SYDNEY COASTAL COUNCILS GROUP

GROUNDWATER MANAGEMENT HANDBOOK

A GUIDE FOR LOCAL GOVERNMENT

First Edition
September 2006

Prepared by
SYDNEY COASTAL COUNCILS GROUP INC

In consultation with the
SCCG GROUNDWATER WORKING GROUP

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Sydney Coastal Councils Group Inc.
Level 12, 456 Kent Street
PO Box 1591
Sydney, NSW 2001
www.sydneycoastalcouncils.com.au

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The SCCG Groundwater Working Group members include:

Name	Organisation
Geoff Withycombe	Sydney Coastal Councils Group
Craig Morrison	Sydney Coastal Councils Group
Dan McKibbin	NSW Department of Natural Resources
Bronwyn Englaro	Botany Bay Council
Dave Paton	Leichhardt Council
Brian McDonald	Willoughby Council
Nik Midlam	City Of Sydney Council
Paul Smith	Manly Council
Daniel Pearse	Woollahra Council
Giselle Howard	NSW Department of Environment and Conservation
Richard Phillips	Formerly Sydney Coastal Councils Group
Clinton Killen	Formerly Waverley Council
Ana Corpuz	Formerly Office of the Member for Heffron
Brad Moggridge	Formerly NSW Department of Environment and Conservation

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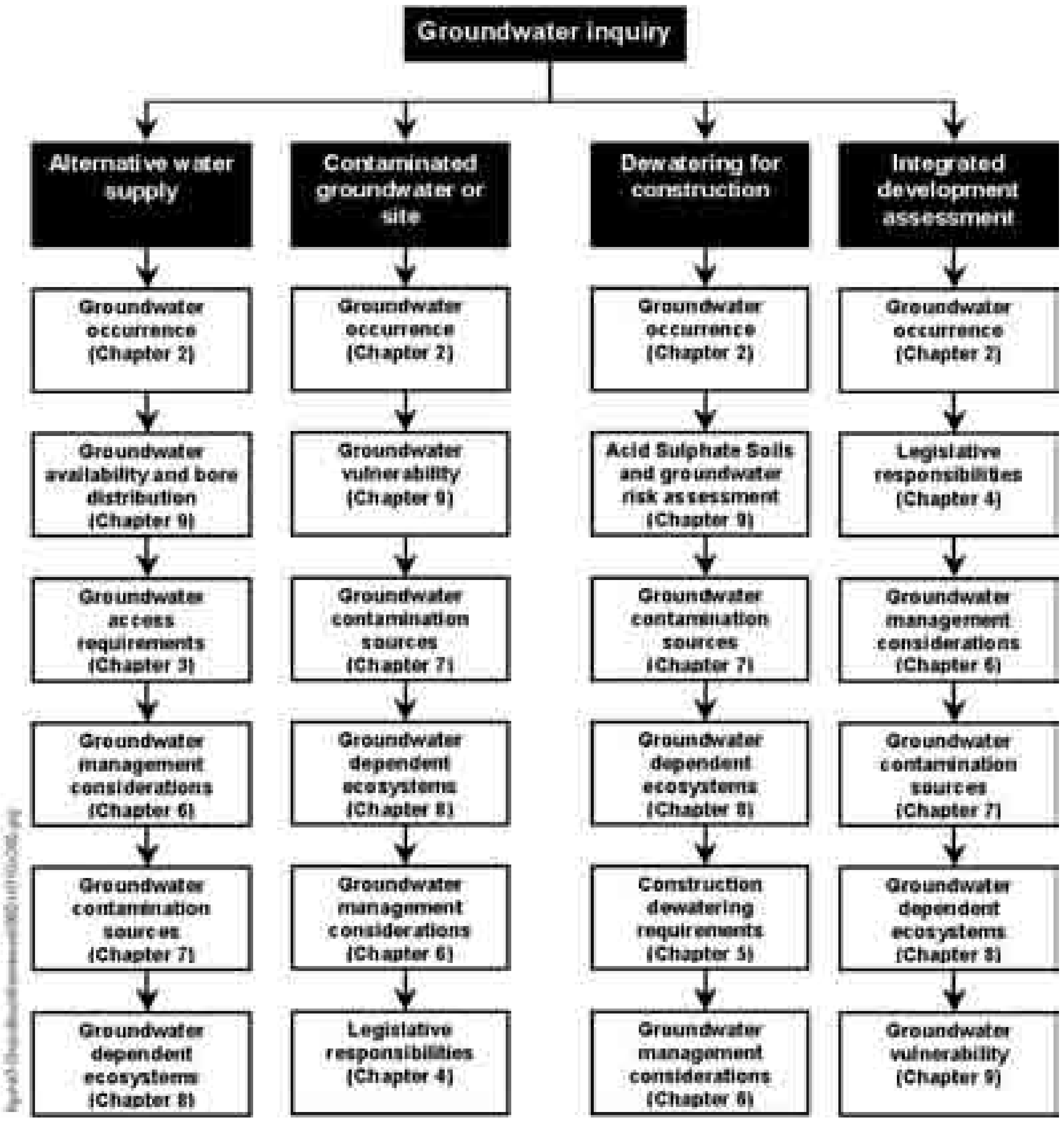
A GUIDE ON HOW TO USE THE HANDBOOK

The Handbook has been structured to facilitate the sourcing of information based on the typical issues and inquiries received from the community, industry and commercial sectors. The following framework delineates suggested paths for Council staff and others needing to identify the critical aspects of development impacts on groundwater. As stakeholders become more familiar with the various concepts and considerations, these paths can be reduced to their pertinent aspects.



Framework for using the Handbook

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Name	**Organisation**
Brett Miller	Water Research Laboratory
Clr. Judy Lambert	Manly Council / Community Solutions
Dr Noel Merrick	National Centre for Groundwater Management - UTS
Dr Paul Byleveld	NSW Department of Health
Greg Russell	NSW Department of Natural Resources
Jason Ip	Riverina Water County Council
Kristina Keneally MP	Member for Heffron
Miah Kesby	NSW Department of Primary Industries
Pradesh Ramiah	NSW Department of Natural Resources
Santo Cannata	South Eastern Sydney Area Health Service
Technical Committee	Sydney Coastal Council Group Member Councils
Trevor Pillar	Centre for Groundwater Studies - Flinders University
Dr Wendy Timms	Water Research Laboratory – UNSW

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FOREWORD

The Sydney Coastal Councils Group (SCCG) region currently has a population of approximately 1.3 million people and continues to grow. A combination of factors including population growth in the SCCG region, combined with tighter water restrictions placed on Sydney residents, triggered SCCG to investigate the issues and needs surrounding alternative water supplies, of which groundwater was the main option considered.

Throughout 2004, it became apparent to the SCCG that there was increased interest from residents, industry and Local Government in:

- Obtaining information on Sydney's groundwater resources.
- Using groundwater resources as an alternative water supply.
- Improving the understanding and knowledge of sustainable groundwater management within Local Government.

In response to these emerging groundwater issues across the region, the SCCG undertook a survey of its member Councils. The survey sought information with respect to the SCCG member Councils' major needs and issues, particularly with a view to addressing how groundwater is currently considered in the assessment of development proposals.

The survey identified a number of important needs and issues on which SCCG member Councils sought further advice and clarification. Most notably was the question of when, or indeed if, the integrated development assessment process is triggered by proposals with regard to groundwater issues.

SCCG formed a Groundwater Working Group in April 2004 to address issues identified in the groundwater survey. The philosophy behind the development of the Handbook was to:

- Provide Councils and other stakeholders with a document that deals specifically with the management and assessment of groundwater resources.
- Provide Councils with a document that provides clear technical information to guide professional staff through the assessment process.
- Provide additional education resources for representatives from industry and the community.

