of Salinity?

Salinity costs councils, developers, industry and home owners.

**Case example: Wagga Wagga**
Population – 58,000
No action - $183 million cost over 30 yrs
Action - positive benefit cost ratio
Installed ~6 dewatering bores, evaporation basins to lower watertable under town
Strict controls on WSUD, drainage

| | |
|---|---|
| Roads | $ 226, 000 |
| Footpaths | $ 4, 400 |
| Parks | $ 103, 400 |
| Houses | $ 72, 500 |
| Industrial | $ 6,000 |

Source: Annual recurring costs of Salinity in Wagga Wagga, Christiansen 1995

**Table A Present value of benefits and costs of 'with plan' scenario**

| Present Value | $ at 7% over 30 years |
|---|---|
| Benefits | 28,929,518 |
| Costs | 26,016,155 |
| Net present value | 2,913,363 |
| Benefit Cost Ratio | 1.11 |

**Table B Total value of benefits and costs of 'with plan' scenario**

| Total Value | $ over 30 years |
|---|---|
| Benefits | 116,074,386 |
| Costs | 59,038,689 |
| Difference | 57,035,697 |

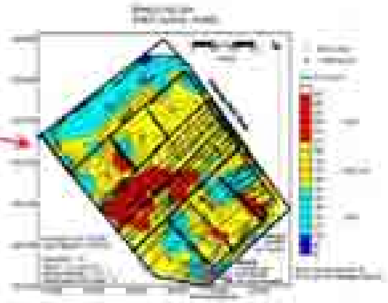


*Source: DIPNR, 2003*
*DIPNR, 2000*

# Mapping salinity

**Step 1**
**Surface or airborne EM survey to locate anomalies**

Apparent conductivity



* Interpretation limited to relative comparisons
* Effective penetration depth of ~6m



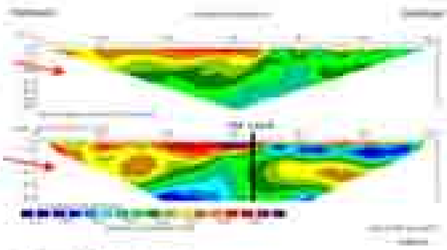
Source: Acworth & Beasley 1998
WRL Solutions 1400

Groundwater Workshop – S4

**Step 2**
**Electrical imaging to investigate vertical structure causing EM anomalies**

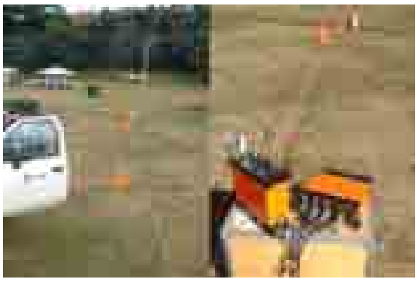
Apparent conductivity

True conductivity model



* Improved distinction between salt, moisture & lithology
* Data processed with RES2DINV for model of true conductivity (or resistivity)
* 2D image 100-600 m long & 10-60 m depth (depending on electrode separation)

**Step 3**
**Test holes in optimized locations**



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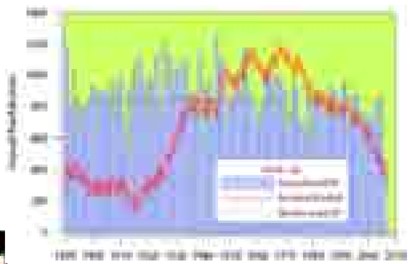
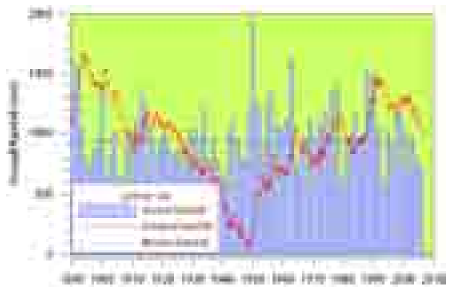
Source: WRL Solutions 1400

# Impacts of Climate Change?

- Warming of 0.2 – 1.6 ºC by 2030, increases in evaporation of 1-8%, changes in rainfall of -7% to +7%, changes in extreme rainfall of -3% to +12%
- It is predicted that the region will be drier and increased evaporation may increase the accumulation of salts, increasing the potential risk of salinisation
- It is also predicted that extreme rainfall event frequency may increase leading to higher velocity stream flow, more erosion events and leaching of salts accumulated in the soils to groundwater
- Rainfall, temperature and stream flow changes may increase salinity of the rivers







*Source: Beare and Heaney, 2002 in CSIRO, 2007*



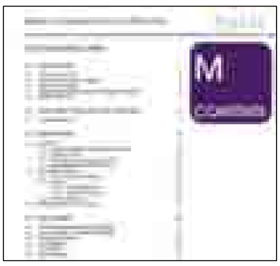
# Principles of Salinity Management

Human impacts on salinity can be prevented by careful management.

Western Sydney Salinity Potential map can be used for the identification of appropriate salinity assessment and management responses.

Site specific salinity investigations, including hydrogeological assessments and water balance assessments may need to be completed to establish the cause of salinity and ensure management is appropriate to the site

Salinity can be managed through the planning process:
- Regional Environmental Plans
- Local Environmental Plans
- Development Control Plans





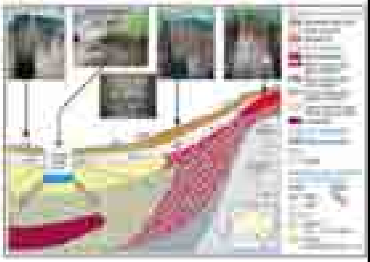
*Source: DIPNR, 2002; WSUD in Sydney, 2003,* Cox et. al., 2002

# Principles of Salinity Management

High risk activities should take special care in completing salinity investigations and establishing salinity management plans.

High risk activities include:

- Quarrying
- intensive agriculture
- activities involving high levels of irrigation
- large scale artificial water bodies
- infiltration to soil or groundwater
- waste water re-use or treatment systems
- major landscape re-shaping



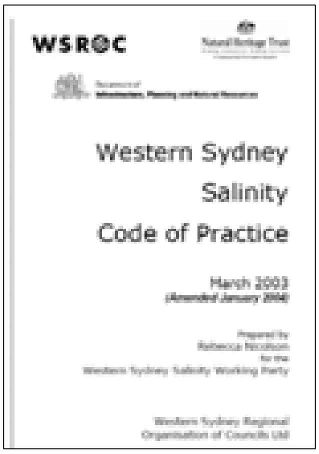


*Source: DIPNR, 2002; WSUD in Sydney, 2003,* Cox et. al., 2002



# Principles of Salinity Management

- Know the salinity processes on the site.
- Maintain natural water balance.
- Maintain good drainage.
- Avoid disturbance or exposure of sensitive soils.
- Retain or increase vegetation in strategic areas.
- Implement building controls and/or engineering responses where appropriate



WSROC

Western Sydney

Salinity

Code of Practice

March 2003

In following these principles, developers must:

- design adequate drainage
- establish gardens away from buildings
- avoid disruption of natural flow lines
- use salt resistant construction materials and techniques where necessary.
- ensure irrigation should be carefully managed to maintain an appropriate water balance using low salinity water sources



*Source: DIPNR, 2002; WSUD in Sydney, 2003.*

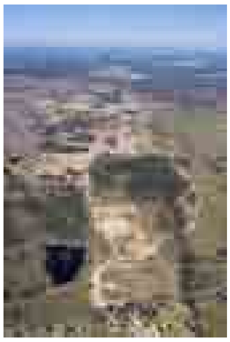
# Case Study: Second Ponds Creek

Second Ponds Creek is a development covering almost 400 ha in the Blacktown area. Salinity issues are intermittent along the creek corridor, peaking in the B2 soil horizon close to the creek, where high sodicity has created dispersive, erosive soils.

Blacktown City Council specified in the development consent that construction must follow the salinity management measures detailed in the Salinity Report commissioned by Council, with consultants overseeing and certifying the salinity compliance of earthworks completed.

During earthworks, different soil horizons were stockpiled separately and replaced as found, and were certified as being in compliance with the Salinity Report. Gypsum was mixed with the sodic B2 horizon to minimize the effects of sodicity, and encourage vegetation growth.

Deep rooted vegetation was planted on public green space to maintain the water balance of the site



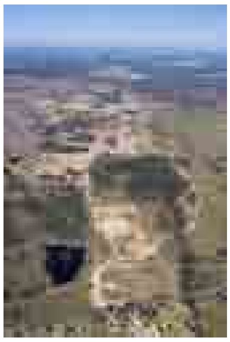
Source: Holmick, 2007, Cox et. al., 2002





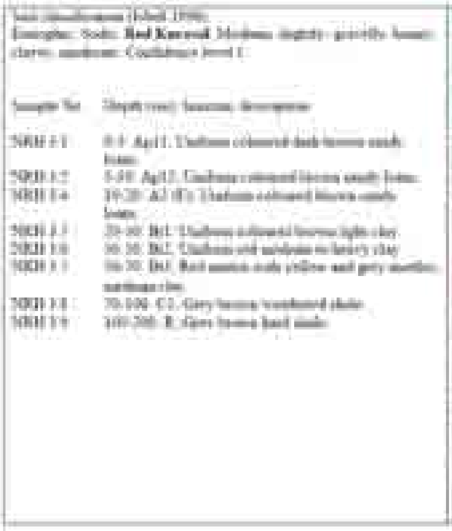
# Case Study: Second Ponds Creek

- All subsoils within 150 m of the creek were sodic (ESP > 15%) and highly dispersive when in contact with low salinity water (e.g. rainwater) and some of these soils had pronounced shrink-swell characteristics.
- Subsoils 20 m either side of the creek were highly saline (i.e. EC > 16 dS/m) due to saline groundwater
- Subsoils 20 to 150 m from the creek were moderately saline (i.e. EC 4 to 8 dS/m) due to leaching of salts in rainfall and natural weathering processes and salt accumulation around the rootzone of past vegetation.
- Some very acid subsoil layers were present and sulfidic materials of unknown extent were observed in the vicinity of the creek.
- The weathered shale layer might have presented problems for buildings and infrastructure (salinity)
- Waterlogging extensive due to a sodic clay B horizon



Source: Cox et. al., 2002

# Case Study: Second Ponds Creek

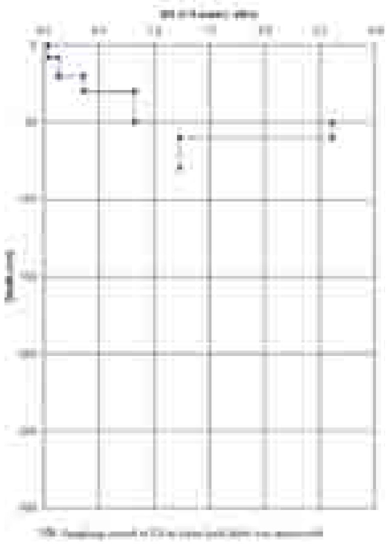


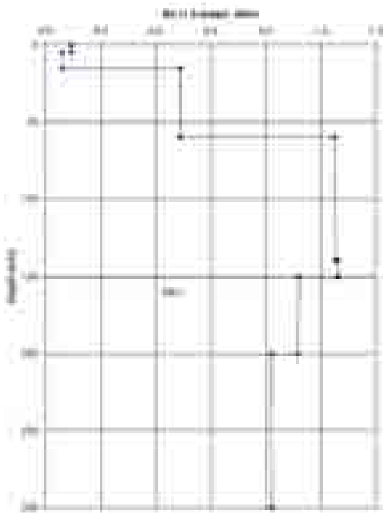


Source: Cox et. al., 2002



# Case Study: Second Ponds Creek







Source: Cox et. al., 2002

# Case Study: Second Ponds Creek

Table 1. Electrical conductivity, salinity hazard, potential impacts of salinity on plants and pH of soil samples

| Sample | Depth cm | $EC_{1:5}$ dS/m | $EC_e$† dS/m | Salinity hazard | Effect on plants | $pH_{1:5}$ (soil:water) | pH (0.01M $CaCl_2$) |
|---|---|---|---|---|---|---|---|
| NRH 1.1 | 0-5 | 0.11 | 1.12 | Non saline | Negligible | 5.9 | 4.9 |
| NRH 1.2 | 5-10 | 0.07 | 0.71 | Non saline | Negligible | 6.2 | 5.0 |
| NRH 1.3 | 10-40 | 0.03 | 0.37 | Non saline | Negligible | 6.9 | 5.5 |
| NRH 1.4 | 40-60 | 0.12 | 1.82 | Non saline | Negligible | 5.6 | 4.5 |
| NRH 1.5 | 60-90 | 0.49 | 3.23 | Slightly saline | Sensitive plants affected | 5.2 | 4.2 |
| NRH 1.6 | 90-110 | 0.83 | 4.73 | Moderately saline | Many plants affected | 4.7 | 4.0 |
| NRH 1.7 | 170-270 | 0.44 | 4.22 | Moderately saline | Many plants affected | 6.2 | 5.3 |
| NRH 1.8 | 270+ | 0.98 | 6.47 | Moderately saline | Many plants affected | 8.3 | 7.5 |
| NRH 2.1 | 0-5 | 0.07 | 0.71 | Non saline | Negligible | 5.8 | 4.8 |
| NRH 2.2 | 5-10 | 0.05 | 0.31 | Non saline | Negligible | 6.3 | 4.9 |
| NRH 2.3 | 10-25 | 0.05 | 0.31 | Non saline | Negligible | 7.0 | 5.5 |
| NRH 2.4 | 25-40 | 0.13 | 0.86 | Non saline | Negligible | 7.3 | 6.2 |
| NRH 2.5 | 40-80 | 0.33 | 2.36 | Slightly saline | Sensitive plants affected | 6.9 | 6.0 |
| NRH 2.6 | 80-170 | 0.76 | 5.85 | Moderately saline | Many plants affected | 5.9 | 5.4 |
| NRH 2.7 | 170-250 | 0.74 | 5.70 | Moderately saline | Many plants affected | 6.5 | 5.9 |
| NRH 2.8 | 250+ | 0.93 | 6.34 | Moderately saline | Many plants affected | 6.4 | 5.9 |

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Source: Cox et. al., 2002

Groundwater Workshop – S4

# Scenario Questions to Consider

Some residents have reported that salt seeps and scalds are appearing on their streets and driveways… or

A development is proposed in a high salt risk area…

What should be the roles of council, DWE and DECC in responding to the reports / assessing the DA?

What investigations should be undertaken to determine the cause of the salt seeps and scalds / nature of the salinity at the proposed site?

What should Council look for in the DA to be satisfied that salinity is being addressed appropriately?

What procedures and planning instruments do Council have in place for managing urban salinity?

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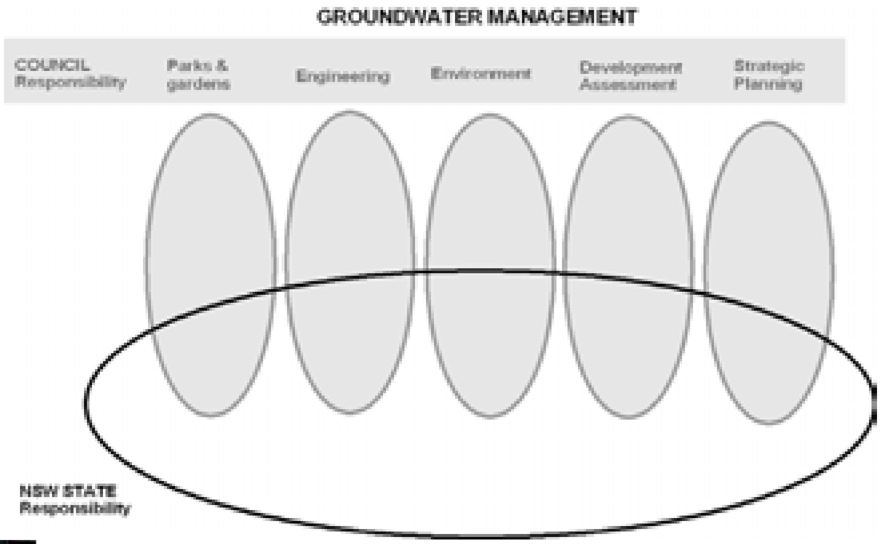
# Scenario Questions to Consider

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*Source: DIPNR, 2002; WSUD in Sydney, 2003.*

# Scenario 5 – Dewatering and Construction

*A number of complaints have been made about a construction site. It has been reported that cracks are appearing on nearby buildings, footpaths adjacent to the site are subsiding and large volumes of discoloured water are being discharged into the gutter.*

- Information from the SCCG *Groundwater Management Handbook*
- Additional Materials:
  - Sample groundwater quality measurements (Botany Aquifer)
  - WA acid sulfate soils guidelines:
  - http://portal.environment.wa.gov.au/portal/page?_pageid=53,84383&_dad=portal&_schema=PORTAL
  - City of Perth dewatering procedures for development applications: http://www.perth.wa.gov.au/web/Business/Planning,-Building,-Health-and-Engineering/Drainage-and-Dewatering/Development-Applications-involving-Dewatering/
  - WA dewatering water quality protection note: http://portal.environment.wa.gov.au/pls/portal/docs/PAGE/DOE_ADMIN/GUIDELINE_REPOSITORY/DEWATERING.PDF
- Case examples
  - Botany Road, Waterloo (March 2008) ?
  - Eastern Distributor
- Questions to consider

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## Information from the SCCG *Groundwater Management Handbook*

Ch4 Legislation, Policy and Other Instruments (addressed in morning session)

Construction, Development and Dewatering

- SCCG (2006) Fact Sheet 5: Development and Construction
- Ch5 p52-66: Construction in Aquifers
  - p52 Site Investigations
  - p53-57 During Construction
  - p57-60 Long Term Impacts
  - p62-63 Groundwater Level Monitoring
  - p63-64 Water Quality Monitoring
  - p64-66 Reporting Requirements
  - p67-71 Suggested Development Controls
- Ch6 Groundwater Management in NSW
  - pg76-78 Information Requirements for Construction Dewatering
- Ch7 Groundwater Quality and Contamination
  - p98 Acid Sulphate Soils

Ch7 Groundwater Quality and Contamination (addressed in Scenario 2)
Ch8 GDEs (addressed in Scenario 1)
Ch9 Hydrogeological Mapping (addressed in Scenario 2)

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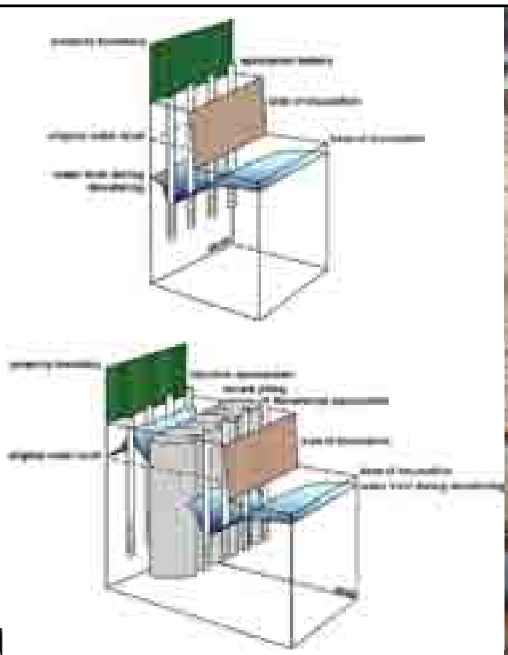

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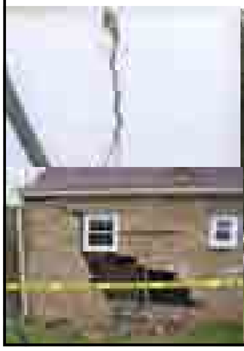
Source: Schematic courtesy of GNR (SCCG Groundwater Management Handbook). Photos courtesy of WAT (WRL)



## Why is Dewatering Important?

- The abstraction of too much water can cause subsidence. Buildings, footpaths and roads may collapse.
- Groundwater quality may be poor or contaminated and require treatment prior to discharge.



http://cni-fl.com/images/mvc-034f.jpg

http://porussolutions.com/assets/images/dewatering.jpeg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Source: SCCG Groundwater Management Handbook

# Subsidence due to poor construction techniques

Source: South Sydney Herald (May 2008)

## Why is dewatering important?

What were the costs of the Botany Rd Collapse?

- 364 truckloads (4732 tonnes) of crushed sandstone? Approximately $600,000
- Police, Sydney Water, Department of Commerce, RTA and BBB Constructions employees scrambling to blame each other?
- A supreme court case?
- A six week road closure to commuters and businesses?
- Provision of temporary housing to displaced residents?
- All that negative media attention?



Source: WRL projects



## How much dewatering is too much?

Depends on:

- the size of the construction site
- the proposed dewatering method
- the nature of pre-construction groundwater flow near the site
- the geology beneath and around the construction site

Steps to determine how much is too much:

- a geotechnical engineer or hydrogeologist determines the nature of pre-construction groundwater flow near the site
- a geotechnical engineer estimates the amount of water that can be safely removed from the ground.
- a council officer or independent expert cross-checks the geotechnical assessment with similar assessments from nearby developments (past and present)

*Geology beneath a site may vary considerably and site investigations may miss key features that ultimately result in subsidence. It should be a condition of the DA that dewatering operations be monitored for unexpected water level changes and subsidence effects and that discharge volumes be recorded.*



Source: SCCG Groundwater Management Handbook

# What water quality issues may exist?

It should always be assumed that groundwater in urban catchments will have some quality problems and will requiring treatment prior to discharge. It should also be assumed that groundwater quality will change with time.

Quality issues with groundwater may include:

- Nutrients (from application of fertilizers)
- Hydrocarbons (from petrol stations or industrial sites)
- High or low pH (perhaps from acid sulphate soils)
- Saline intrusion from pumping (refer to fact sheet)

*A DA involving dewatering should not be approved unless there has been a check of the contaminated sites register and all necessary precautions are in place.*

*Water quality samples should be obtained, analysed, interpreted and reported to Council and DWE prior to the commencement of dewatering and regularly throughout the construction period.*



Source: SCCG Groundwater Management Handbook

Groundwater Workshop – S5

# Sample Chemical Analysis

Sample chemical analysis from construction site tailwater:

A monitoring report to Council and DWE containing such data should also contain interpretations by a qualified hydrogeologist. The interpretation should specify any issues with the groundwater quality and whether it can be safely discharged to the proposed location (i.e. stormwater or aquifer reinjection)

Note that organochlorides and hydrocarbons were not sampled in this analysis. This should be justified by the hydrogeologist (i.e. no petrol stations or industry have ever been located nearby)

| Parameter (concentration mg/L unless indicated) | Guidelines for fresh waters (ANZECC, 2000) | Guideline for secondary contact (ANZECC, 2000) | Groundwater discharge | Lower Limit of Analysis |
|---|---|---|---|---|
| EC (µS/cm) @ 25°C | [illegible] | | [illegible] | |
| pH | 6.5-8.5 | | [illegible] | |
| Temperature (°C) | [illegible] | | [illegible] | |
| Dissolved oxygen (mg/L) | [illegible] | | [illegible] | |
| Calcium | | | [illegible] | |
| Magnesium | | | [illegible] | |
| Sodium | | | [illegible] | |
| Potassium | | | [illegible] | |
| Alkalinity as CaCO3 | | | 44 | |
| Sulphate | | | [illegible] | |
| Chloride | | | [illegible] | |
| Iron - total | 1000 | | [illegible] | 0.01 |
| Arsenic - total | [illegible] | | [illegible] | [illegible] |
| Cadmium - total | [illegible] | | BDL | [illegible] |
| Chromium - total | [illegible] | | BDL | [illegible] |
| Copper - total | [illegible] | | BDL | [illegible] |
| Nickel - total | [illegible] | | BDL | [illegible] |
| Lead - total | [illegible] | | BDL | [illegible] |
| [illegible] | | | [illegible] | [illegible] |
| Thermotolerant coliforms [illegible] | | [illegible] | [illegible] | |
| Total cations (meq/L) | | | [illegible] | |
| Total anions (meq/L) | | | [illegible] | |
| Total Dissolved Solids | | | [illegible] | |

BDL is below detection limit

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## What are Acid Sulphate Soils (ASS)?

ASS are soils containing iron sulphides (i.e. pyrites)

ASS are common in coastal areas

When exposed to air (i.e. from excavation or dewatering) ASS react with oxygen to generate large amounts of sulphuric acid (pH < 4)

Discharge of groundwater containing sulphuric acid can damage infrastructure and cause ecological damage (i.e. fish kills)

ASS Risk zones in NSW have been mapped by DWE and can be accessed online via the Natural Resource Atlas at:
http://www.nratlas.nsw.gov.au/

*Council should not approve dewatering applications in an ASS risk zone unless a DA includes a hydrogeological assessment stating that ASS are not present in the zone affected by dewatering*

Source: WCG, WRL



## When should dewatering be considered by Council?

Dewatering should be considered during the development application stage of any construction project.

Dewatering will be required if construction occurs below the water table and other construction methods (i.e. tanking) are not feasible

Dewatering requires a licence from DWE (and it is only valid for 1yr). Permanent dewatering will not be approved by DWE

A licence <u>may not be required</u> by DWE if the development is in unconsolidated deposits (like sands and alluvium) and:

- the duration of dewatering is short (i.e. repair to a pipeline or construction of a swimming pool)
- Water table drawdown does not exceed 0.5 m

A licence <u>may not be required</u> by DWE if the development is located in porous and fractured rocks (i.e. sandstone and shale) provided:

- pumping is not continuous, and
- Groundwater inflows come from a perched aquifer which is limited in extent and is not supporting any ecosystems (i.e. spring discharge)



Source: SCCG Groundwater Management Handbook

# What is the responsibility of the proponent?

The onus is on the developer to:

- undertake the necessary site investigations prior to construction,
- prove that a water table is present or absent,
- assess the feasibility of alternative construction methods,
- assess potential contaminated site, acid sulphate soil and saline intrusion issues,
- design an appropriate and safe dewatering system,
- apply for a dewatering licence,
- provide a detailed geotechnical and hydrogeological report regarding construction dewatering and monitoring,
- design and implement a monitoring program,
- monitor, analyse, interpret and report on dewatering to Council, DWE and possibly DECC throughout construction.

*A full list of DWE licensing requirements for dewatering can be found on page 77 of the groundwater management handbook. Could these become consent conditions for the development?*



Source: SCCG Groundwater Management Handbook

Groundwater Workshop – S5

# Dewatering Licence Requirements

A bore licence is required for dewatering (refer Scenario 1)

Councils are encouraged by DWE to apply the following requirements for construction developments below the water table (Handbook, pg 77)

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# What is the responsibility of Council?

> **Note**
>
> It is the responsibility of Council to ensure that adequate investigation and assessment has been undertaken by qualified personnel with expertise in the relevant field (e.g. geotechnical engineering, civil engineering, etc.) prior to the approval of any Development Application.

Council should be satisfied that the proponent has met the DWE licensing requirements. In particular that the proponent has:

- realistically and accurately assessed the water table location
- demonstrated that dewatering is the only feasible construction option
- proposed an appropriate dewatering method and assessed impacts
- checked the contaminated sites register and liaised with Council and DECC regarding any water quality treatment that may be required
- implemented a monitoring, analysis, interpretation and reporting program and will report to Council, DWE (and maybe DECC) on a regular basis
- been notified to inform Council of unexpected site conditions (such as water tables or high seepage rates) and subsidence issues



Source: SCCG Groundwater Management Handbook



# What can Council do?

*Council can:*

- *use geotechnical and hydrogeological assessments in previous DA's (and groundwater level monitoring data where available) to cross-check whether a water table may be present and whether the proposed dewatering volumes are appropriate*
- *review monitoring results and complaints regarding subsidence and action relevant approval conditions in the DA*
- *seek review from an independent geotechnical engineer, hydrogeologist or DWE if they are concerned about a construction dewatering proposal or activity*
- *Refuse applications requiring permanent dewatering unless they have been approved by DWE*
- *Set and enforce approval conditions on a development application which require best practice*



Source: SCCG Groundwater Management Handbook

# Scenario Questions to Consider

The public have reported subsidence of the footpath around a construction site and have complained about the quality and volumes of water being discharged to the storm water system.

1) What should you do and what might happen if you don't?

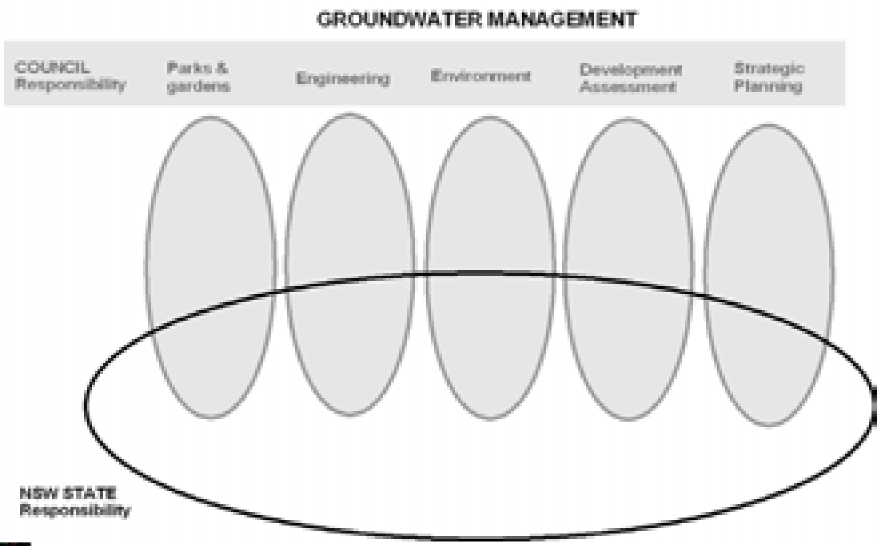
2) What could be improved for the next development application?

- What should be the roles of council, DWE and DECC in assessing the DA?
- What information did council require to approve dewatering?
- What approval conditions for construction and dewatering?
- What planning 'loopholes' or resource assessment errors might allow subsidence to occur? Can you prevent these?
- How can you enforce appropriate monitoring and reporting by the proponent?
- What can be done to prevent discharge of water to the stormwater system?
- What should be done if the water quality was acidic or contaminated and how should this be detected in advance?





# Scenario Questions to Consider



# Suggested Questions to Consider:

**Did the Geotechnical and Hydrogeological Reports:**

- Clearly describe the material properties and condition of the subsurface both on and around the site (especially those like clay which might be prone to subsidence)?
- Report on the contamination status of the site
- Detail the depth of the excavation?
- Demonstrate that the water table and groundwater flow direction had been measured accurately both on and around the site prior to construction and dewatering?
- Propose different methods of construction work below the water table?
- Determine what groundwater pressure changes might cause geotechnical failure of the excavation walls or floor?
- Include a quantitative assessment of errors or uncertainty in the assessment? i.e. what natural groundwater level change or rate of groundwater pumping might cause subsidence issues?
- Demonstrate that groundwater quality was safe for aquatic ecosystems and secondary contact and soils were free of acid sulphate soils
- Design a satisfactory ongoing water quality monitoring and geotechnical and hydrogeological assessment program that would regularly report to council, DWE, or DECC? What is a satisfactory groundwater monitoring program? What happens if offsite conditions change? i.e. groundwater abstraction from supply or dewatering at another site?
- Identify whether pumping might cause saline intrusion?