As a result of the survey and contributions from Groundwater Working Group members, SCCG has developed this *Groundwater Management Handbook – A Guide for Local Government.* The Handbook is focussed on the member Council areas included in the SCCG region, in particular the geological and hydrogeological settings that dictate the patterns of groundwater occurrence. Because these settings are specific to the SCCG region, much of the discussion in the Handbook may not be relevant to other areas of the state. However, parts of the Handbook dealing with legislation and information that have carriage state-wide could conceivably be utilised by other Councils in the development of their own guidance documents. Councils of the SCCG region are encouraged to adopt or develop the information in this Handbook into their core planning and environmental management systems. This will promote recognition of the importance of local and regional groundwater resources, the protection of groundwater dependent ecosystems, the prevention of contamination and will encourage sustainable use.

This Handbook provides an outline of the basic principles of groundwater occurrence and behaviour, and includes discussion of:

- Accessing groundwater for water supply.
- Dewatering for construction.
- Licensing requirements for groundwater installations.
- Groundwater dependent ecosystems.
- Relevant legislation and planning instruments.

Comprehensive reference, bibliography and website information is provided to present opportunities for further reading and more detailed study of groundwater systems.

This document is the First Edition and will be updated when the need arises.

Geoff Withycombe
Regional Coastal Environment Officer / Executive Officer
Sydney Coastal Councils Group Inc.

1.0 INTRODUCTION TO THE HANDBOOK

1.1 Introduction

This document is intended as a guidance manual to assist Council staff and the community in understanding how groundwater occurs and the processes by which impacts upon it are managed. Many Development Applications have the potential to impact on groundwater, either through changes to flow patterns or quality, and this is often not apparent until after the project is completed. In certain cases, by not fully assessing groundwater impacts, there has been a substantial financial burden incurred to overcome the results of poor development practices. It is anticipated that this Handbook will help to avoid such circumstances arising in the future.

1.2 Objectives

Objectives

The objectives of this Groundwater Management Handbook - A Guide for Local Government are:

- To provide background information on groundwater occurrence and behaviour.
- To describe groundwater environments within the SCCG region.
- To provide an assessment of current legislation in relation to groundwater management.
- To provide technical advice on the management of groundwater.
- To identify the information available from the groundwater database maintained by the NSW Department of Natural Resources.
- To outline the mapping capabilities available through the Community Access to Natural Resource Information (CANRI) program.

1.3 Background

The drought conditions across eastern Australia in the past few years, combined with a greater demand on resources from an increasing population, have seriously depleted the water supplies on which Sydney depends. It is becoming more apparent that the drought may persist for possibly several more years, further exacerbating water supply pressures.

In response to restrictions placed on the use of mains water, there has been a significant interest amongst the community in accessing and using groundwater. This heightened level of interest has stretched the resources of Councils throughout Sydney, and those of the State Government agency responsible for authorising groundwater access, the NSW Department of Natural Resources.

Throughout the past year increased interest was expressed by the community in obtaining information on groundwater and in the access and use of this resource as an alternative water supply. Because of this the Sydney Coastal Councils Group carried out a survey of member Councils to determine the nature of groundwater issues recently faced by Local Government personnel.

The survey identified a number of important needs, together with issues relating to groundwater, on which member Councils sought further advice and clarification. In many cases, respondents had no clear indication of when to apply the integrated development assessment process. Similarly, many respondents sought guidance in assessing the potential for groundwater impacts resulting from proposed developments.

A technical working group was formed in April 2004 to address issues arising from the groundwater survey. That "Groundwater Working Group" was tasked with providing a document that:

- Dealt specifically with the management of groundwater.
- Could be used to guide professional staff through the assessment process.
- Could be used to develop education material for widespread distribution to the community.

The Groundwater Working Group comprised representatives from:

- Sydney Coastal Councils Group (SCCG).
- Member Councils (City of Botany Bay, Leichhardt, Manly, City of Sydney, Waverley, Willoughby, Woollahra).
- NSW Department of Environment and Conservation (DEC).
- NSW Department of Natural Resources (DNR).

1.4 Sydney Coastal Councils Group region

The Sydney Coastal Council Group region incorporates the Local Government Areas (LGAs) of fifteen individual Councils (Figure 1.0).

The LGAs included in the group are Botany Bay, Hornsby, Leichhardt, Manly, Mosman, North Sydney, Pittwater, Randwick, Rockdale, Sutherland, City of Sydney, Warringah, Waverley, Willoughby and Woollahra. These Councils all manage parts of the coastal and estuarine fringe north and south of the Sydney CBD, including some of the more urbanised parts of the metropolitan area.

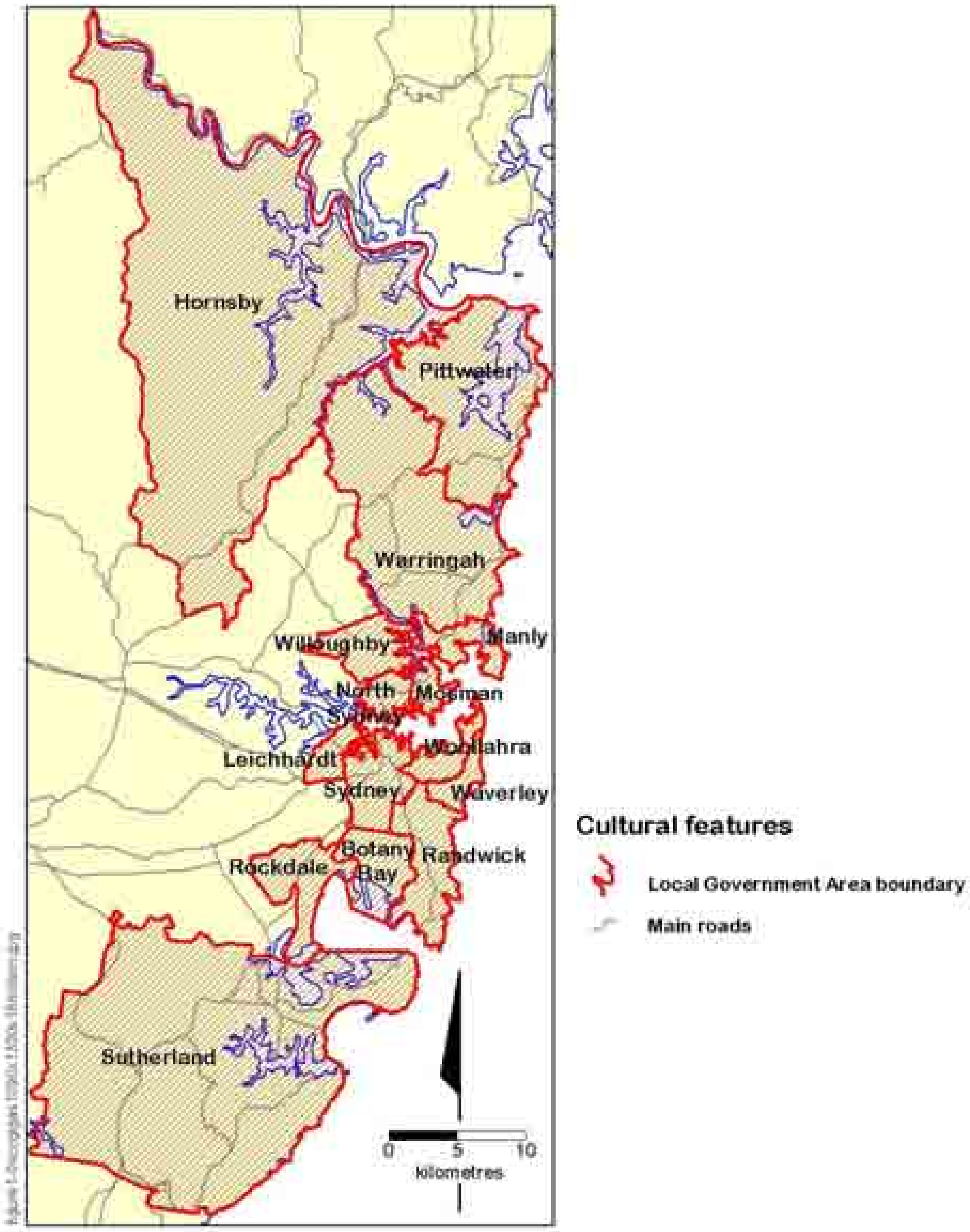

Figure 1.0 LGAs included in the Sydney Coastal Councils Group

1.5 Groundwater as a resource

Groundwater in the broad sense is all water that occurs below the land surface (ARMCANZ / ANZECC 1995). It is an integral part of the "water cycle" (or "hydrologic cycle") and interacts directly with the water present on the Earth's surface. Groundwater provides significant contributions to rivers, lakes, wetlands and swamps, being an ongoing source of water during seasonally dry periods. It also maintains the dynamics of estuarine and near-shore marine water bodies, contributing inflows of fresh water to otherwise saline environments.