**Does Council have any Groundwater mapping information or data from previous assessments which can be compared to the current assessment?**

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Groundwater Workshop – S5

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Source: SCCG Groundwater Management Handbook

## Scenario 6 – Managed aquifer recharge

*A Council golf course proposed to harvest stormwater from a shopping complex and store it underground for irrigation. It is unknown whether a suitable aquifer is available or what the benefits/risks area.*

- Information from the SCCG *Groundwater Management Handbook*
- Additional information
  - update on Australian MAR guidelines (May, 2008)
  - common local issues
- Case example
  - Botany aquifer and other sandy aquifers
- Questions to consider





## Information from the SCCG *Groundwater Management Handbook*

Ch4 Legislation, Policy and Other Instruments

- EPAA 1979, PEOA 1997, WMA 2000, CLMA 1997

Ch6 Groundwater Management

- p83 sustainable yields & local impacts
- p80 artificial recharge

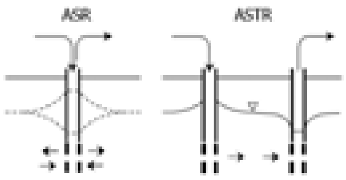
Ch7 Groundwater Quality & Contamination (covered in S2)

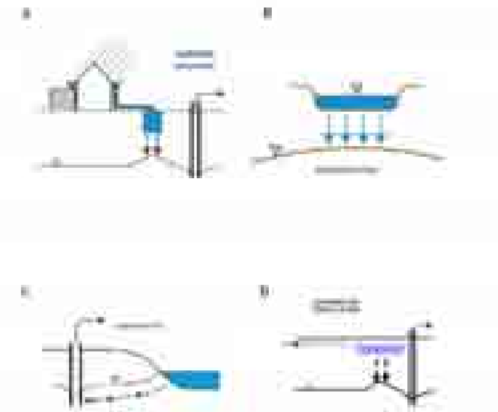
## Managed aquifer recharge (MAR)

**Harvest stormwater & treated wastewater**
**For recharge via injection bores & leaky structures**

**Objectives:**

**1. Boost storage for beneficial use**
**2. Improved water quality**
**3. Storage without evaporative losses**
**4. Flood mitigation**



Dillon 2006



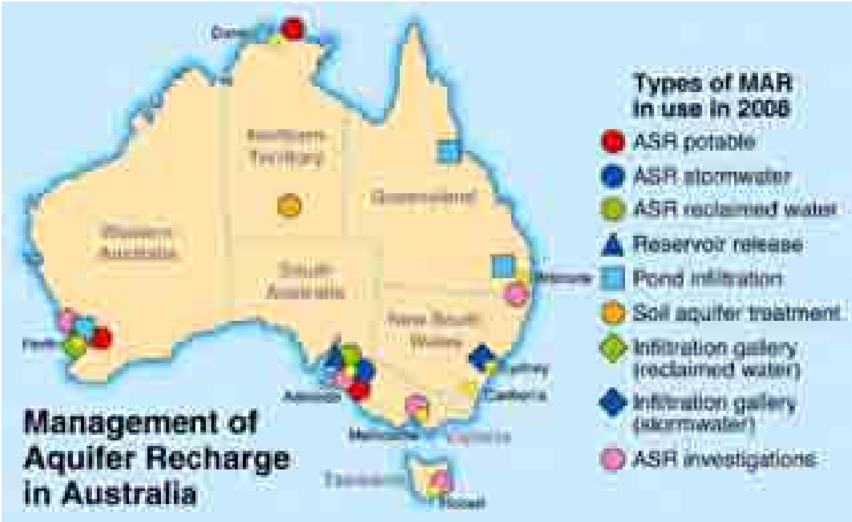
## MAR in Australia

Pioneered in Burdekin area, Qld.

Adelaide
~22 ASR schemes using ponds, galleries & injection bores
• artificially recharge treated stormwater and wastewater
• mostly confined limestone aquifers

Perth – sand aquifers
• gw supplies 70% of water use
• gw supplies 30% of potable water
• practice MAR with stormwater
• trials beginning with treated wastewat

New in Sydney
eg UNSW Village Green




MAR: An Introduction
(May 2009)

## Aquifer recharge - part of the treatment train

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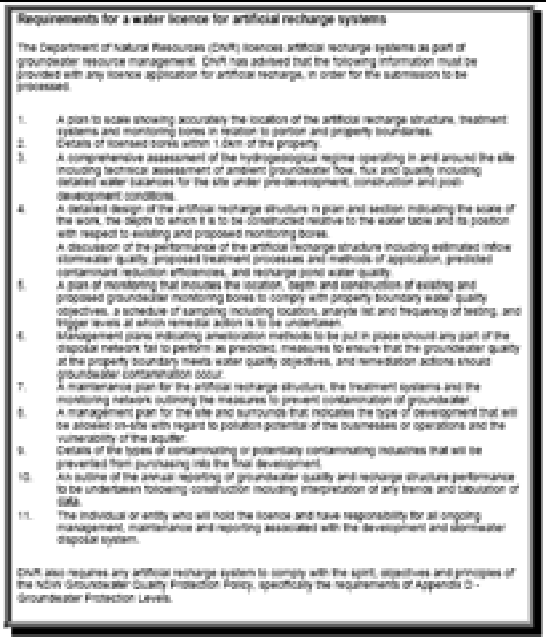
## NSW licenses for artificial recharge systems


Requirements for a water licence for artificial recharge systems

The Department of Natural Resources (DNR) licences artificial recharge systems as part of groundwater resource management. DNR has advised that the following information must be provided with any licence application for artificial recharge, in order for the submission to be processed.

SCCG Groundwater Handbook p81



## Australian MAR Guidelines ……draft May 2008

- All NWQMS guidelines adopt precautionary principles & risk management
- Part of 2nd phase of water recycling guidelines
- Effective implementation of MAR is a test of integrated water resources management in any jurisdiction because it involves quantity + quality; surface water + groundwater
- Guidelines aim to minimise time & effort for successful schemes, reduce risks & failures, early warning of extent of work required, discard unlikely projects at an early stage

Includes

- Hazard analysis – pathogens, nutrients, pressure, waterlogging, aquitard stability etc.
- Risk profile – level of acceptable risk at each stage of investigation
- Entry level risk assessment checklist

**Also State guidelines/codes for MAR:**
SA EPA, 2002
Vic SWF Technical Guidance for ASR, March 2006

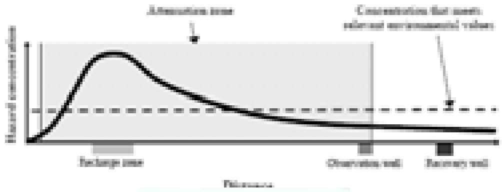
## Australian MAR Guidelines ……draft May 2008

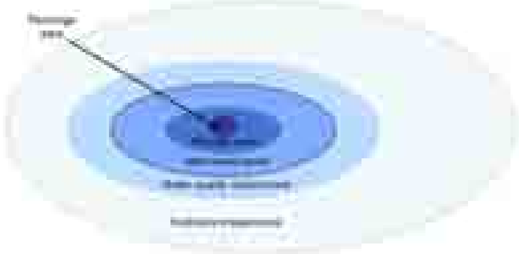
• Guidelines allow for attenuation zone during recharge
eg. 50 m around a stormwater MAR

Attenuation requirements depend on:
• source water quality
• environmental values for groundwater quality

eg. Pathogens in wastewater require specific residence time for inactivation

Eg. Nutrients in stormwater may require either pre-treatment or soil-aquifer-treatment



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## MAR: An Introduction Feb 2009

www.nwc.gov.au/resources/documents/Waterlines_MAR_completeREPLACE.pdf


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## Case example – stormwater diversion

**Weir to divert stormwater**

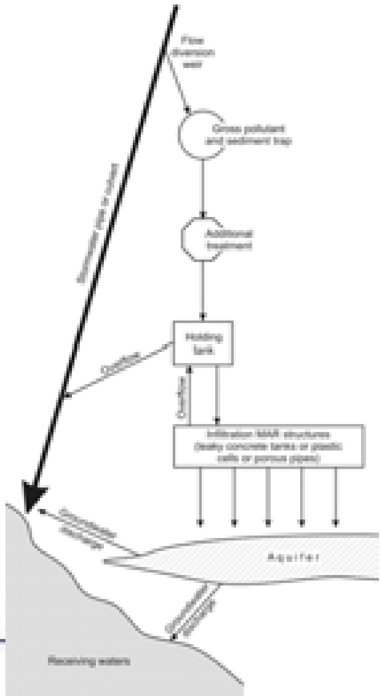
- MAR is add-on rather than replacement of existing stormwater system
- Flows needed for flushing & environmental requirements ?

**Low flow diversion**

- for stormwater harvesting
- 90-97% of total yield from <1 in 3 mth ARI events (Wong et al. 2000)

**High flow diversion**

- assist with flood mitigation
- multiple systems distributed in sub-catchments required for large events

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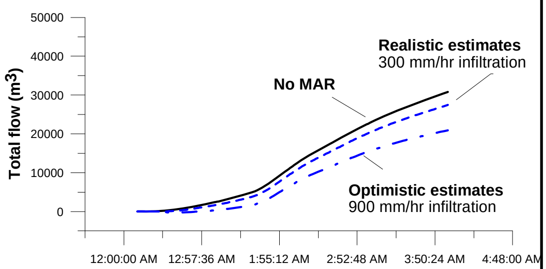
## Case example – stormwater diversion

- Preliminary stormwater modelling with various MAR scenarios
- Hydraulic performance of MAR structures is very sensitive to infiltration rates
- Quoted infiltration rates appear optimistic, particularly over long term
- Realistic infiltration rates depend on methodology, duration & depth of testing with upscaling issues etc.
- Next steps - continuous modelling, improved infiltration loss data, coupling with groundwater flow models




**Calculations using modelled stormwater hydrograph**
1 in 100 yr ARI storm
~100 hectare catchment
Peak pipe flow ~ 4 $m^3$/s
~3,000 $m^2$ infiltration gallery

Courtesy: City of Sydney

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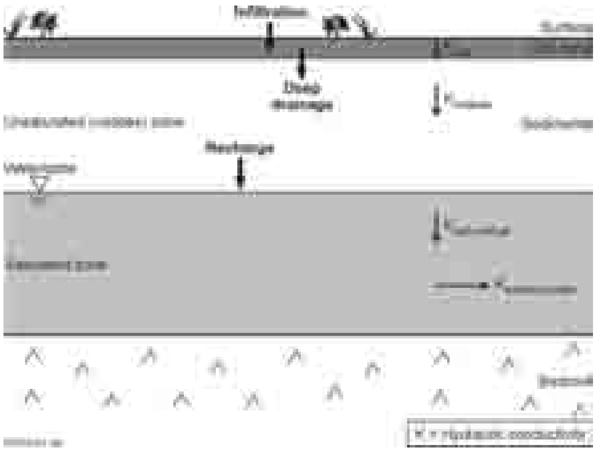
## Infiltration, deep drainage and recharge

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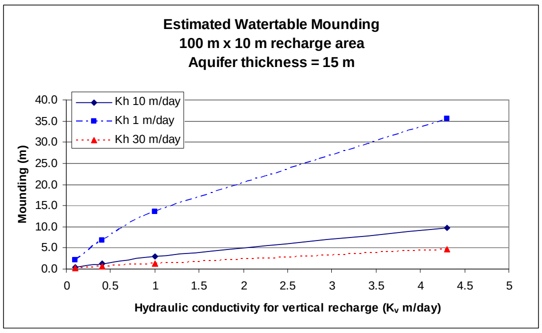
## Common local issues with MAR in sandy aquifers

- Draft Australian MAR guideline (May, 2008) require higher level of assessment for urban sites where watertables <8 m below ground – good opportunities going into “too hard basket”
- Infiltration rates quoted by market suppliers appear optimistic, particularly over long term
- Inappropriate permeability measures & flow estimates
  - $K_v$ vs. $K_h$
  - Saturated vs. unsaturated
  - Surface vs. target depth
- Can use analytical estimates of predicted height & lateral extent of mounding, then numerical modelling if required
- Currently lack of ‘pioneering’ examples where success has been proven




WRL estimates

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## The Botany aquifer

- Hydraulic connection is one-way towards south & south-west
- Groundwater levels in north-east of aquifer are **~40 m above** levels at Botany Bay
- Water moves through sand aquifer at about **150 metres per year**
- ~**60 years** travel time over **~8 km** from Centennial Park recharge area to Botany Bay over
- excessive groundwater pumping can cause minor northwards flow

  Zones 1 major contaminated area

  Zones 2-4 point contamination

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## Pre-feasibility assessment

**www.nwc.gov.au/publications**

**Study by UNSW-WRL & UTS in November 2006**
**Funded by National Water Commission**

**Hydrogeological attributes**
- located where water is needed
- shallow sandy aquifer – cost effective access
- only significant aquifer in Sydney region
- high recharge rates, high permeability
- continuous base groundwater supply
- no need to wait years for recharge
- generally high quality water in north-east
- sustainable yield & usage largely unknown

**Potential for MAR**
- water treatment required – pre & post
- many types of MAR may be suitable
- potential for multiple MAR schemes
  - each scheme ~ 5 ML/day
- total capacity comparable to small recycling schemes
  - possibly ~7 billion L/year ???
- significant knowledge gaps identified

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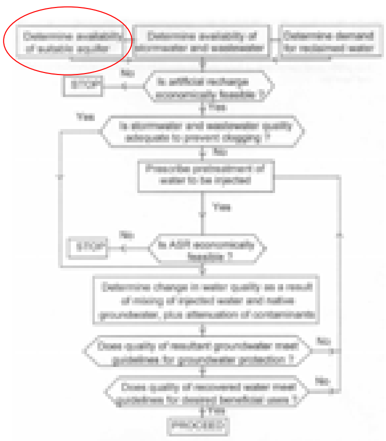
# Assumptions & limitations of report

**Limitations**
- Rapid desktop assessment
- First pass assessment focused mainly on hydrogeological aspects
- No updated hydrograph data
- Current status of Botany aquifer not well defined
- Groundwater investigations have been for specific projects, rather than catchment scale

**Assumptions**
- Economic feasibility
- Demand for additional groundwater supplies
- Suitable source waters are available for recharge
- Regulatory issues and rights to a proportion of extra recharge & recovered water to be addressed




Source: Dillon and Pavelic, 199



# How much extra groundwater ?

- About 20 million liters per day of additional groundwater supply ?
- Continuous base load of water which is sustainable over long term
- Minimal footprint impact for ASR bores
- Insures amenity of green spaces and ponds south of Sydney City
- Relatively accessible, water is close to surface
- Lower costs than pumping water from deep rock bores or up to Warragamba Dam

| Project | Million L/day | Billion L/ 10 yrs |
|---|---|---|
| Daily usage – Sydney Water | 1380 | |
| Bondi STP discharge | ~200 | |
| *Nepean rock bores** | *50 ??* | *36.5 ??* |
| Blue Scope Steel, Illawarra | 20 | |
| Rouse Hill | 3.5 to 9 | |
| *CP ponds-aquifer* | *5 ?* | *18 ?* |
| *Northeast Botany aquifer* | *20 ?* | *72 ?* |
| West Camden | 5 | |
| Carlton Farm, Picton | 0.8 to 4 | |
| Dunheved Golf Course | 0.35 to 0.5 | |
| Liverpool Golf Course | 0.15 | |
| Kogarah sewer mining | 0.1 to 0.75 | |

* Nepean bores pumping 2 years, recovery 8 years

## Water quality - protection & natural attenuation

**Source water protection required for vulnerable shallow sand aquifers**

Zone I - 50 day travel time

Zone II - 400 day travel time

Zone III – catchment

**Aquifers can be an excellent natural filter and attenuation media**

– Trace metals in stormwater
– Nutrients like phosphorous
– Bacteria & pathogens
– Chemicals of concern
  eg. PhACs

**Careful management to protect groundwater supplies needed**

eg. HACCP


Sydney Morning Herald 6/8/06



## Challenges for Managed Aquifer Recharge

**What we don't know….**

- Data for northeast Botany aquifer – depth, hydraulic characteristics
- Current groundwater usage is not metered, many unlicensed bores
- Percentage of rainfall recharge – spatial & temporal variability
- Potential for clogging of aquifer pores
- Capacity of sediments to remove contaminants
- Residence time of bacteria & pathogens in aquifer

**Water quality challenges….**

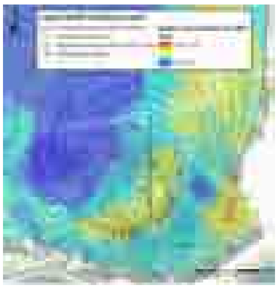
- Turbidity and suspended solids in available water
- Ensuring water quality is maintained or improved
- Iron bio-fouling of injection and pump bores

**Operational challenges….**

- Delivery of captured stormwater to recharge points
- Maintaining natural groundwater levels for dependent ecosystems
- Currently no allocation system for crediting ASR inputs
- Retrieving the same water, or an equivalent volume of water
- Geotechnical constraints in urban areas

⇒ **Need site investigations, research of unknowns, feasibility assessments, groundwater flow and geochemical modelling, pilot testing and on-going monitoring**

Iron bio-fouling



Groundwater flow modelling

## Case example – MAR @ UNSW

**Objective to harvest stormwater & boost groundwater yield**

•Installed in Sep06 under playing field "Village Green" as condition of consent for new buildings

• Subsurface storage cells (1 ML) infiltrates to groundwater

• ~180 ML/ yr for irrigation, cooling towers & toilet flushing

Increased groundwater pumping from 130 to 350 ML/yr ?

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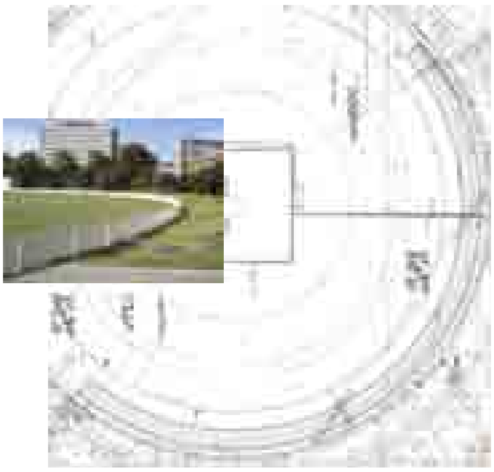
## MAR @ UNSW



**Detention system**

Village Green also acts as a stormwater detention basin - drains 60% of campus for 5 yr ARI storms

**Recharge system**

Reduced flood discharge to Barker St.
Increased groundwater supply

Construction Budget ~$800 k
Hughes Trueman Engineering
ANA Technical Services

• Includes GPT & CDS Technologies filter
• 900 mm /hr design infiltration rate
• Open polyethylene boxes wrapped in geotextile (Atlantis modular tank system)
• 90% of annual rainfall expected to be harvested to recharge aquifer

**Performance monitoring in progress…**

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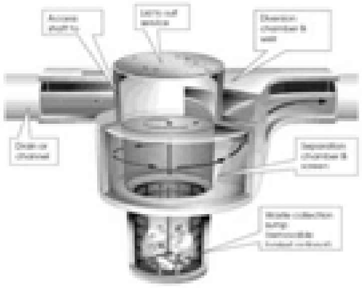
## MAR @ UNSW

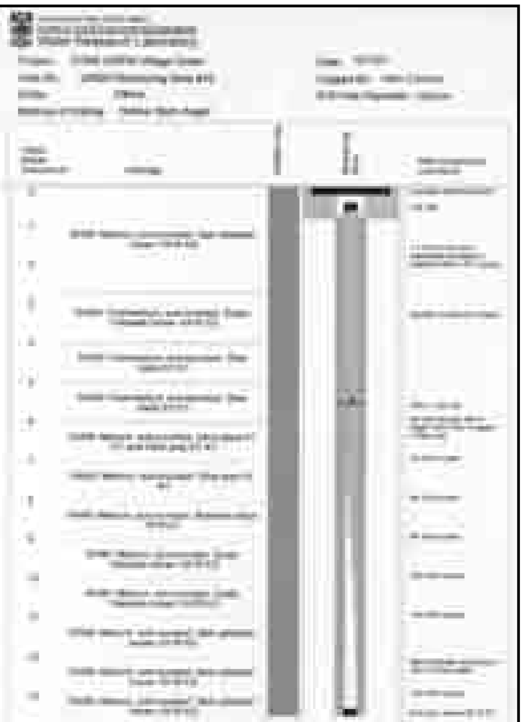
**CDS treatment unit for stormwater**

- Separates litter & sediment + metals
- Effectiveness in removing 80% of heavy metals sorbed on sediments ?





## MAR @ UNSW



## MAR @ UNSW

**Storm event in April 2007**
- harvested water = 8 olympic swimming pools
- about 20 megalitres ?
- about 5% of annual groundwater usage ?
- data to available to verify

**Lessons so far**
- implementation of water level & water quality monitoring before commissioning
- groundwater quality is good but not pristine
- additional stormwater treatment may be required ?
- significant operational costs
- blockages due to gross pollutants is common

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## Questions to consider

- What role can MAR play in future water security ?
- **What are the risks to public health ?**
- Is MAR sustainable ?
- Is MAR cost-effective ?
- Can MAR improve water quality ?
- Will aquifer water quality be protected ?
- What are the suitable beneficial uses ?
- Suitable water sources for recharge ?
- How to protect an urban aquifer catchment ?
- **How to regulate/license MAR schemes ?**
- **Should 100 litres in = 100 litres out ?**
- Design life & long term performance ?
- Public awareness / consultation strategies ?
- How to assess the feasibility of an aquifer site ?
- **Relevant guidelines /codes ?**

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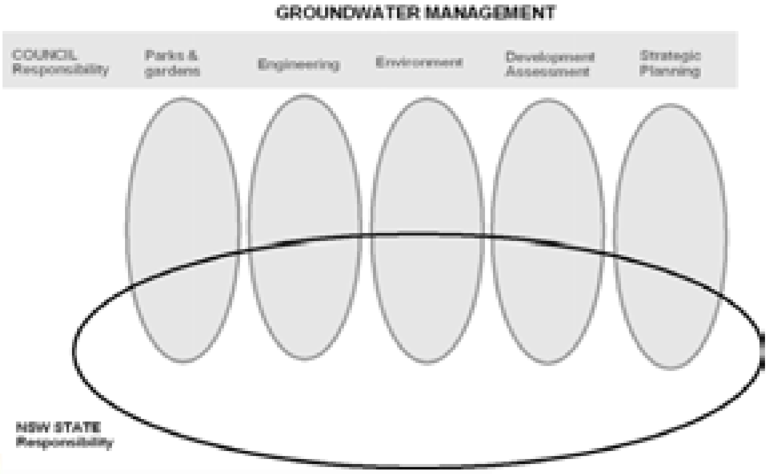
## Role of Councils & State

**An outcome of this workshop aims to clarify who is responsible for which aspects of groundwater management within Councils & State agencies**



# Outcomes, Knowledge Gaps and the Future

## The Future – we can do better !

- Better capacity in local council for groundwater management
- Clarity in council, DWE & DECC roles
- DIY monitoring of groundwater levels & quality
- Efficient usage of groundwater that is extracted
- Updated hydrographs & aquifer status reporting
- Reduced uncertainty in recharge & sustainable yield estimates
- Research to better understand processes & identify emerging issues

Groundwater is increasingly valuable - worth protecting & investing in monitoring, research and information for all stakeholders

.....constrained by available funds & shortage of trained personnel

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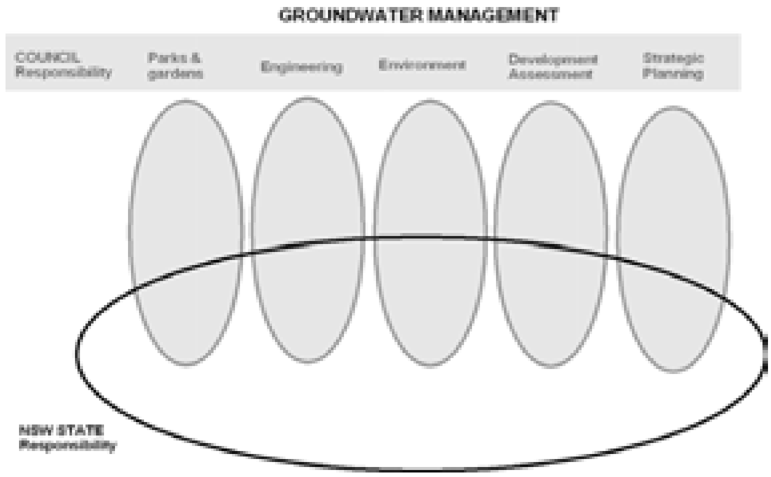
## Role of Councils & State

An outcome of this workshop aims to clarify who is responsible for which aspects of groundwater management within Councils & State agencies

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# Your responsibilities:

**What have you gained from this workshop?**

**1. awareness of local groundwater conditions**

**2. adverse impacts on groundwater are possible from developments**

**3. key NSW groundwater license requirements for council to promote?**

**4. which other sections of council do you need to liaise with to fully implement council's roles & responsibilities?**

**5. actions will you implement to ensure council meets it's responsibilities in groundwater management?**





# Seeking advice?

**Department of Water & Energy**
waterinfo.nsw.gov.au

Water Licensing Unit - Sydney
ph. 02 9895 6263

**Department of Environment & Climate Change**

**Australian Centre for Environmental Law**
www.law.usyd.edu.au/accel

**Australian Drillers Association**
www.adia.com.au

**International Association of Hydrogeologists**
www.iah.org.au

**Australian Contaminated Land Consultants Association**
www.aclca.asn.au

**Centre for Groundwater Studies**
**- technical short courses**
www.groundwater.com.au

**UNSW Connected Waters Initiative**
**– training & research**
www.connectedwaters.unsw.edu.au

## Where to find professional support services….

**International Association of Hydrogeologists (IAH – NSW Branch)**

www.iah.org www.iah.org.au

www.connectedwaters.unsw.edu.au/technical/iah/iah.html

**Check qualifications? Groundwater training typically only at Masters level**
**Check relevant experience? Several specialities within hydrogeology**

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## Do we know enough?

***"We know more about celestial bodies than we do about the earth underfoot"***

**Leonardo De Vinci d. 1519**

***"Our ability to develop computer codes capable of simulating complex systems now exceeds our ability to supply the necessary input data necessary for calibration"***

**Fred Ghassemi, 2000**

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## Technical knowledge gaps – Sydney groundwater

**Groundwater supply sustainability**

- hydrostratigraphy of sandstone – Unit A & C?
- rainfall recharge coefficients of sand aquifers
  - large range of values assumed by various numerical models
  - need independent physical & geochemical & isotopic measures
- viability of managed aquifer recharge schemes (MAR)
  - long term infiltration rates at target depth
  - recharge in shallow watertable areas
- actual costs of ‘self-supply’ of groundwater
- comparative Life Cycle Analysis (LCA) of groundwater & alternatives
- potential impacts of sea-level rise and variable climate
  - saline intrusion & inundation in coastal sand aquifers
  - changing recharge/discharge for inland aquifers

WRL rainfall simulator for recharge studies



## Technical knowledge gaps – Sydney groundwater

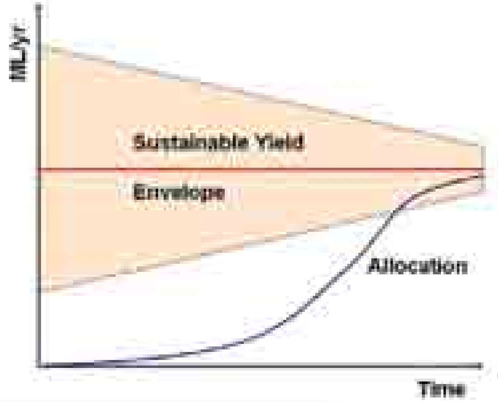
**Groundwater quality & GDEs**

- potential impacts of groundwater extraction & tunnel leakage
  - reduced stream flow ? equilibrium times?
  - groundwater dependent ecosystems ?
- leakage of salt from shales
- monitoring salinity management successes in Western Sydney
- strategies to manage iron bio-fouling of bores
- geochemical & isotopic study of flow sources in sandstone

GDE study in Botany aquifer (Macquarie Uni/UTS testing at UNSW bores)

## The Future – overall aims

- Continued delivery of groundwater resources in 10 yrs & 100 yrs – sustainability
- Equitable access for groundwater users including rivers & environment
- Improved science to reduce uncertainty




Brodie, 2004

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## The Future - improved practices

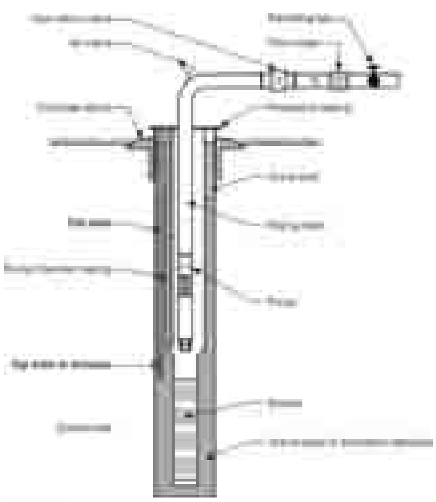
ADIA 2003 Minimum construction requirements for water bores in Australia

AS 2368-1990 Test pumping of water wells

Overlooked design features:

1. Sealing & grouting during bore construction to prevent leakage of saline water
2. Protective bore monuments to prevent seepage down bores
3. Water usage meters & sampling tap
4. Dip tube within casing to enable water level monitoring

Decommissioning old bores – sealing with grout to prevent mixing of saline water



See fact sheets…

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## The Future – real time web info

- Irrigators now rely on real time soil moisture data…
- Why not real time groundwater info ?
- Real time information is at least 5-10 times more expensive than a manual dip measurement 4 times per year – but much more useful to gauge groundwater response to rainfall, flooding and extraction.


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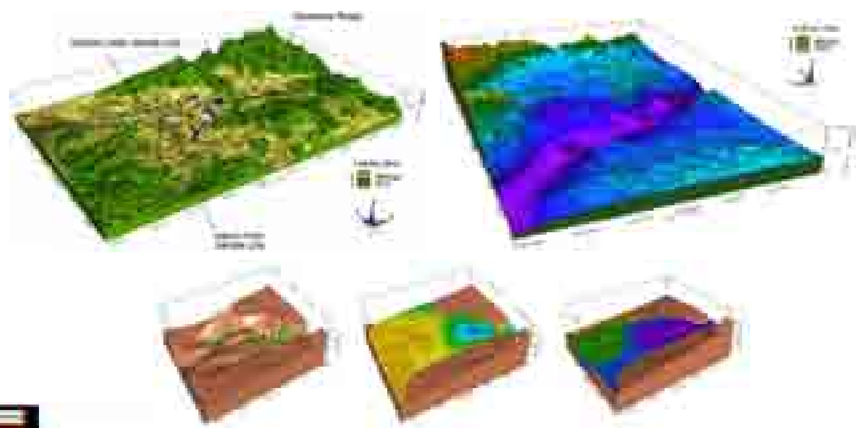
## The Future

- Advanced techniques such as 3D geologic modelling & animations
- Far more useful in understanding real systems than 2D maps
- Widely used by mining industry & increasingly by agricultural sector



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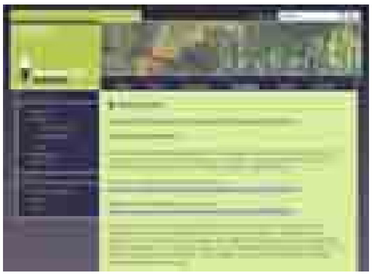
Courtesy – Bryce Kelly
www.connectedwaters.unsw.edu.au

## Do you know enough?

**This 1 day workshop is a great start!**

**Are you interested in further training?**

- **Centre for Groundwater Studies**
  **~3 day courses for in-service training**
  **www.groundwater.com.au**
  **Some of these are run by UNSW WRL**
  **(A core member of CGS)**



- **Shortcourse subjects @ UNSW**
- **Masters by coursework or research**
  **Contact i.acworth@unsw.edu.au**
  **or b.kelly@unsw.edu.au**

  **www.connectedwaters.unsw.edu.au**
  **www.civeng.unsw.edu.au**
  **www.bees.unsw.edu.a**

**When required consult a professional hydrogeologist!**

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## Ground Water + @ UNSW

**Consulting Projects:**

*Bill Peirson (WRL Director)*
*Brett Miller (WRL Manager)*
*James Carley*
*Dr Wendy Timms*
*Dr Wil Glamore*
*Steve Wyllie*
*Doug Anderson*
*Alexandra Badenhop, Conrad Wasko*
*Duncan Raynor, Maureen Schwarz*
*Hamish Studholme*
*& support staff*

- Full time, dedicated project engineers providing expert services to industry & government
- Over 70 projects a year - locally & internationally
- Quality managed for certification AS/NZS ISO9001:2000

**Business areas**
Groundwater, Coasts & Estuaries, Environmental Data, Environmental Modelling, Water Resources, Civil Engineering Hydraulics

**Research Programs:**

*Professor Ian Acworth*
*Assoc/Prof Bryce Kelly*
*Dr Ian Turner*
*Dr Martin Andersen*
*Dr Beatrice Giambastiani*
*Andrew McCallum*
*Anna Greve*
*Hamish Studholme*
*& support staff*