In New South Wales the volume of groundwater is estimated to be 5 billion megalitres (ML), more than 200 times the storage capacity of all water supply dams in the state. Approximately 200,000 people in 130 communities rely on groundwater for their drinking supply (NSW EPA 1995). Hence, groundwater can be an invaluable alternative water supply and may be a reserve that can be utilised when surface water sources are depleted.

1.6 Recommendations

Recommendations

It is recommended that:

- Local Government personnel familiarise themselves with the pertinent aspects of their LGA as outlined in this Handbook.
- Councils obtain geological maps for their individual LGAs from the Department of Mineral Resources.
- The staff dealing with Council planning matters be made aware of the relevant NSW legislation dealing with groundwater.
- All Local Government staff using this Handbook to further investigate the internet resources listed at the end of this Handbook and other sites dealing with groundwater.
- Sydney Coastal Councils Group consider developing model provisions dealing with groundwater, in consultation with DNR, DEC and NSW Health, for distribution amongst member Councils.

1.7 Suggested technical and further reading

1. **ARMCANZ/ANZECC, 1995**. Guidelines for Groundwater Protection in Australia. Agriculture and Resource Management Council of Australia and New Zealand and Australia and New Zealand Environment and Conservation Council. National Water Quality Management Strategy Report No 8. September. ISBN 0 642 19558 7. Available on-line at: http://www.affa.gov.au/corporate_docs/publications/pdf/nrm/water_reform/guidelines-for-groundwater-protection.pdf [accessed 10 May 2004].

2. **NSW EPA, 1995**. State of the Environment Report 1995. New South Wales Environment Protection Authority. Available on-line at: http://www.epa.nsw.gov.au/soe/95/11_1.htm [accessed 7 April 2005].

2.0 GROUNDWATER OCCURRENCE

2.1 Introduction

This chapter provides a basic foundation for the understanding of groundwater systems. It includes discussion of the different geological units that can contain groundwater and the differences that allow such strata to be defined as aquifers or aquitards. This chapter also describes the geological and hydrogeological settings occurring throughout the SCCG region.

2.2 Objectives

Objectives

The objectives of this chapter are:

- To provide the reader with a general background on groundwater and its occurrence.
- To explain the differences between aquifer types and their physical characteristics.
- To improve the understanding and knowledge of groundwater systems.
- To describe the geological and hydrogeological settings throughout the SCCG region.

2.3 Groundwater fundamentals

2.3.1 Water in the subsurface

In simple terms all water in the subsurface occurs as part of the water profile, a section through the ground from the land surface to the rocks forming the geological basement (Figure 2.0). Water below the ground may be considered subsurface water, interstitial water or vadose water.

Between the land surface and the level at which pores spaces are saturated, the profile is infrequently and incompletely wetted, with many air-filled voids. Water passing through this zone may be referred to as **vadose water**. In the part of the profile extending from the land surface to the geologic basement, water is found within pore spaces, or interstices, in the soils or rock. Because of this, it can be termed **interstitial water**. Within the geologic basement water is usually only present as part of the chemical make-up of the rock itself, and not within voids or pores. In general, therefore, any water below the land surface can be classed as **subsurface water**.

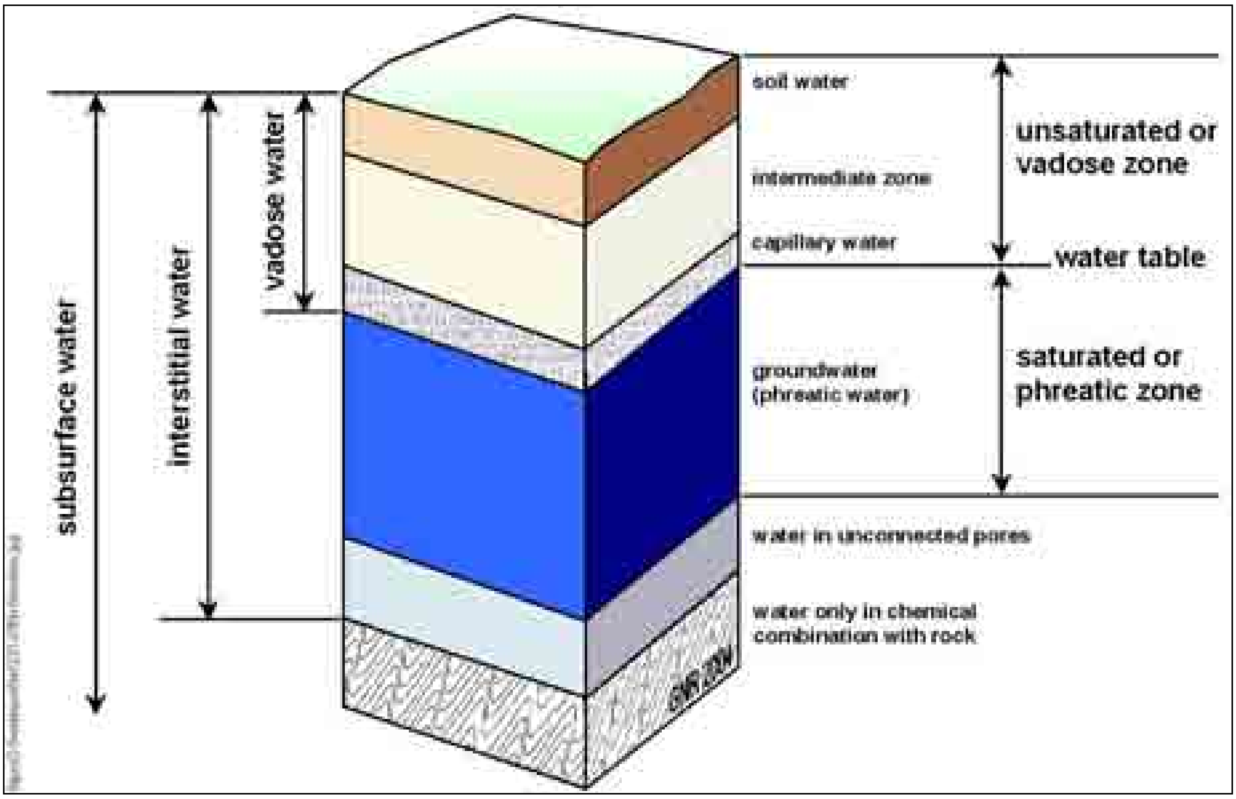

Figure 2.0 The water profile (modified from: Driscoll 1986, Domenico and Schwartz 1990)

In terms of management, only a part of the water profile contains the resource known as "groundwater".

Groundwater originates from water coming into contact with the land surface. As water **infiltrates** into the ground, it passes through the topsoil where a small part is retained as **soil water**. This water is the component that provides essential moisture to plants. Water descending further passes into an **unsaturated zone**, which is dominated by the presence of air in pore spaces within the soil or rock. This part of the profile contains vadose water and is known as the **vadose zone**. Water continuing to pass through (or **percolate** through) the unsaturated zone under the influence of gravity reaches a level at which the pore spaces in the soil or rock are saturated. This level represents the boundary between the unsaturated and saturated parts of the profile and is known commonly as the **water table** or **phreatic surface**.

Immediately above the boundary is a zone where physical suction (molecular attraction) can raise water above the phreatic level without fully saturating the pores. This is known as the **capillary zone**, and its thickness varies depending on aquifer characteristics. In circumstances where fine-grained, well sorted materials form the aquifer, this zone has been reported to be up to 3 metres in thickness (Driscoll 1986). Capillary water within this zone is significant in certain instances of contamination where pollutants can be dispersed above the water table, retained in the pore spaces, and then remobilised on saturation following a rise in groundwater level.