**Connected Waters Initiative**
Funded by Gary Johnston
UNSW Faculty of Science
UNSW Faculty of Engineering
Research Grants

**Cotton Catchment Communities CRC**

**Collaborative Links**
Centre for Water and Wastewater UNSW
US Army Corp of Engineers

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Water Research Laboratory

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*Water Sculpture by the Sea….*

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# Groundwater Management Information Fact Sheets

# Groundwater Management Information Fact Sheet :

## Groundwater & Time

This fact sheet provides a brief review of groundwater flow rates in the context of the hydrologic cycle.

| Hydrologic cycle stages | Average residence time |
|---|---|
| Atmosphere | 9 days |
| Oceans | 3,200 years |
| Glaciers | 20 to 100 years |
| Soil Moisture | 1 to 2 months |
| Lakes | 50 to 100 years |
| Rivers | 2 to 6 months |
| Shallow aquifer | 100 to 200 years |
| Deep aquifer | 10,000 years |

*Source: Pidwirny (2006)*

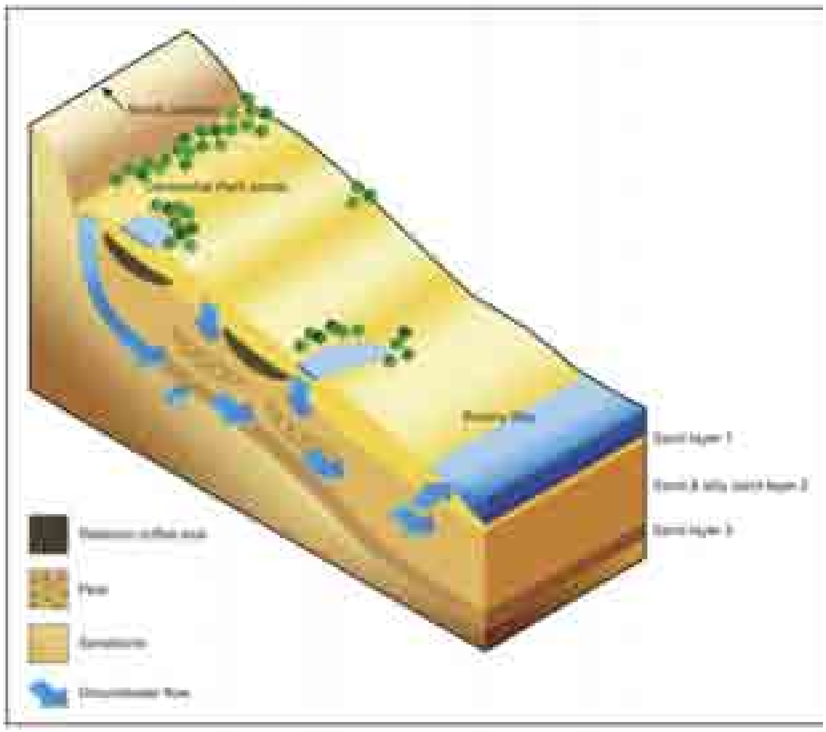
The hydrological cycle represents the transfer of water between different parts of the environment. Water moves through the stages of the hydrologic cycle relatively quickly, or over very long periods of time. The residence time is calculated by dividing the total amount of water at that stage by the rate at which water is added and removed from it. For example, while the residence time of water varies from 9 days in the atmosphere it can be up to to 3,200 years in the oceans. The velocity of water in the hydrologic cycle varies resulting in the estimated ranges of residence time. For example, glaciers can move in millimetres or several metres per day.

Water stored as groundwater generally has a long residence times and relatively slow rates of flow compared to the movement of surface water. Groundwater flow can occur over both very short and very long time scales, depending on the length of the flow path, the permeability (or hydraulic conductivity) of the substrate and the pressure gradient that drives flow.

Flow through the various types of sub-surface materials is as follows:

- Aquifer – relatively rapid groundwater flow through relatively porous and permeable substrates
- Aquitard – relatively slow groundwater flow through low permeability substrate
- Aquiclude – no flow though a substrate that is virtually impermeable to groundwater

A confined aquifer is overlain by a relatively impermeable layer of rock or sediment that acts as either an aquiclude or aquitard. These relatively impermeable materials can effectively disconnect water sources and often protect an underlying aquifer from pollution at the surface. In contrast, a watertable aquifer is an unconfined aquifer where the groundwater level marks the boundary between the unsaturated and saturated zone.



The figure left (not to scale !) indicates the groundwater flow paths in the Botany sand aquifer. Groundwater flows at a rate of about 150 m/year from the upper catchment (primary recharge areas), to discharge into creeks and Botany Bay. A drop of rain that falls on Centennial Park takes about 60 years to make its way down to Botany Bay.

*(Source: Modified from Sydney Morning Herald, 26/8/2006)*

As shown in the Table (see over), the time taken for water to flow through aquitard materials can be thousands to millions of years. Sandstones and coal seams can be either aquifers or aquitards depending on

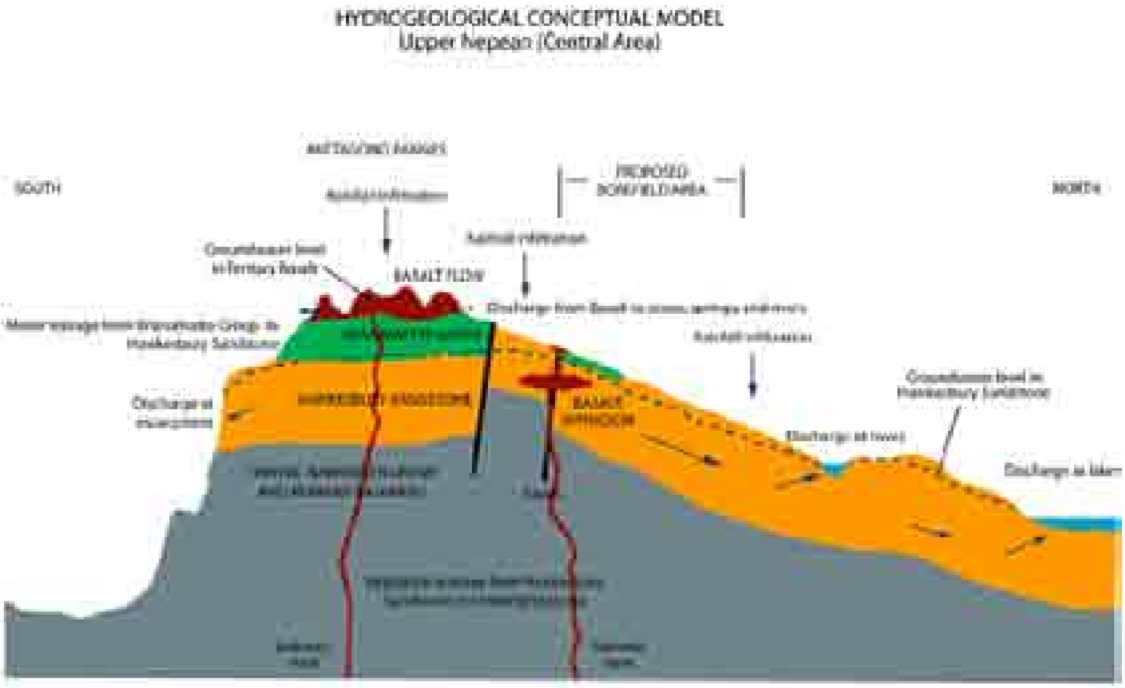
The information in this fact sheet has been has been prepared by the UNSW Water Research Laboratory as part of the Groundwater Education Project in partnership with the following organisations:

many site specific factors. At the other end of the scale, much faster travel times are typical of gravel and sand aquifers. Flow rates in sand aquifers are <1 m/year where there are low pressure gradients due to flat topography. In contrast, flow rates about 150 m/year were measured in the Botany sand aquifer where there is a 40 m height difference over less than 8 km.

| Groundwater system | Geology | Hydraulic conductivity (m/day) | Groundwater flow (ML/year)[#] | | Time to travel 100 metres (days)* |
|---|---|---|---|---|---|
| | | | @ low gradient | @ high gradient | |
| Aquitard | Clay – wet | 0.0001 | 0.000007 | 0.004 | 2,000,000 |
| | Clay liner | 0.001 | 0.00007 | 0.04 | 200,000 |
| | Sandstone 1 | 0.01 | 0.007 | 0.4 | 20,000 |
| | Coal seam 1 | 0.1 | 0.07 | 4 | 2,000 |
| Aquifer | Shoestring sand | 0.4 | 0.28 | 16 | 500 |
| | Sandstone 2 | 1 | 0.7 | 40 | 200 |
| | Coal seam 2 | 2.0 | 1.5 | 70 | 100 |
| | Gravel aquifers | 10 | 7.3 | 400 | 20 |

# Low hydraulic gradient = 0.002 m/m, High hydraulic gradient = 0.1 m/m, aquifer thickness 10 m, width 100m. * Assuming Darcy flow (porosity of 0.2 and high hydraulic gradient) with no preferential flow paths. These values are for horizontal flow. Vertical hydraulic conductivities are typically 1/10$^{th}$ of horizontal values.

There are many different scientific methods that can be used to measure groundwater flow rates in permeable aquifers, although realistic measurements in aquitards are much more challenging. Available methods include in-situ downhole testing and laboratory testing of sediment and core samples to provide data inputs for numerical computer modelling. Flow tracers using natural or artificial geochemical species, and stable or radiogenic tracers can be used. The Sydney Catchment Authority (KBR, 2008) recently used environmental tracers to assist in defining a groundwater conceptual model (see Figure below). Source: Coffey, 2006 and Sydney Catchment Authority



Stable isotopes (oxygen-18, deuterium, carbon-13) and radiogenic tracers (tritium and carbon-14) were used to provide information on groundwater in the Hawkesbury Sandstone aquifer near Kangaloon in the Southern Highlands. The results, combined with other investigations showed that in the study area:

- All groundwater is of rainfall (meteoric) origin.
- Perched water in the upland swamps may have negligible connection with the deep sandstone aquifer.
- Age of groundwater in the primary recharge areas is modern (less than 50 years old), with increasing age along flowpaths to the north and with depth.
- Groundwater in the Hawkesbury sandstone is a mixture of modern rainfall and older groundwater, with the oldest groundwater about 5,000 to 10,000 years of age.

Another example of environmental tracer findings for a sandstone bore (40-160 m depth) near Bondi Junction is provided in the following table.

| Isotope | Result | Unit | Finding |
|---|---|---|---|
| Oxygen-18 | -4.90 | $\delta O^{18}$ $\pm$ 0.1 per mil SMOW | Recharged by rainfall during post-glacial period with negligible evaporation. |
| Hydrogen-2 (deuterium) | -26.2 | $\delta H^{2}$ $\pm$ 0.2 per mil SMOW | Recharged by rainfall during post-glacial period with negligible evaporation. |
| Hydrogen-3 (tritium) | 0.9 | $\pm$ 0.1 TU | Apparent age >45 years* |
| Carbon-14 | 65.09 | 0.4 pMC | Uncorrected age of 3,450 $\pm$ 50 years* |
| Carbon-13 | -16.4 | $\delta C^{13}$ per mil | Apparent age of 2,800 years assuming matrix $C^{13}$ of 0.0* |

** Assuming negligible mixing.*

It is important to note that groundwater pressure changes can move much faster than water molecules move with groundwater flow. This is like turning on a tap at the wall, resulting in a rapid pulse of pressure moving through a garden hose. However, the pressure change that is felt at the end of the hose at that time is not due to the instant arrival of water molecules from the tap. Pressure released at the tap is transferred through the water in the hose so that the molecules nearest the end of the hose are forced out. In reality, detection of pressure changes in a confined aquifer due to pumping activity is distinct from physical flow of groundwater that may or may not follow.

In summary, this fact sheet has shown that groundwater moves relatively slowly and may have been stored in sediments and rocks for hundreds or thousands of years. This means that it is important to use groundwater wisely and to protect groundwater from contamination.

Sources: WRL Projects, Pidwirny, M (2006). The hydrologic cycle. Fundamentals of Physical Geography; KBR 2008 Upper Nepean (Kangaloon) borefield project. Environmental Assessment prepared for Sydney Catchment Authority. Coffey Geosciences (2006) for the Sydney Catchment Authority.



Production of this information has been assisted by the NSW Government through its Environmental Trust.

# Groundwater Management Information Fact Sheet :

## Groundwater Myths

This fact sheet provides a brief review of groundwater myths that are commonly encountered, and the reality based on current scientific understanding.

### 1. Underground lakes lay beneath our feet

***Myth****: Ancient myths refer to magical underground lakes, while some ideas persist today of underground lakes or channels buried beneath our feet like pipework or veins.*

**Reality:** In reality groundwater in most areas is found in the tiny pore spaces between sand and gravel, or in rocks with narrow fractures. Underground lakes or caverns with ponds are geological features that are only found in landscapes made of limestone. Limestone can be identified by sharp patterns eroded by rainfall and bubbling when dissolved by acidic liquids. Limestone landscapes in NSW are limited to Jenolan Caves, Wellington and other ancient reefs in the Lachlan Fold Belt rocks.

---

### 2. We can always count on groundwater

***Myth****: There is a common belief that groundwater is freely available for all to tap, so many people have a casual attitude to how much groundwater they take. Every day new bores are drilled, and water is drawn without thought given to consequences, or without regard to the rules of civil society (AWA 2007).*

**Reality:** If groundwater systems are pumped too hard, by too many bores there may be no recovery of useable water. Groundwater is a finite resource and, as with any valuable supply of fresh water, should not be wasted. Pumping at unreasonable rates and durations depletes the resource for all users and can permanently damage an aquifer. The responsibility for not misusing a groundwater resource rests with all those who utilise the water, and is supported by sustainable management decisions for the aquifer as a whole. Licences allowing access to groundwater are required for all water supply bores and include conditions of use which must be complied with.

---

### 3. Our groundwater comes from the New Guinea Highlands

***Myth****: There's a favourite drilling story about aquifers found beneath the western plains that are strangely similar to those found by drilling in the New Guinea Highlands, or Inner China. Some people are convinced that groundwater in Australia is somehow connected to distant sources overseas.*

**Reality:** Aquifers that support agricultural enterprises in the Murray-Darling Basin are part of regional groundwater flow systems that can extend thousands of kilometres, but have no connection with outside Australia. The fact is that the Murray-Darling Basin is like a bathtub that is partially filled with sand and mud, where the base and sides are sealed and cannot transmit water.

---

### 4. Drilling of bores can crack an aquifer

***Myth****: Concerns over drilling test bores and exploration bores commonly suggest that an aquifer can be cracked. The idea that an aquifer can be cracked like a piece of china has perhaps come from images of geological materials that have been fractured during movement of the earth.*

**Reality:** Alluvial aquifers comprised of sand and gravel cannot crack. Moist clay sediments cannot crack. Surface fracturing or cracking can occur in swelling clay sediments due to moisture changes or in rock aquifers in response to changes in pressures or stresses. Over the past decades thousands of bores have been drilled through alluvial sediments into underlying rock in NSW. There is no evidence that drilling of any type (whether for water, testing or mineral resources) could damage aquifers through cracking, provided that sealing procedures in the Australian Standard and NSW DPI standards are adopted*. However, old corroded bores and water bores that have been gravel packed to the surface have caused leakage of shallow saline groundwater. The risk of impacts on groundwater levels or quality due to monitoring test holes or exploration drilling is negligible compared with other potential risks to the sustainability of groundwater resources.

> *"There appears to be much misunderstanding about groundwater, and some seem to believe it is a magic pudding of infinite good quality water".*
> Peter Cullen, 1943-2008.

---

The information in this fact sheet has been has been prepared by the UNSW Water Research Laboratory as part of the Groundwater Education Project in partnership with the following organisations:

### 5. Divining rods are the answer

***Myth**: "Dig here", says the fellow with the forked willow rod, "and you'll find water 60 feet down". A well is drilled and strikes water. In the US today there are 20,000 to 30,000 water witches who practice the art finding water more often than not (Chapelle 1997).*

**Reality:** There is as yet no scientific evidence supporting divining or witching to find water. The way in which the divining rod is typically held is like a spring which amplifies slight movement of the body. The claim that the rod dips involuntarily may well be telling the truth, but the fact is that if you pick any spot at random to drill, at least some groundwater will be found 90% of the time. An experienced local driller will often be able to pick suitable bore locations on the plains based on their knowledge rather than the rod. Drilling in rock however can be a hit or miss affair regardless of divining rods, and two holes drilled only a few metres apart can yield very differently. This is due to the 3D hydrogeological structure of underlying strata, including changes induced post-deposition, with variable permeability and connectivity, leading to different water bearing zones.

**A brief history of the divining rod or water witching**

Ancients - the Scottish used the witch elm for divining rods, with immigrants to America becoming known as "water witches".

1518 - Martin Luther declared the use of the witching rod a violation of the First Commandment "Thou shalt have no other Gods before me"

1556 - first written account of witching used by metal miners in Bohemia

1568 - St Teresa of Spain secured a plot of land for a monastery after a diviner guided diggers to a gushing source of underground water.

1645 - Athanasius Kircher tested the usefulness of a rod used by a diviner, by then suspending the same rod from a string. This time the rod failed to move when past over the drilling target identified by the diviner.

1850's - Scientific methods for finding groundwater become available

*Source: Chapelle 1997*

### 6. The depth, yield and salinity of a bore can be guaranteed

***Myth:** For a fee, company X gives a 100% guarantee that a 20 L/second supply of fresh water can be tapped at a depth of 45 feet if the rig drills at the marked site.*

**Reality**: The level of confidence that groundwater bore drilling will result in sufficient yields of fresh water depends on the extent of information that is available. At a specific site, there may be a low, moderate or high probability that a good fresh groundwater supply can be obtained. However, it is not possible to guarantee the depth, yield, long term supply, or salinity of a bore due to natural variability in the subsurface. Two bores drilled just metres apart can yield quite differently, particularly if drilled into fractured rock.

The best possible outcome for groundwater supplies is obtained by engaging the services of a hydrogeologist and a water bore driller. Feasibility assessments for large groundwater supply projects should include examination of geological maps and remote sensing (eg. satellite imagery) to identify promising geological structures. Drilling targets are best optimized on a local scale by geophysical surveys (eg. resistivity or electromagnetic surveys) that detect anomalies in the sub-surface due to changes in sediment type or groundwater salinity. There is currently no scientific method that can accurately predict depth and yield and salinity of groundwater.

### *Sources and references:

ADIA (2003), Minimum construction requirements for water bores in Australia. Edition 2, Published by National Minimum Bore Specifications Committee including Australian Drilling Industry Association.

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For more information on groundwater management please see the other fact sheets in the series. All fact sheets are available at www.sydneycoastalcouncils.com.au.

Production of this information has been assisted by the NSW Government through its Environmental Trust.

# Groundwater Management Information Fact Sheet :

## DIY Groundwater Monitoring

This fact sheet provides a brief review of groundwater monitoring for owners and users of water bores.

### Why monitor ?

If you aren't watching your groundwater source, it is like running a car without checking the oil. Keeping track of groundwater levels and quality is a very important part of ensuring resource availability and, sustainable management. It is the responsibility of users to test and treat bore water to ensure the quality is fit for the intended usage.

### What to monitor ?

Monitoring can involve groundwater level monitoring and/or quality monitoring. Groundwater level should be measured from a standard reference point such as ground level or the top of casing.

Water salinity can be monitored simply by an EC meter (electrical conductivity). Water salinity should also be periodically analysed by a laboratory to measure concentration of major cations and anions including sodium, calcium, magnesium, chloride, sulphate and bicarbonate salts. Full laboratory analysis can be used to check more frequent EC measurements.

Other basic water quality tests are nitrate and *E.Coli,* an indicator of bacterial contamination. Note there are hundreds of water quality parameters that can be tested depending on the intended use of water. This fact sheet concentrates on monitoring for irrigation and possible salinity impacts; other water quality tests should be undertaken based on advice from hydrogeological specialists.

### What equipment is needed ?

Sampling methods in the Australian Standards* or more specific regulatory guideline should be followed by personnel who are trained in groundwater quality sampling.

1. Access point for monitoring on the bore casing and preferably a dip tube installed next to the pump main (Figure 1). A monitoring dip tube can be made from at least 25 mm PVC tube, with slotted sections near the base and one should be installed with the pump, and a second one in the gravel pack outside the bore casing.

2. Measuring tape and "dipper" device. Alternatively, a commercial dip meter provides more accurate data.

3. Basic EC meter & clean measuring cup (or sample bottles if laboratory analysis to occur).

### How often to monitor ?

Groundwater level – weekly during pumping season, monthly at other times. A consistent record over many years is most important.

Water salinity (EC) – monthly during pumping season.

Water salinity (major salt ions) – once per year, preferably during the non pumping season.

### What to do with the data ?

Data can be recorded on the attached form.

If there is a change in groundwater levels or salinity then professional hydrogeological advice should be obtained. Further assessment is required if the change is larger than previous variations, or there is a consistent pattern of falling groundwater levels or increasing salinity. Results should be provided to the agency that licenses water bores so that permanent records are available in the future.

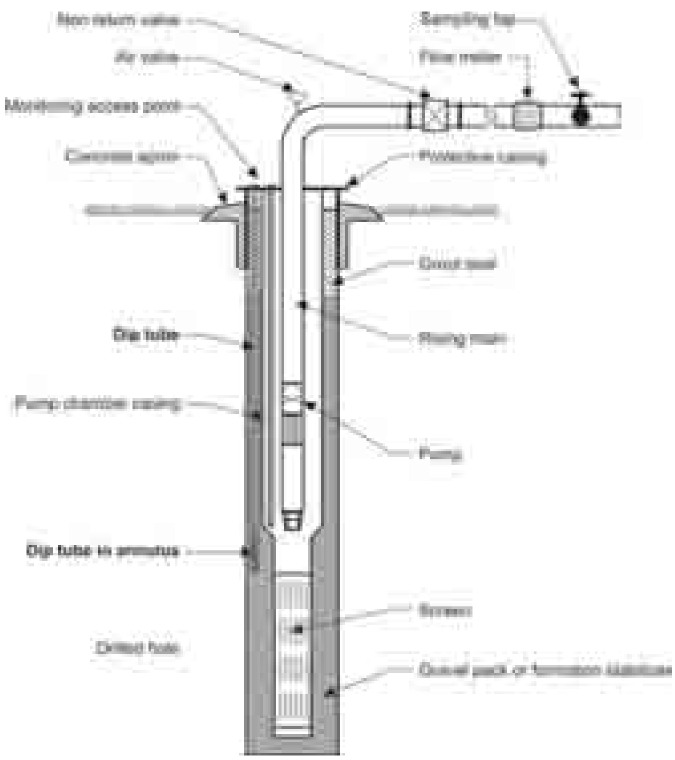


*Figure 1 – Monitoring dip tubes in an irrigation bore*

The information in this fact sheet has been has been prepared by the UNSW Water Research Laboratory as part of the Groundwater Education Project in partnership with the following organisations:

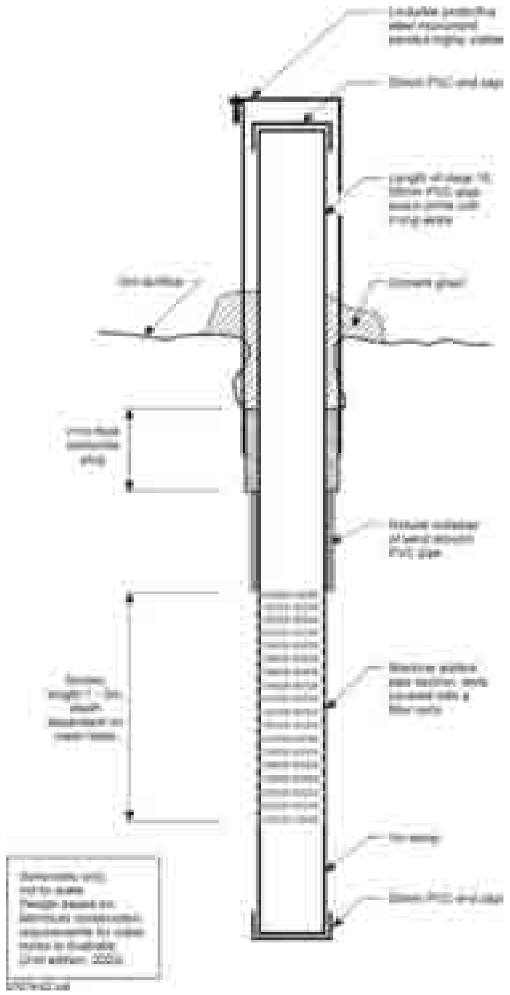

*Figure 2– Groundwater monitoring piezometer*

## What is a piezometer ?

A piezometer is a specially designed bore with a short intake screen to monitoring groundwater levels at a specific point in an aquifer. Ideally, monitoring should be undertaken in both irrigation bores and piezometers.

Figures 2 and 3 show how to construct a shallow monitoring piezometer and the materials that are required. Shallow piezometers can be installed in an auger hole to about 5 m depth. Deep piezometers require a drilling rig and specialised materials to prevent leakage between different aquifer systems.

*Sources: Modified after Timms, 1997.* * Standards Australia & Standards New Zealand (1998) *'Water Quality –Sampling Part 11: Guidance on Sampling of Groundwaters'* Australian/New Zealand Standard AS/NZS 5667.11:1998

*Figure 3 – Materials to install a shallow monitoring piezometer*

## How much does monitoring cost ?

Your time is the most significant cost. Keep in mind the costs of not monitoring the water that you use could be incalculable. A water level dipper and pocket EC meter (Figure 4) can be purchased from companies such as www.enviroequip.com.

*Figure 4 – Example of water level dipper and pocket sized salinity EC meter.*

A consulting hydrogeologist (www.iah.org.au) or laboratory that is NATA certified for the tests that are required should be contacted for current prices. A rough guide for EC and major salt ions is about $50 per sample, and about $20 per sample for nutrients. Labs can also advise about suitable methods*, sample handling procedures, and can provide bottles to use to ensure that the data is reliable. A consulting hydrogeologist will provide a full assessment service that will provide interpretation of laboratory results.

For more information on groundwater management please see the other fact sheets in the series. All fact sheets are available at www.sydneycoastalcouncils.com.au.

Production of this information has been assisted by the NSW Government through its Environmental Trust.

# GROUNDWATER LEVEL MONITORING DATA SHEET

| Property name: | Postal address: |
| --- | --- |
| Contact person: | Phone: |

| Bore Number & Location | 1 | 2 | 3 |
| --- | --- | --- | --- |
| Bore depth (m below ground level) | | | |
| Pipe height (m above ground level) | | | |
| Slotted interval (m below ground level) | | | |

*It is recommended that water levels be measured at least every month, and every week during intensive pumping.*

| Bore | 1 | | 2 | | 3 | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Date** | SWL (m top pipe) | EC (mS/cm) | SWL (m top pipe) | EC (mS/cm) | SWL (m top pipe) | EC (mS/cm) | Comments (e.g. rainfall, landuse change, cleaned bore and pump) |
| | | | | | | | |
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# Groundwater Management Information Fact Sheet :

## Groundwater Modelling Matters

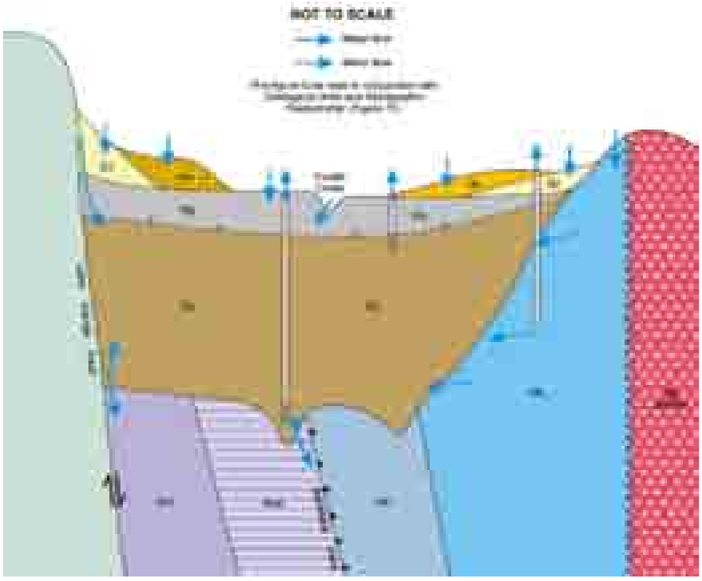
This fact sheet provides a brief review of groundwater modeling by introducing the types of models, how to pick the right model, the modeling steps involved and the typical proportion of a project budget that is allocated to modeling.

### Why a model?

Models are generally used to answer a range of questions. The questions can range from being as simple as "what is the volume of groundwater flow, and what direction is it moving?" to "will the level of water in the river decrease significantly if we increase the yield from our groundwater bores, and will this affect the amount of salt in our soil?" It would seem that groundwater modelling is the answer to all our questions, but is it?

### So what is a model?

Models range in size, cost and complexity. The simplest of models is a conceptual model. A **conceptual** model gives a broad view of the underlying groundwater system without giving any quantitative results. It is in most basic terms a map of the groundwater system.




*A conceptual model of the Bungendore groundwater system.*
*(Courtesy Palerang Council and Timms & Badenhop, 2005, 2006)*

The next level of model is a **basic** model. A basic model involves some calculations, so the answers are quantitative, but there is still no necessity for large computational resources, it can be thought of as equivalent to calculations in an Excel Spreadsheet. Models of this complexity typically cost in the order of $20,000.

The third level of model is an **impact assessment** model. There is a moderate level of complexity for this model with a substantial amount of data required, and model taking months to fully develop. An impact assessment model is capable of predicting the impacts on the groundwater system of certain management policies. With the increase in data and time required to make these types of model, the cost ranges from $20,000 to $100,000. The actual cost depends on whether steady state or transient flow is modeled, the complexity of boundary conditions, and whether processes such as surface-water connections, density dependent flow and solute transport is included.

The final and highest complexity model is an **aquifer simulator**. For such a model large computing resources are required, with a three-dimensional grid being designed in an attempt to represent current groundwater conditions and make specific calculations and prediction about groundwater movement due to changed weather conditions or farming practices. Aquifer simulators start at $100,000, with the price increasing depending on the complexity of the question being answered.

It is important to realise that in order for even the most complex model to be a successful predictive tool, it assumes that the conceptual model on which it is based is reliable and realistic. Advanced modeling techniques report probability associated with results (eg. 80% probability of 100 ML/year sustainable year). However, such results can be misleading if the conceptual model that underpins the results does not include important processes, such as flow along unidentified geological features, or realistic recharge functions for rivers and irrigated land.

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The information in this fact sheet has been has been prepared by the UNSW Water Research Laboratory as part of the Groundwater Education Project in partnership with the following organisations:

## How is a model made?

The **first step** is to try to conceptualise the model. That is, try to get an overall idea of how the groundwater system works and what questions are trying to be answered.

That being achieved, the **second step** is to collect the data which will form the basis of the model. Data is single biggest constraint on what model can be chosen, with the more complex the model, the more data being required. The Earth's geology is very variable and, when modelling groundwater, areas spanning hundreds and even thousands of kilometres in length tend to be modelled. With groundwater model data being sourced from boreholes, it is easy to see that when making a model it's like trying to build a haystack from a few pieces of straw. Commonly up to 50% of time spent is spent gathering data for the model.