Immediately beneath the water table, groundwater is present in the **saturated zone**. The quantity and quality of groundwater in this zone varies depending on hydraulic characteristics and the nature of the material in which it is held. Not all of the groundwater in this zone can be extracted, some small portion remains due to molecular forces, even during pumping.

2.3.2 The water cycle

Groundwater is an integral part of the water cycle (or hydrologic cycle), the circulation of water throughout the various parts of the land, sea and air (Figure 2.1). This circulation includes all surface water (rivers, lakes, oceans), the atmosphere, and groundwater. The water cycle comprises three main phases: precipitation, migration and evaporation.

Precipitation occurs when the weight of water vapour condensing in the atmosphere is too heavy to be supported by air pressure. Precipitation occurs as rainfall, fog, mist, hail, and even snow and frost, and may be associated with topography or generated by moist air originating from evaporation over the oceans.

Precipitation reaching the land surface is then either transported as runoff, evaporated off the surface of vegetation and the soil, or infiltrates into the ground. Runoff from rainfall and other precipitation accumulates as creeks, streams and then rivers and is transported to lakes and oceans under the influence of gravity. Some precipitation infiltrates through the land surface and then descends to the saturated zone.

This groundwater moves due to the influence of gravity (and often other pressures) and eventually reaches a discharge point where it is released to surface waters. Water then re-enters the atmosphere by evaporation, condensing as clouds and returning to the earth's surface through precipitation (mostly rainfall).

The rate at which water moves through the groundwater phase of the cycle varies considerably, from tens of metres a day, to as little as a metre a year, or even less. In general, the occurrence and behaviour of groundwater is not well understood because it is not generally observed except where springs occur.

2.3.3 Aquifers, aquitards and aquicludes

Geologic formations (either rock or sediment layers) in which groundwater occurs can generally be classed as aquifers, aquitards or aquicludes.

An **aquifer** is a geologic formation that can store and transmit groundwater in useable quantities, that is, in volumes that can be extracted economically. Aquifers generally occur within three broad groups of geological formations: unconsolidated sediments (predominantly river valley alluvium and coastal sand deposits); porous rocks (extensive sandstone or limestone layers within large geologic basins); and fractured rocks (generally massive bodies such as slates, granites or basalt dissected by joints or fractures).

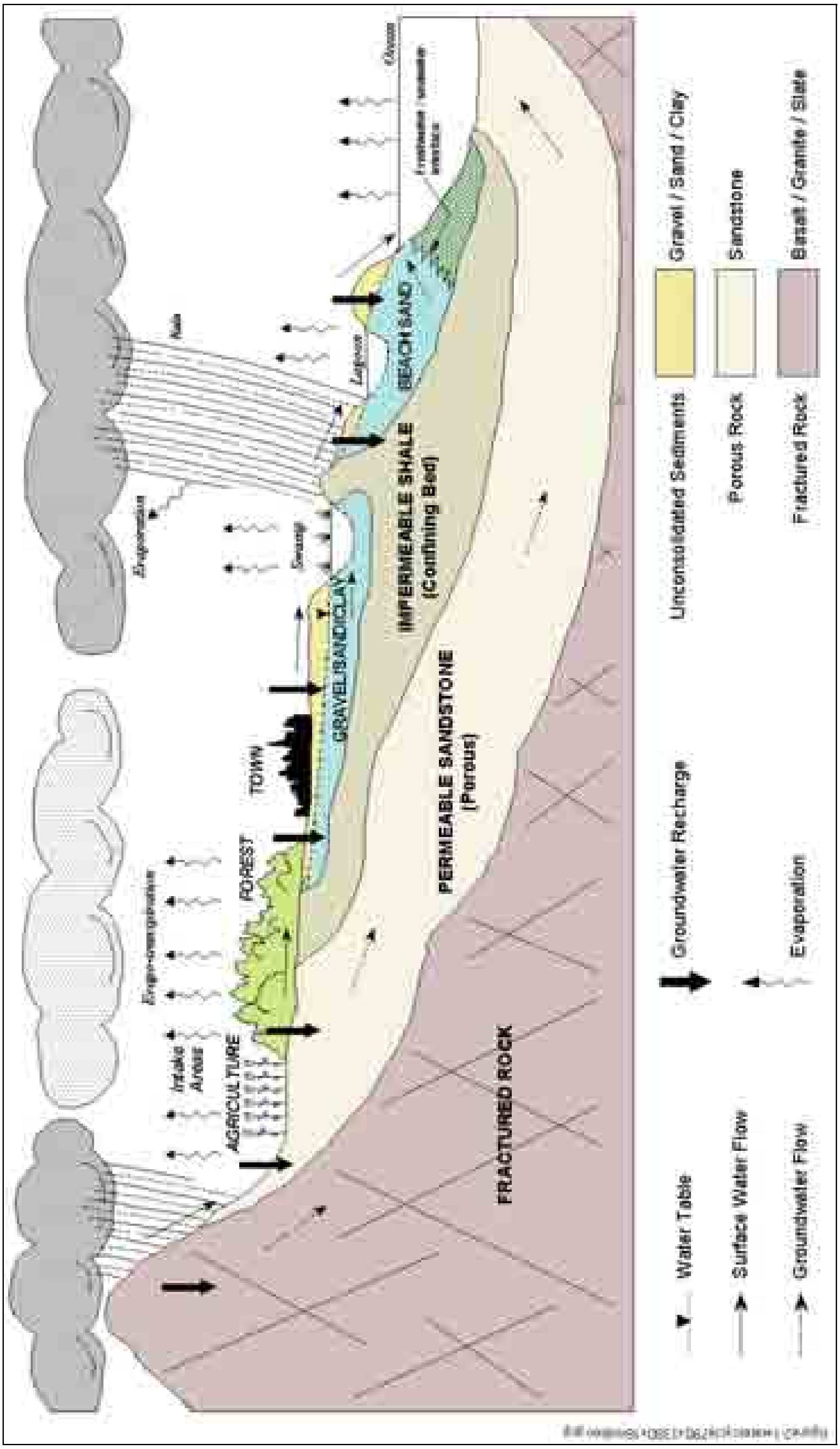

Figure 2.1 The water cycle (source: NSW Government, 1998)

In contrast to aquifers, aquitards and aquicludes do not allow groundwater to be readily extracted. An **aquitard** is a geologic formation that can transmit groundwater but in much smaller, uneconomic quantities than an aquifer. Aquitards generally have low permeability and may act as leaky barriers between aquifers.

An **aquiclude** is a generally impermeable geologic formation that does not allow the passage of groundwater flow.

2.3.4 Types of aquifers

2.3.4.1 Unconfined Aquifers

An **unconfined aquifer** has a saturated zone below the atmospheric pressure level defined by the water table (Figure 2.2). It is representative of the level at which the groundwater and atmospheric pressures are equal. It is not static, but varies in level according to atmospheric and climatic conditions.