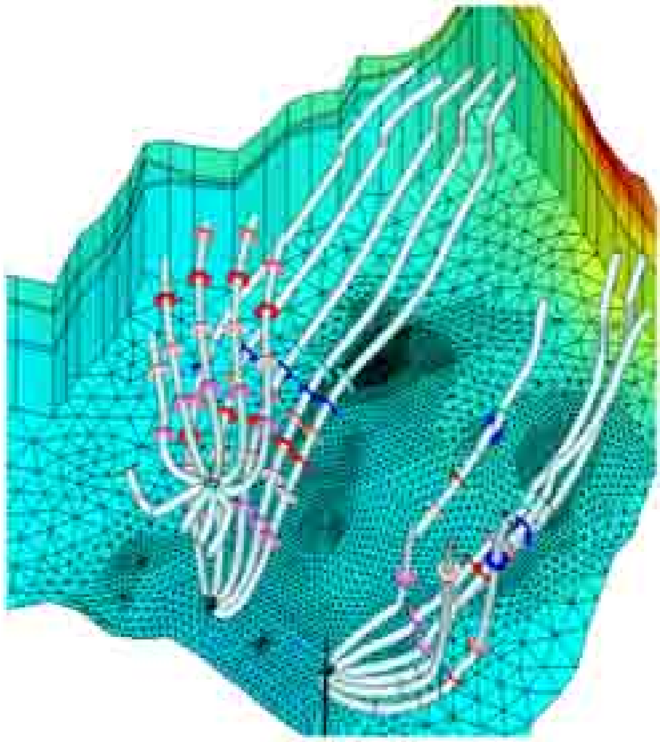
The **third step** in building a model is to convert the data and conceptual model into one which the computer can simulate. The majority of the time henceforth is spent adjusting the parameters in the model so that when the model does simulate real life conditions (like pumping from a borehole or recharge from a flood), the groundwater behaviour is accurately predicted.

With all this done, and sometimes 80% of the budget spent, the **fourth step** is to actually answer the questions that were asked in the first place.

There is however one final **fifth step**, that is often forgotten after those questions have been answered. That step is to validate the model. All models, regardless of their complexity should be checked to see if the results they predicted were valid. This step is often performed several years after the model was initially created. Best practice management would see observations over time integrated into the model, and if necessary, the conceptual model adjusted.

## How to pick the right model

When buying a new car you need to decide what fits. You probably wouldn't buy a large four wheel drive if all you needed was a small car to go to work and back everyday. Likewise when buying a car you might also consider the inputs and outputs, the fact being that although a four wheel drive might give you more power, it also needs more fuel to run. This is exactly what choosing a groundwater model is like. It needs to be considered what exactly are the questions that need answering? If it's a simple question, is a conceptual model enough? Because, the more complex the model becomes the more data that is needed to be gathered, and the more expertise that is required from the modelling team. Both these facts mean that the cost of the model can increase substantially with increased complexity. There is often a trade-off between the resources available and the objectives that can be met by using a groundwater model.

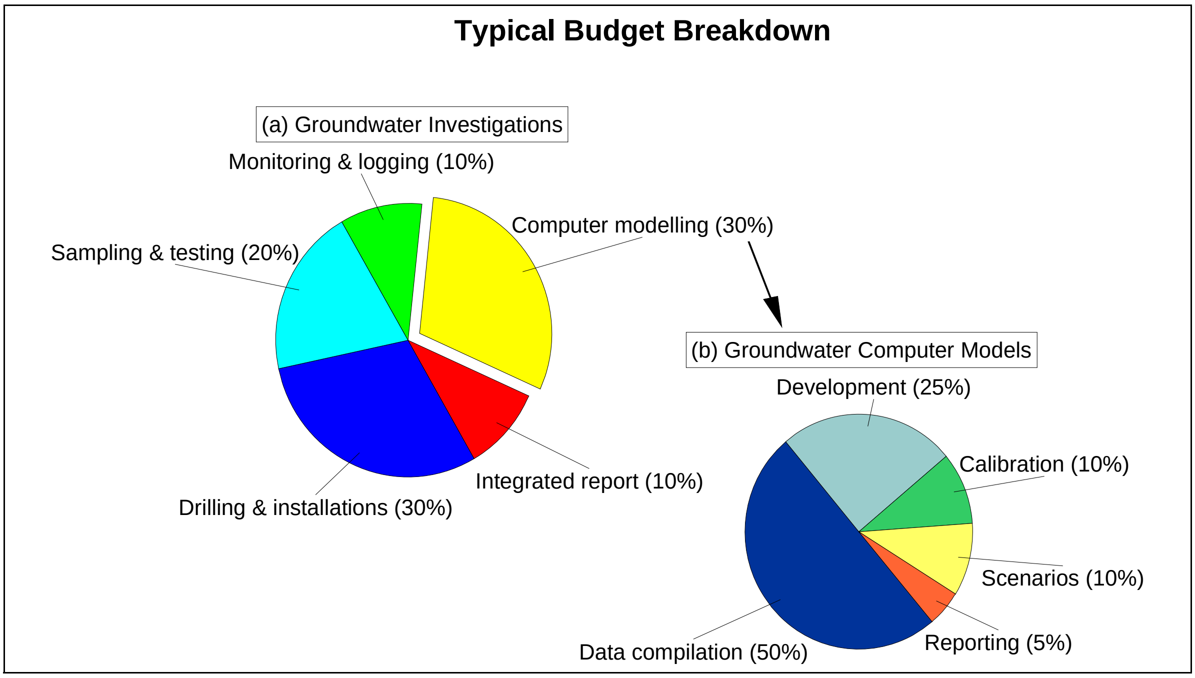


*Pathlines showing particle movement from an aquifer simulator (after FEFLOW v5.2, 2006)*

## Summary

Groundwater models are a very important and useful tool for effective management of one of our most precious resources, and when applied appropriately serve to enhance our sustainable management of groundwater. The reality is however is that all models have assumptions built in and although useful are incorrect. The key challenge for the person asking the questions is to make sure their model is useful as possible, and consider validating and updating their model assumptions with observations over time. Some general rules of thumb are:

- Set clear objectives for the modelling exercise.
- Go with the simplest model that can achieve your objectives.
- Go with a model that fits your time, budget and most importantly, available data.
- If unsure about what model is suitable talk to a groundwater modeller.




## References

Murray-Darling Basin Commission (2003), *Groundwater Models – A community guide to better understanding.*Cooperative Research Centre for Catchment Hydrology, *General approaches to modelling and practical issues of model choice.*

Murray-Darling Basin Commission (2000), *Groundwater Flow Modelling Guideline.*

WRL Solution Capability – Groundwater flow and reactive transport modelling. Download at www.wrl.unsw.edu.au/consulting/capsheets/groundwater/WRL-Solutions-02500.pdf

Timms, W. and Badenhop, A., 2006. Bungendore Regional Groundwater Flow Model - Historic Rainfall Variability and Uncertainty Analysis, UNSW Water Research Laboratory 2006/02.

Timms, W. and Badenhop, A., 2005. Bungendore Regional Groundwater Flow Model, UNSW Water Research Laboratory Technical Report 2005/15.

*Source and references www.connectedwaters.unsw.edu.au*

For more information on groundwater management please see the other fact sheets in the series. All fact sheets are available at www.sydneycoastalcouncils.com.au.

Production of this information has been assisted by the NSW Government through its Environmental Trust.

# Groundwater Management Information Fact Sheet :

## Potential impacts of sea-level rise and climate change on coastal aquifers

This fact sheet provides a brief review of potential impacts of sea-level rise and climate change on coastal sandy aquifers. Information is presented on where salinisation has occurred, the value of coastal aquifers, measured and predicted sea-level rise, saline intrusion and inundation processes, and finally, possible options for management of coastal aquifers.

Climate change and sea level rise could impact on the quantity and quality coastal aquifer systems which are important strategic water resources. Fresh water contaminated with only 5% of seawater means it is unusable for many beneficial purposes, including supplies for drinking, irrigation of crops, parks and gardens and for groundwater dependent ecosystems.

### Potential Impacts

Sea level rise that contributes to saline intrusion or inundation is probably the most direct impact of climate change, particularly for shallow sandy aquifers along low-lying coasts. However, natural groundwater equilibrium as shown in Figure 1 can be disturbed by changes in recharge and discharge associated with climate change.

Sea-level rise and climate change can potentially impact groundwater in the following ways:

1. **Seawater intrusion** (progressive encroachment through the subsurface) and inland migration of the fresh-saline interface
2. **Seawater inundation** (surface flow into low-lying areas) and flooding of unconfined aquifers
3. **Contamination of bores** by storm surges and flooding of surface fittings
4. **Changing recharge** due to variable rainfall and evapotranspiration resulting in an altered distribution of freshwater in the aquifer
5. **Changing discharge** patterns that can generate waterlogged conditions and may impact on aquatic and wetland ecosystems
6. **High watertable impact on infrastructure** including leakage to septic tanks, sewer systems, and basements and causing instability of swimming pools, tanks and other subsurface structures that are not anchored

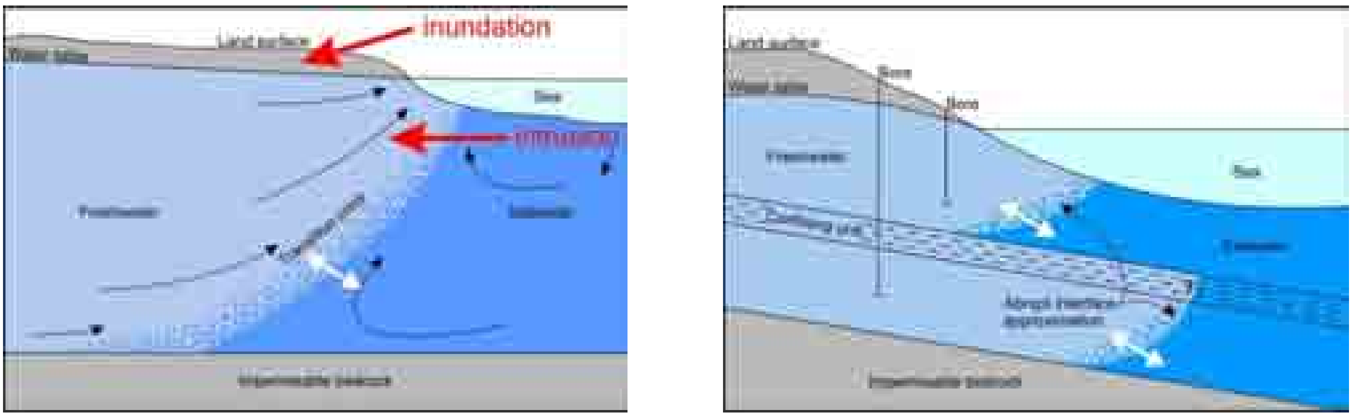



*Figure 1 – Fresh-saline boundaries beneath coastlines for simple and layered aquifer systems. Arrows indicate potential change in interface location with sea level fluctuation. Source: Adapted from Reilly 1985 and Cooper 1964*

Clearly, a much broader consideration of potential impacts on groundwater systems need to be considered than simply seawater intrusion. Whether or not these potential impacts occur in a local groundwater system depends on site specific factors. The relative importance of each potential impact could vary substantially. For example, changes to recharge and discharge patterns may be difficult to distinguish from natural climatic variability. It is also possible in some areas that changing groundwater extraction from water bores, and subsidence of the land surface may exacerbate the potential impacts of climate change and sea-level rise.

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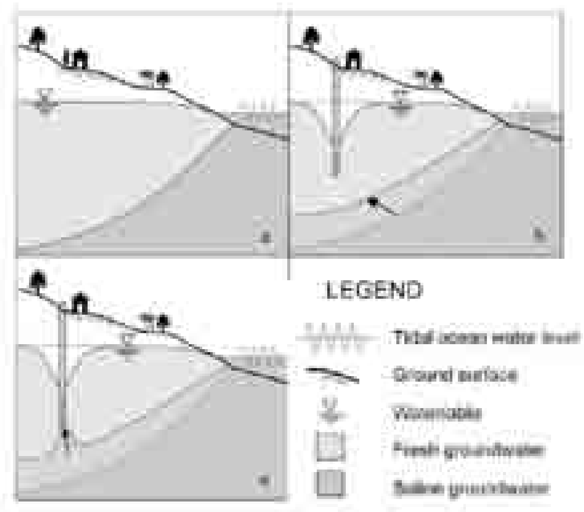
The information in this fact sheet has been has been prepared by the UNSW Water Research Laboratory as part of the Groundwater Education Project in partnership with the following organisations:

### Where has salinisation of coastal aquifers occurred?

Saline intrusion has occurred in many coastal aquifers around the world due to over-extraction (Figure 2), including Los Angeles and the Mediterranean coast (FAO, 1997). About 60% of Spanish coastal aquifers are impacted by saline intrusion (Herrera, 2007). Salinisation of groundwater is expected to be exacerbated by climate change in many areas.

Despite reports of seawater intrusion in the majority of states, comprehensive seawater intrusion investigations have only been completed for coastal systems in Queensland and to a lesser degree in Western Australia and South Australia (Werner et al. 2008).




The most comprehensive studies include those of the Pioneer Valley and Burnett basins in Queensland, for which detailed conceptual and mathematical models have been developed at the regional scale.

*Figure 2 – A schematic example of the progression of pumping-induced seawater intrusion: (a) an initial state of equilibrium, (b) lateral seawater intrusion and (c) up-coning intrusion. Climate change may be expected to bring about similar intrusion through the mechanisms described on page 1, including interface migration. Source: Werner et al. 2005.*

### Value of Coastal Aquifers

Freshwater in coastal aquifers are strategic water resources with many beneficial uses including town water supply, domestic supply, irrigation of crops and pastures and industrial usage. Coastal aquifers also provide base flow to creeks and rivers during dry periods, thus supporting diverse ecosystems. The coastal Gnangara Mound aquifer supplies about 60% of Perth's scheme water while the coastal Tomago aquifer provides about 13% of the Hunter Valley's scheme water. The Tomago aquifer supplies 50 ML/day (Hunter Water 2004/05), or $23 million worth of water per year. Coastal irrigation areas between 0 and 5 m AHD that are potentially at threat from seawater salinisation cover an estimated 46,060 hectares or 1.4% of Australia's irrigation area (Werner et al., 2008). The productivity value of coastal irrigation areas that may rely on groundwater supplies has not yet been determined.

### Measured and Predicted Sea-level Changes

Sea-level rise has been measured around the world for many years, providing evidence that the rate of rise is increasing. For example, the average sea-level rise that is evident in tide gauges around Australia is 1.2 mm/year (BOM). Global sea-levels have risen on average about 2 mm/year with a total rise of about 0.2 m over the last century.

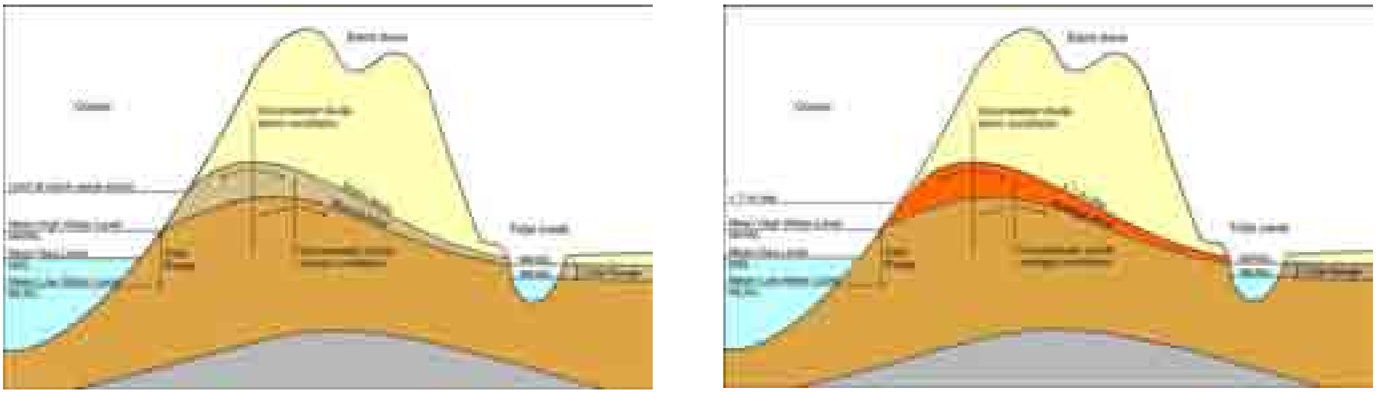
There are various scenarios of sea-level rise in the future based on current understanding and models of the many factors and feedback processes that contribute to sea-level rise. Currently, the best estimates provided by the IPCC (2007) indicate sea-level increase of 0.2 to 0.5 m by 2050 and 0.5 to 0.9 m by 2100. Current coastal management and construction guidelines around Australia generally allow for up to 1.0 m of sea-level rise by 2100 (NCCOE, 2004). A planning period to 2100 is considered to be appropriate for the design life of most coastal structures.