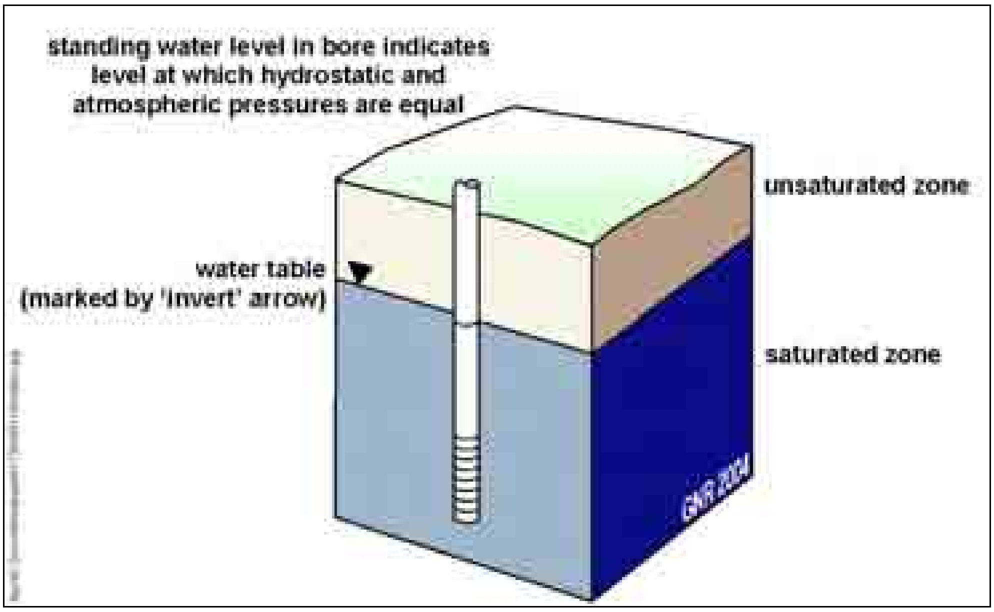

Figure 2.2 Defining attributes of an unconfined aquifer

2.3.4.2 Confined Aquifers

A **confined aquifer** contains groundwater under pressure imparted by the weight of both overlying impermeable materials (overburden pressure) and water elsewhere in the aquifer at higher elevation (hydraulic pressure). Confined aquifers (Figure 2.3) are restricted at the upper boundary by a confining layer (either an aquitard or aquiclude), and may also be bound by an impermeable layer below. In these aquifers groundwater generally rises to a level (which is known as the **potentiometric surface**) above the upper boundary provided an appropriate flowpath exists (such as when a bore intersects the aquifer). An **artesian aquifer** (e.g. the Great Artesian Basin) is a special case of a confined aquifer where the groundwater pressure is so great that, once intersected, it will flow freely at the land surface without the need for pumping.

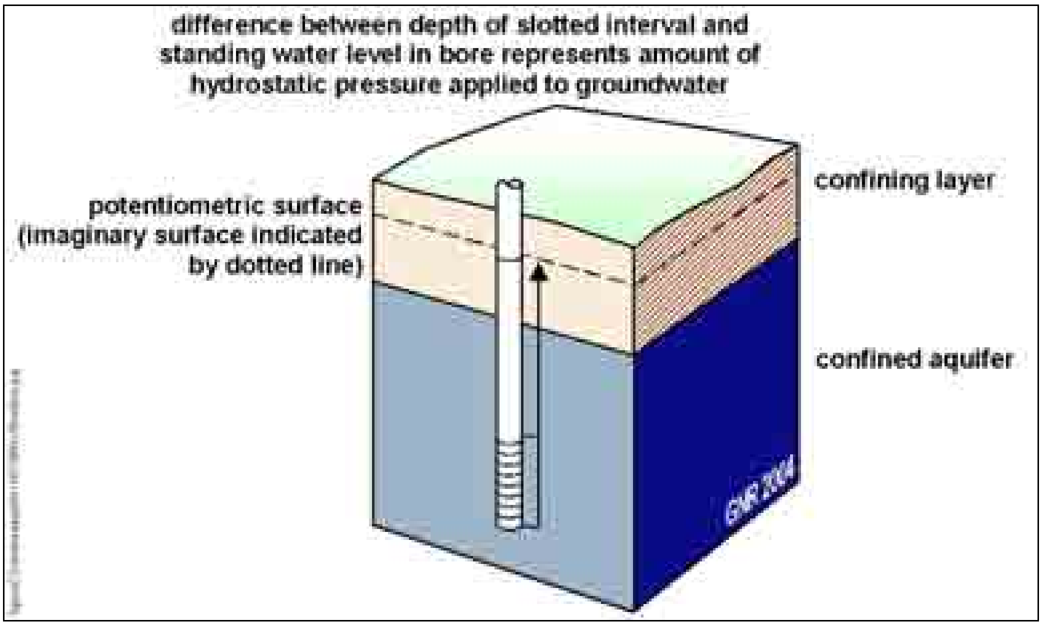

Figure 2.3 Defining attributes of a confined aquifer

2.3.4.3 Perched Aquifers

Perched aquifers are a type of aquifer of generally limited extent that occur where an impermeable layer prevents the downward infiltration of groundwater. The formation of perched aquifers may occur within soils or rocks, but are most commonly presented as groundwater retained upon clay layers within unconfined alluvial aquifers (Figure 2.4). In examples of that kind, perched aquifers are defined as being separated from the main water table by an unsaturated zone.

Perched aquifers are generally of minor importance with regard to management and do not ordinarily retain significant quantities of groundwater in storage. They may provide some level of support to dependent ecosystems, but are usually not of sufficient scale to provide useable water supplies.

2.3.5 Groundwater flow

The direction and rate of groundwater flow is determined by the hydraulic gradient applied, through differences in water level or pressure. The **hydraulic gradient** is the difference in groundwater level (either water table or potentiometric surface elevation) between two points (usually monitoring bores). The direction of groundwater flow may be inferred to be perpendicular to contours of equal water level elevation (Figure 2.5).