However, these estimates do not include the possible melting of the Artic, Antarctic and Greenland icesheets. The IPCC (2007) notes a possible scenario involving the total melting of the Greenland ice sheet which it estimates would elevate global sea levels by a further 7 m over a time period that is suggested to be millennia.

### Saline intrusion and inundation processes

Sea level rise that contributes to saline intrusion or inundation is probably the most direct impact of climate change, particularly for shallow sandy aquifers along low-lying coasts. More detailed knowledge of hydrogeological processes, interaction with surface waters and aquatic ecosystems is required to assess possible future impacts, particularly for aquifers that are yet to reach equilibrium with current groundwater extraction rates. For example, it is commonly, but wrongly assumed that groundwater level is at mean sea-level, with continuous groundwater discharge below the 0 m AHD level

(Turner et al., 1997). In reality, the action of waves cause mounding of groundwater at the coast mean that the watertable is at about mean high tide level (~1.0 m AHD). Storm events, and local wind & wave climate can push the coastal groundwater level to ~2.0 m AHD. Increased mean sea-levels could further increase groundwater mounding and change groundwater discharge dynamics as shown in Figure 3.



***a.*** ***b.***

*Figure 3 – Coastal groundwater levels compared with sea-levels for a) storm levels; and b) +1 m sea-level rise (Source: UNSW WRL)*

The UNSW Water Research Laboratory has led many process studies of coastal aquifers including studies at Hat Head (eg Acworth et al. 2007), Lake Ainsworth (eg Turner et al., 1997) and Lakes Beach (eg. Timms et al. 2006; Anderson et al. 2005). In addition, studies of coastal seawater inundation have been completed by Andersen et al. (2007).
http://www.connectedwaters.unsw.edu.au/technical/research/projects/projects_coastal.html

Current research by Ian Turner with European and US ACE collaborators is measuring the response of coarse sediment beaches to changing tide, wave and groundwater conditions. A million litres of water, 500 tonnes of gravel and a wave machine the size of a two-storey building are being used to recreate and simulate a full-scale 'beach' within the laboratory.
http://www.connectedwaters.unsw.edu.au/news/bringingthebeach.html

## Assessment and Monitoring

Sustainable yield estimates for coastal aquifer systems should account for possible seawater intrusion, with appropriate monitoring systems and adaptive management of groundwater resources. A staged level of assessment is recommended commencing with a desktop evaluation using available information (for example Clarence City Council in Tasmania by Carley et al., 2008). Information requirements for a desktop assessment include:

- Geology and hydrogeology maps, Hydrology and catchment topography data
- Bore survey data, intake screen depth and stratigraphy
- Groundwater level variation – spatially, with aquifer depth and over time
- Groundwater quality – EC, pH, T and major ions at a minimum
- Groundwater usage volumes and dependence of communities and ecosystems on groundwater.
- Aquifer status relative to sustainable groundwater yield assessments

In the Clarence study, each of the possible impacts of sea-level rise and climate change on groundwater systems (Nos 1 to 8 above) were ranked as of high, moderate, low or unknown importance so that future work, if required could be prioritized. The study found that the magnitude of potential risks to groundwater was variable, and that the possibility of high watertables causing damage to infrastructure was a major concern.

If high value water resources or infrastructure threats are identified, field investigations, monitoring and computer groundwater modelling can assist in decision making and management. Geophysical surveys are recommended to identify targets for test bores and monitoring. The most reliable information on groundwater flow direction and salinity concentrations is obtained from nested monitoring bores (or mini-piezometers) with short intake screens that are positioned at different depths. Installing automated loggers to record groundwater level and salinity changes in monitoring bores is now cost effective monitoring strategy. However, groundwater sampling for pH and major cations and anions on at least an annual basis is important because geochemical changes such as decreased $HCO_3$ can provide early warning of saline intrusion.

### Adaption and Management

There are a number of options for adaptive management of coastal groundwater supplies that are at-risk of salinisation.

Options for 'retreat' include restricting groundwater use, or optimizing pumping locations and schedules.

Options to 'accommodate' include raised bore heads to reduce the risk of bore flooding. Where other water sources are limited, desalination of saline borewater that has been filtered through coastal aquifers can be more efficient than desalinating raw seawater from intakes in the ocean.

Options to 'protect' include engineered flow barriers, managed aquifer recharge and active management of catchment water balances particularly through vegetation cover that transpires water.

**Fact sheet is based on the following conference presentation which includes full list of references:**

*Timms, W; Andersen, M and Carley, J (2008). Fresh-saline groundwater boundaries below coastlines – potential impacts of climate change. Coast To Coast Crossing Boundaries Conference, 18-22 August, 2008, Darwin.*
Available at: www.connectedwaters.unsw.edu.au and www.ozcoasts.org.au

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Water Sensitive Urban Design in the Sydney Region

PRACTICE NOTE 12

# Urban salinity

A salt-damaged public building in Western Sydney

Water sensitive development involves simple design and management practices that take advantage of natural site features and minimises impacts on the water cycle. It is part of the contemporary trend towards more 'sustainable' solutions that protect the environment.

This Water Sensitive Practice Note gives a general introduction to urban salinity issues and their management in relation to water smart practices.

- **Causes of urban salinity**
- **Managing salinity processes**
- **Design & construction principles**

# Urban salinity

## Introduction

Salt is a natural part of the Australian landscape. Areas of naturally high soil or water salinity exist throughout the continent. However, it is increasingly recognised that land management practices may enlarge the area of land affected by salinity. Conversely, salinity is having a greater impact on human activities and development.

While salinity is widely recognised as a problem in agricultural areas, the impacts of salinity are also being felt in urban areas. Urban salinity is now recognised as a growing problem with potentially high costs to affected communities. Impacts go beyond the degradation of vegetation and soils. If unmanaged, urban salinity can result in significant problems for a variety of urban assets, including buildings, roads, underground services, parks and gardens.

Salinity is an issue for large areas of Sydney, particularly on the Cumberland Plain. Possible sources of salt are:

- *geology*—Wianamatta Shales, which occur extensively in the region, have a naturally high fossil (connate) salt content
- *climate*—the region's rainfall contributes approximately 10 to 20 kilograms of salt per year to each hectare of land.

A draft *Salinity Hazard Map for Western Sydney* was released in December 2000 by the Department of Land and Water Conservation. The map, and the models that support it, indicate that salinity may occur throughout the region. It should be noted that salinity has been observed in areas of shale in other parts of the Sydney region. Salinity may also need to be considered in other areas with similar geology and climate characteristics.

## Causes of urban salinity

Salinity occurs when salts found naturally in soil or groundwater are mobilised. The processes of capillary rise and evaporation concentrate the mobilised salts at the ground's surface. Such movements are caused by changes in the natural water cycle. Development, infrastructure and resources in contact with mobilised salt in soil or groundwater may be adversely affected.

In urban areas the processes which cause salinity are intensified by the increased volume of water added to the natural system. Additional water comes from irrigation of gardens, lawns and parks, from leaking underground pipes and pools, and from concentrated infiltration of stormwater. Urban salinity can also be triggered by changes in stormwater distribution and flow. For example, salinity outbreaks may be related to impedance of sub-surface water flows by roads or structures, or poor drainage conditions on a site.

Urban salinity may damage vegetation in a manner similar to that observed in rural areas. It may affect lawns, playing fields and gardens. It can also place additional stress on remnant natural areas such as bushland, wetlands, rivers and creeks.

Fig 1: Salt-affected land in Western Sydney

# Urban salinity

Urban salinity may affect built infrastructure, due to the chemical and physical impacts of salt on concrete, bricks and metal. Salt moves into the pores of bricks and concrete when these materials are exposed to damp, salt-laden soils. The salt then becomes concentrated as the water evaporates from the material. Over time, this can cause substantial corrosion and damage the material's structure. Salinity damage can appear in a number of forms, including:

- bricks that are crumbled, eroded or flaking
- mortar that is powdered
- concrete that is cracked or corroded.

Salt within the material may also have a corrosive effect on steel reinforcing.

Fig 2: Salt-affected buildings in Western Sydney

Underground service pipes, such as those used for water supply or sewerage, may be damaged. Leakage from pipes and corroded joints may also contribute to salinisation processes.

Waterlogging and salts associated with urban salinity have a considerable impact on roads and pavements. Physical and chemical degradation of the road base may occur, causing it to become more susceptible to cracking, pot-holing and eventual failure.

Fig 3: Salt-affected roads in Western Sydney

# Urban salinity

Urban salinity also affects stormwater infrastructure, causing problems such as erosion of swales and detention basins, and damage to concrete channels or pipes. The design of stormwater infrastructure may result in impeded groundwater flows, or may intercept groundwater, resulting in saline discharge through the stormwater system.

Much of the cost of urban salinity will be borne by local government in the form of increased repair and replacement of infrastructure, decreased useability of assets and the environment, increased environmental management obligations, and a potentially reduced rate base. Without appropriate management, urban salinity may become a significant future cost to government and the community.

Fig 4: Salt-affected stormwater infrastructure in Western Sydney

## Managing urban salinity as a development issue

Urban salinity is a complex problem that can operate at both a local and regional scale. Because of the significant changes to surface and groundwater systems that result from urban development, mapping the potential occurrence and impact of urban salinity is difficult. Additionally, there are lags between cause and effect, both in time and distance, making it difficult to undertake modelling. As salinity problems can change substantially over time, it is difficult to predict exactly where salinity will occur and how it will respond to the changing environmental conditions associated with development.

It is also important to recognise the two-way relationship between development and salinity. Salinity may not only have an impact on the development, as discussed above, but the impact of development on salinity should also be given equal consideration.

Urban development may contribute to salinity problems in the following ways.

- *Exposure of sodic or saline sub-soils*—the processes of cut and fill, particularly for slab-on-ground construction, disturbs the upper layers of the soil. If the lower soil profile has saline or sodic properties, salinity problems and erosion can result. This effect may also be to bring the land surface closer to the water table.
- *Increase in the level of regional groundwater*—urban development tends to increase the amount of water entering the natural system, such as by irrigation of parks and gardens, leaking stormwater and sewer pipes, and changes in stormwater flows and concentrations. In addition, soil compaction and filling changes permeability and soil drainage, and can contribute to the creation of perched water tables.

- *Changes to soil groundwater flow*—by changing the way that groundwater flows through the soil, development may cause sub-soil salinity to be expressed at the surface. For example, groundwater levels may be raised as a consequence of roads, house slabs, retaining walls or trenches that impede or intercept the soil water flow, cause compaction, or create hydraulic pressure.
- *Disturbance of sensitive areas*—some areas exist in a delicate balance such that, once disturbed, they are difficult to restore and can rapidly deteriorate. For example, removal or disturbance of established salt-resistant vegetation in riparian corridors can increase erosion. Due to their high salinity levels, such areas can be very difficult to revegetate and stabilise.

## Understanding salinity processes

To effectively manage urban salinity it is important to understand and manage the processes by which it occurs, and in particular, the role of the water cycle.

Over the last decade there has been widespread reliance on a single model to explain salinity processes. This model, developed following studies in northern Victoria, is based on the idea that removal of vegetation from hills and slopes causes an increased flow of water to saline groundwater ('recharge'). Saline groundwater then begins to rise, emerging at low-lying areas in the landscape ('discharge').

Until recently, most assumptions about how to best manage salinity are derived from this model. In particular, the model promotes the view that planting deep-rooted vegetation in key 'recharge' areas will address low-land problems. However, questions are now being raised as to the general applicability of the model and the management strategies based on it.

As part of the production of the draft Salinity Hazard Map for Western Sydney, the Department of of Infrastructure, Planning and Natural Resources (DIPNR, formerly Department of Land and Water Conservation) has developed a number of alternative models for processes that may be contributing to urban salinity. These are discussed in the draft guidelines and technical report that accompany the map. Relevant processes include:

- localised concentration of salinity through flow in shale landscapes
- surface interactions from deep groundwater
- areas of deeply weathered soil landscapes.

It must be noted that these processes may occur on a site individually, or in combination with each other.

In these models, separate 'recharge' and discharge' areas are not defined. Instead, the entire landscape can be considered as a recharge area, and the particular processes operating on a site, at a particular time, determine the location of discharge areas.

In order to select the most appropriate and effective management response for a site, it is necessary to identify the processes causing salinity at the site. Consequently, site-specific investigations will be necessary within salinity hazard areas to identify and understand the potential processes present at the site, as well as potential interactions between these processes and the proposed development, including stormwater management systems.

If no investigations are available it may be useful to undertake some salinity investigations for the site as part of the stormwater design process. Appropriate site-specific investigations for urban salinity are discussed in the booklet, Site Investigations for Urban Salinity. This booklet and further information about the need for and use of salinity investigations are available from the Department of Intrafrastructure, Planning and Natural Resources.

# Urban salinity

## Stormwater management in salinity hazard areas

Stormwater management is a very important issue in salinity hazard areas due to the role of water in all salinity problems. The information provided below is general. It is highly recommended that a professional be consulted regarding specific drainage and stormwater requirements or alterations. This is particularly important in areas with reactive clay, where changes in soil moisture levels can cause serious damage to structures.

Correct drainage on a site helps to protect foundations, footings and walls from salt attack. Salinity problems generally occur in areas where water accumulates, or which are subject to continuous wetting and drying cycles. Examples include situations in which:

- natural through-flow or surface flow is impeded by buildings, retaining walls or land resurfacing
- water does not drain away due to the slope of the ground or paving on the site
- gardens or landscaping are sited directly against buildings.

The design and maintenance of development in areas potentially affected by urban salinity should take these factors into account. Damp soils have been found to contribute to salinity problems in areas with even mildly saline soils.

Salinity hazard needs to be carefully considered when developing on-site stormwater or wastewater treatment options. In particular, the use of infiltration and irrigation to manage water needs to be reviewed. Additionally, in areas with rising water tables and groundwater salinity, the recharge from such systems may be undesirable. In most cases, some site-specific investigations will be needed to predict likely impacts, as discussed above. In the case of on-site wastewater treatment, the salt load of the water, surface concentration over time, and impact on potential soil or groundwater salinity needs to be well investigated.

Stormwater detention structures or artificial wetlands with some holding capacity may need to be constructed with impermeable linings to avoid the infiltration of water to the surrounding landscape or to groundwater. When choosing a lining, the possibility that on-site clays may be saline should be investigated before they are selected for this purpose. An impermeable geotech fabric may be a better choice in such situations.

It is also important to consider the impact of any earthworks or reshaping required by the design or construction of stormwater infrastructure, as this may result in exposure of saline or sodic sub-soils. Once disturbed, these soils are very hard to stabilise and problems associated with tunnel erosion and poor revegetation may result.

Reshaping of creeks lowers the surface closer to the watertable and removes vegetation believed to be important in maintaining a lowered watertable in these areas. As a result, discharge or capillary rise may cause surface concentration of salts.

The relationship between the proposed stormwater system, sub-surface flows and the groundwater system also needs to be considered. It is possible for pipes or channels to impede flow causing accumulation of water and concentration of salts.

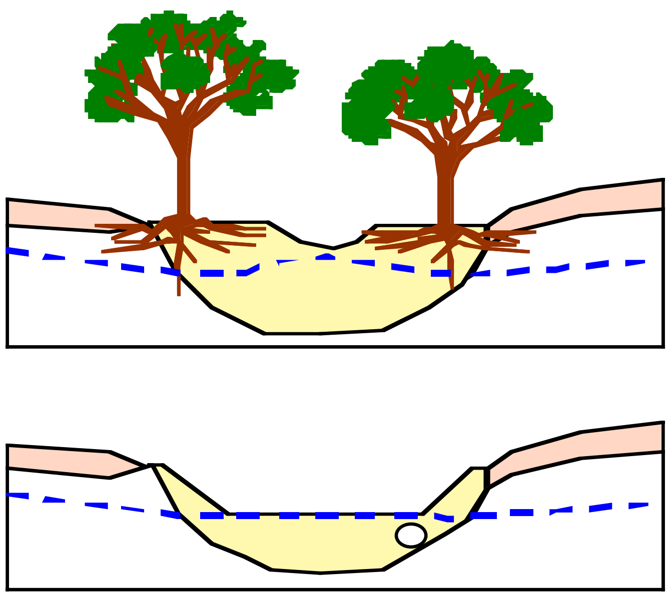

Fig 5: Urban salinity and stormwater channels