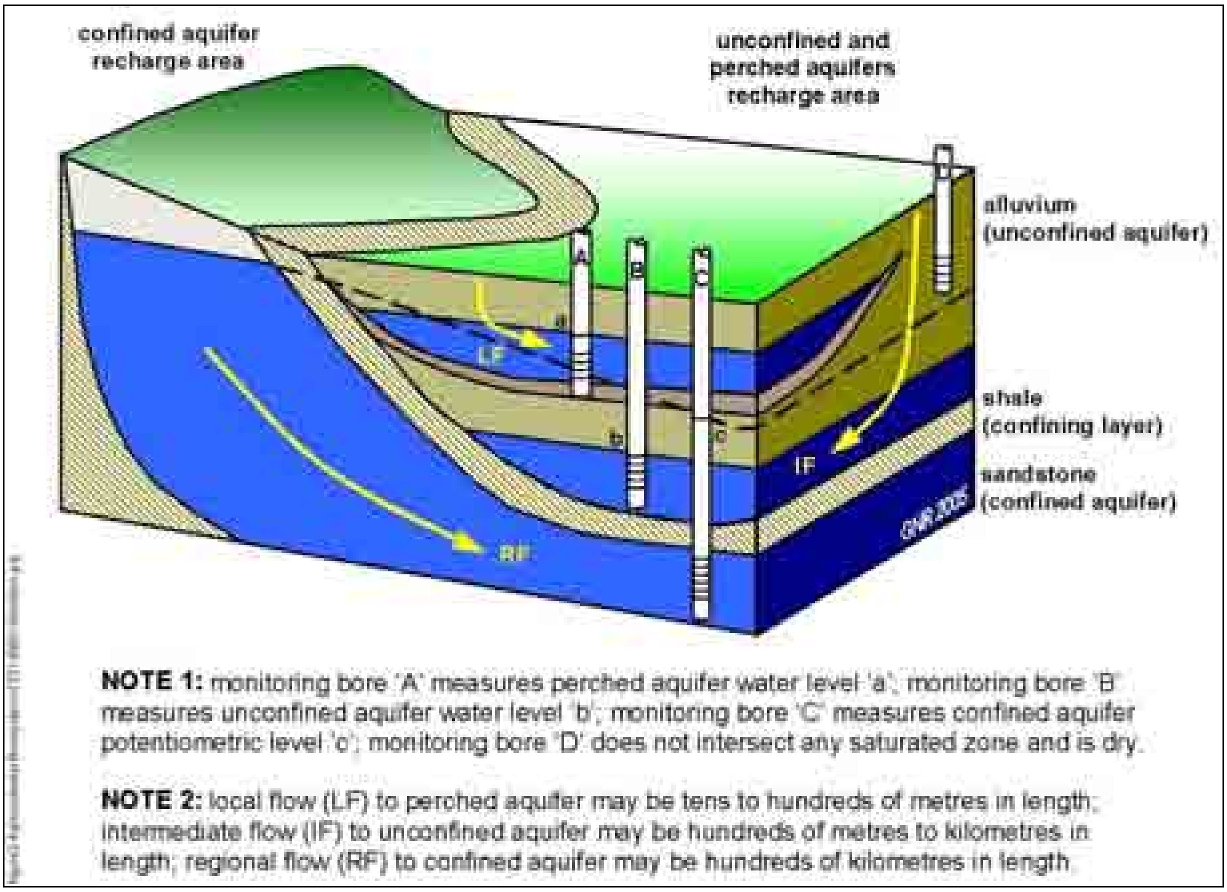

Figure 2.4 Comparison between perched, unconfined and confined aquifers

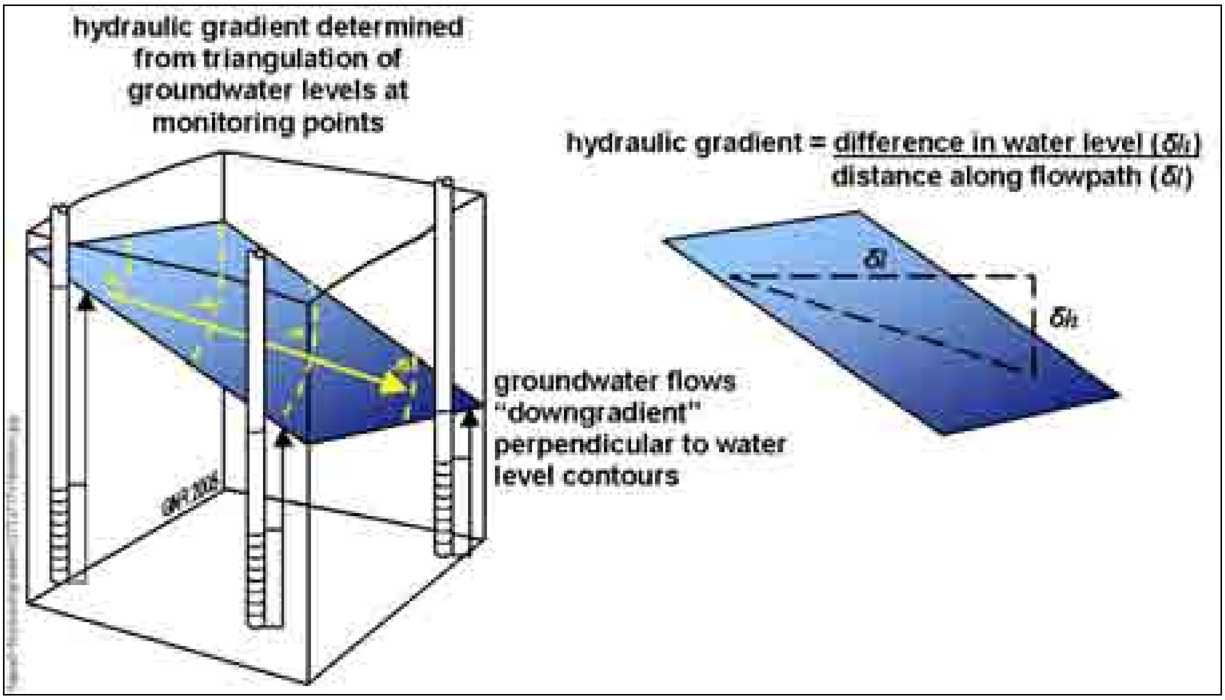

Figure 2.5 Explanation of hydraulic gradient

In unconfined aquifers, the difference in water table elevation drives groundwater downgradient (i.e. from high to low water level). For confined aquifers, however, differences in pressure usually dictate the hydraulic gradient.

For small areas the hydraulic gradient is usually assumed to be a planar surface between monitoring points. However, hydraulic gradients can vary depending on the type of aquifer material through which the groundwater passes. Where the lateral movement of groundwater is restricted by fine-grained materials, the hydraulic gradient may substantially increase over short distances. Hence, the hydraulic gradient should really be considered as an irregular surface, although this may be difficult to define accurately.

2.3.6 Aquifer hydraulic characteristics

The hydraulic characteristics of aquifers that have the most significant bearing on groundwater management are porosity and permeability. These characteristics describe different physical aspects (Figure 2.6) and determine how groundwater is stored and moves through the aquifer.

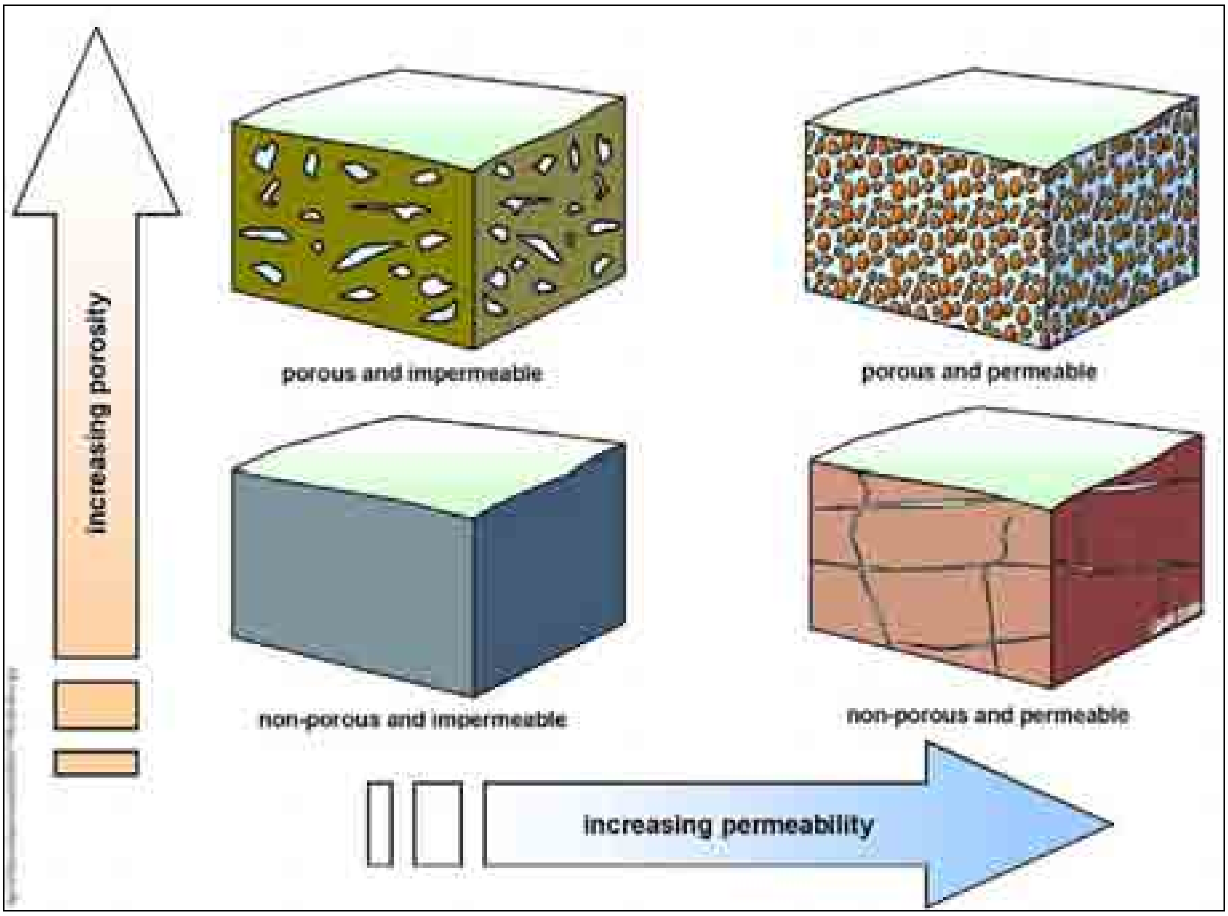

Figure 2.6 Comparison of porosity and permeability

Porosity is defined as the ratio of the volume of void space to the total volume of the geologic formation. The porosity of a material may be developed at the time of deposition (primary porosity) or it may be induced by fracturing or weathering after the material was formed (secondary porosity). In some cases, a formation may have both primary and secondary porosity, in which circumstance it is said to be a “dual porosity aquifer”.

The **permeability** of a geologic formation is related to the degree to which existing void spaces are interconnected. Aquifers have voids that are well interconnected, allowing groundwater to pass through readily. Less permeable aquitards may have only a limited network of voids or may be primarily interconnected in planes perpendicular to the predominant groundwater flow direction. Hence, aquitards may be “leaky” and allow some small flow of groundwater through, but not in significant quantities. Aquicludes may have some degree of porosity, however there is no interconnection to allow the passage of groundwater and hence they are impermeable.

Permeability is generally indicated as a measurement of transmissivity or hydraulic conductivity. **Transmissivity** (T) is defined as the rate of horizontal groundwater flow through the full saturated thickness of an aquifer across a unit width under a unit hydraulic gradient (i.e. a metre decline in level for every metre of distance travelled). It is generally expressed in terms of metres squared per day (m^2/day). **Hydraulic conductivity** (K) is defined as the rate of horizontal groundwater flow through a unit area (i.e. 1 metre x 1 metre) of an aquifer under a unit hydraulic gradient. This parameter is usually expressed in terms of metres per day (m/day).

Hydraulic conductivity values commonly range between 0.02 and 40 m/day for unconsolidated sediment aquifers, less than 0.5 m/day for sandstone, and below 0.0001 m/day for clays or shale. The determination of hydraulic conductivity can be achieved through falling or rising head tests, laboratory permeameter trials, or comprehensive field pumping tests with multiple observation points (which produce the most representative values).

Transmissivity values are generally derived from the graphical analysis of pumping tests results using published methods. These can be converted to hydraulic conductivity values by dividing the transmissivity by the saturated thickness of the aquifer tested. The determination of hydraulic conductivity from field pumping tests, therefore, requires knowledge of the groundwater level and the depth to the base of the aquifer.

2.4 Groundwater in the SCCG region

2.4.1 Geology of the SCCG region

The most common geological unit across the SCCG region is the Hawkesbury Sandstone Formation. This formation comprises fine to medium sand grains cemented into a hard matrix. On weathering, the sandstone develops thin, skeletal sandy soils and weakens to a friable (crumbly) consistency. Some harder areas remain as steep cliffs or vegetated hills, and these may also be supported by occasional shale bands of moderate thickness.

Along the coast, the deeper Narrabeen Group is exposed as sandstone cliffs below the Hawkesbury Sandstone outcrop. The deeper geological unit is more apparent in the northern coastal parts of the SCCG region, such as the Local Government Area of Pittwater, and is generally made up of a more fine-grained matrix than the overlying Hawkesbury Sandstone.

Minor outcrop of Wianamatta Group shales occurs in parts of the LGAs forming the SCCG region. These form generally impermeable caps to Hawkesbury Sandstone outcrops. To the west of the SCCG region, in Western Sydney, these shales form a significant confining layer above the Hawkesbury Sandstone, reaching thicknesses in excess of 100 metres. However, in the SCCG region, the thickness of the shale caps is expected to be considerably less, generally no more than 10 metres. The shales weather to a stiff clay and form more rounded, less steep hills than the sandstones.

Some significant areas of coastal sand bed deposits also occur, most notably the Botany Sand Beds. These deposits are generally formed from medium- to coarse-grained sands deposited through wind action. The grains are generally well sorted (i.e. fairly uniform in size), and angular, which allows for varying degrees of packing and compaction. Commonly interspersed between sand layers are clays, originating from estuarine creeks and lagoons, and peats, formed from swamp deposits. A hard layer of cemented sand known as "Waterloo rock" in the Botany Sand Beds, or "coffee rock" elsewhere, may also be present in these deposits.

Some limited areas of alluvium associated with major drainage lines, such as Cooks River and Muddy Creek, also occur within the LGAs of member Councils. These deposits are predominantly comprised of clayey and silty sands derived from past fluvial activity.

The distribution of these geological units amongst the LGAs in the SCCG region is illustrated in Figure 2.7 and identified in Table 2.1.

Table 2.1 Major, secondary and minor geological units in member Council areas.

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	

2.4.2 Hydrogeology of aquifers in the SCCG region

The different geological units described above may be categorised into generic aquifer classes based on the predominant mode of groundwater occurrence in each system. These are: unconsolidated sediments; consolidated porous rocks; and variably fractured rocks. Each of the geological units in the SCCG region may be classified as follows:

- Unconsolidated sediments - Coastal sand bed deposits and alluvium.
- Porous rock - Hawkesbury Sandstone Formation and Narrabeen Group sandstones.
- Fractured rock - Wianamatta Group shale.

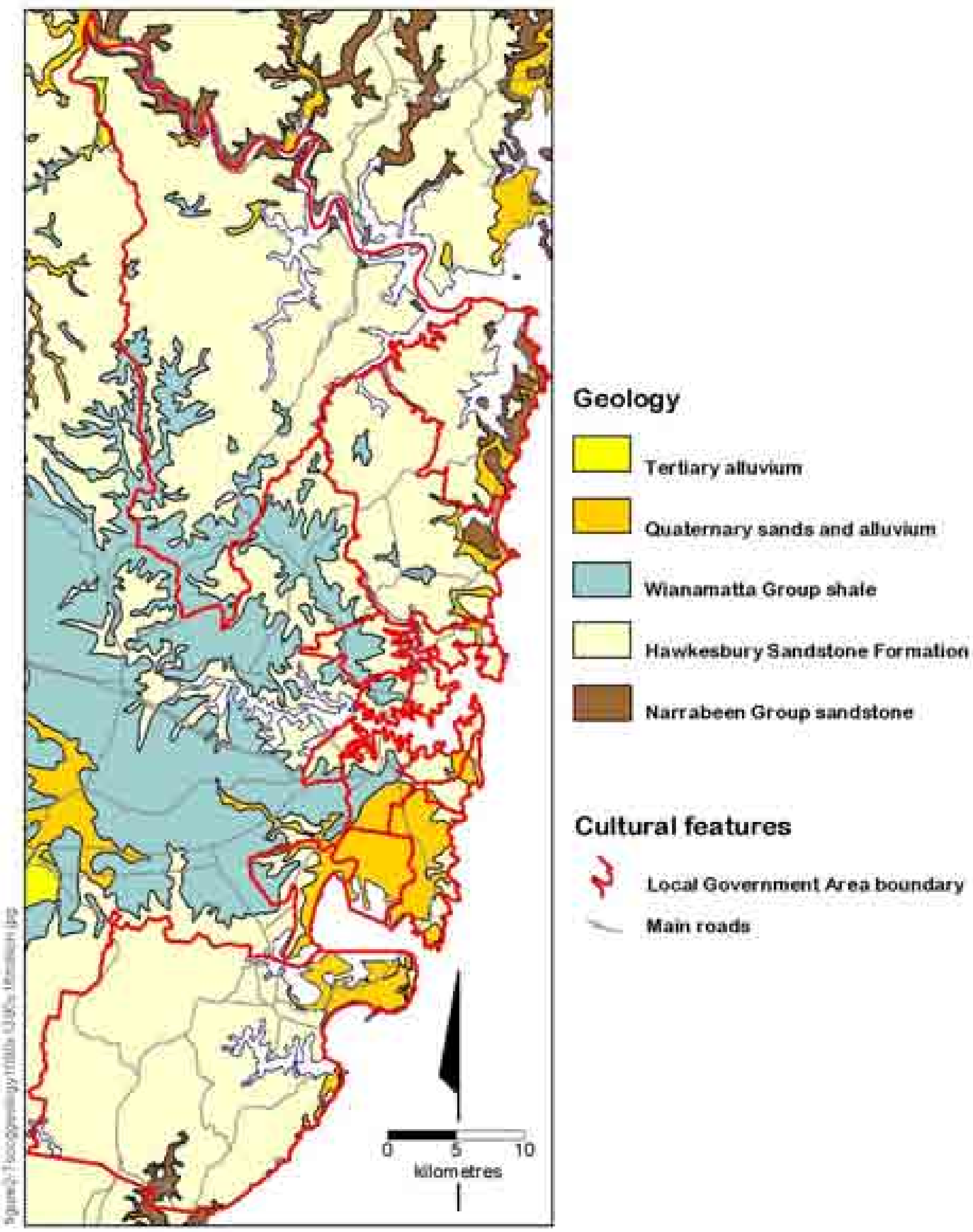

Figure 2.7 Simplified geological map of the SCCG region

2.4.2.1 Unconsolidated sediments - coastal sand bed deposits and alluvium

Coastal sand bed aquifers are located throughout various districts along the NSW coast. They contain significant groundwater resources because they have a subsurface characterised by sandy material that is highly permeable and porous. These deposits form the characteristics of the type unconfined aquifer, with a well defined water table that is responsive to recharge events, and even tidal influences in some cases.

Coastal sand bed aquifers are readily recharged by direct rainfall infiltration. These aquifers generally have a relatively shallow water table, often less than a few metres below the natural ground surface level in low-lying areas. Because the groundwater in these aquifers is close to the ground surface, they are very vulnerable to contamination, particularly in urban environments. They also have a substantial ecosystem support function for Groundwater Dependent Ecosystems (GDEs), such as wetlands, swamps, estuarine habitats and coastal terrestrial vegetation. The Botany Sand Beds aquifer south of the Sydney CBD is a major example of this type of system.

Alluvial aquifers in the SCCG region are generally of limited extent and of minor significance. In the main, they are comprised of clayey and silty materials with low inherent permeability, often yield poor quality groundwater and therefore do not generally incorporate a substantial resource. Because of this, these aquifers will be included with the coastal sands type in this Handbook as the management issues to be dealt with are generally applicable to both.

Groundwater management is particularly relevant to proposed developments in coastal and estuarine areas that are underlain by unconsolidated sediments. In the SCCG region this mostly relates to the Botany Sand Beds aquifer. However, there are smaller localised areas along the Sydney coastline, such as Double Bay, Rose Bay, Coogee, Collaroy and Manly, where such management issues also apply.

2.4.2.2 Porous rock - Hawkesbury Sandstone and Narrabeen Group

The **porous rock aquifers** in the SCCG region contain limited quantities of groundwater because of the manner in which the water bearing zones formed. Generally, the sandstones are fine- to medium-grained and cemented, making the bulk of the rock mass relatively impermeable. Groundwater occurs within sub-horizontal porous layers (coarser sands and gravels in which the cementing agents have been dissolved) at various depth intervals throughout the rock mass (primary porosity). In addition, fissuring due to movement of the rock mass after it had formed generated a secondary porosity comprising fractures and joints.

Porous rock aquifers in the SCCG region have not strictly developed the type characteristics of a confined aquifer. The sandstone itself often forms both the confining layers (cemented fine-grained intervals) and the aquifer (water bearing zones of coarse-grained and fractured rock). In parts the sandstone is capped by Wianamatta Group shale, however these occurrences are generally of limited extent within the SCCG region and of insufficient thickness to act as a type confining layer.

The member Council areas of Hornsby, Leichhardt, Manly, Mosman, North Sydney, Pittwater, Sutherland, Warringah, Waverley, Willoughby and Woollahra are dominated by porous rock (sandstone) aquifers.

Porous rock aquifers can be characterised by the presence of springs, where groundwater discharges at the land surface. Springs occur where water bearing zones intersect the land surface on cliff faces or in excavations, or in places where shale bands within the sandstone force groundwater to flow laterally rather than infiltrate deeper into the rock mass (Figure 2.8). Such springs are generally developed from shallow, perched groundwater systems that are of limited lateral extent and can be depleted rapidly in the absence of continuing recharge.

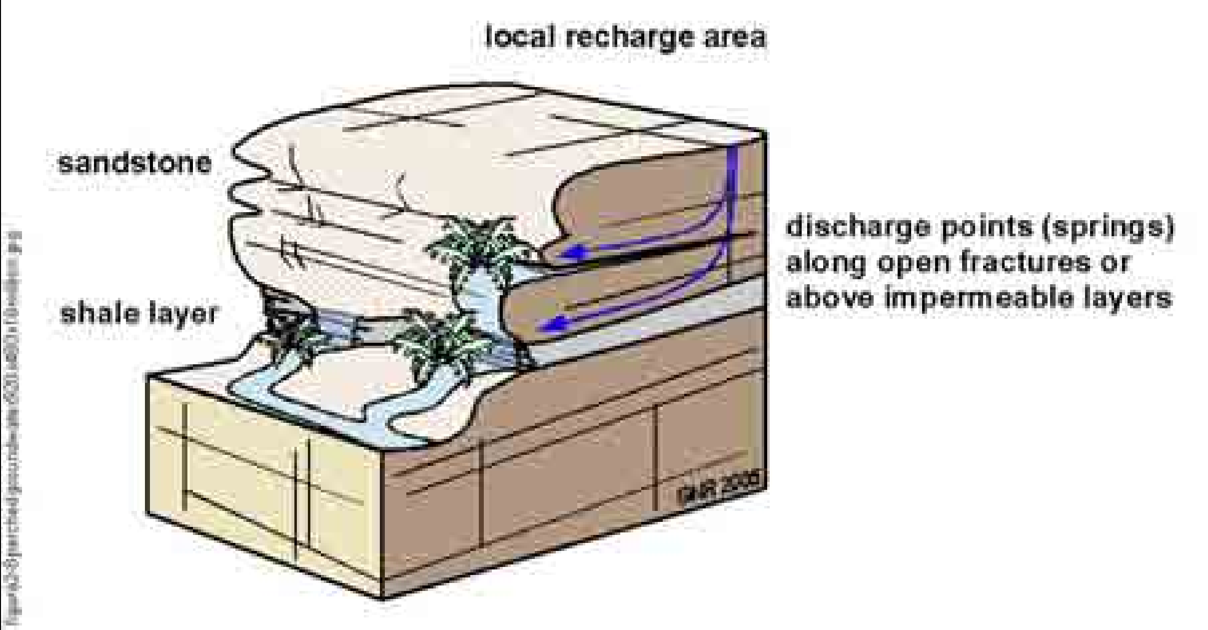

Figure 2.8 Perched groundwater systems in sandstone areas

Commonly, these perched systems are formed on steep sandstone slopes or cliffs and are recharged from the tops of the hills where they occur. Whilst the perched aquifer systems are generally not significant as a water resource, they frequently provide support to small, dependent ecosystems that have developed in response to the semi-permanent discharge. Springs resulting from the perched aquifer systems may be numerous and significant on local scales in preserving a variety of vegetation and therefore the amenity of many suburban areas.

2.4.2.3 Fractured rock - Wianamatta Group

Only limited exposure of Wianamatta Group shales occur within the SCCG region. Council areas bordering the region to the west have more substantial outcrop of these rocks, where they can contribute to problems with salinity at the land surface and in the deeper underlying sandstone aquifers targeted for water supply.

Because the outcrops in the SCCG region generally only form minor caps to sandstone hills and ridges they may not be significant as fractured rock aquifers. However, the influences of these aquifers are not well understood in the SCCG region, and therefore they should not necessarily be discounted as unimportant.

Member Council areas with minor exposures of Wianamatta Group shales are Hornsby, Leichhardt, North Sydney, Rockdale, Sydney, Warringah and Willoughby.

2.5 Recommendations

Recommendations

It is recommended that:

- This Handbook be distributed to all SCCG member Councils.
- Educational materials on groundwater is developed in consultation with all SCCG member Councils.
- Fact sheets outlining the typical occurrence, behaviour and characteristics of groundwater be developed by Councils, in consultation with DNR and others, for wider distribution to the community.

2.6 Suggested technical and further reading

1. **Bish, S. and Gates, G., 1994**. Environmental concerns halt proposed shallow water development in a NSW coastal aquifer. Conference Paper *Water Down Under 94* volume 1 – Groundwater/Surface Hydrology Common Interest Papers, pp. 399-403. ISBN 85825 607 X.

2. **Branagan, D.F., 2000a**. The Hawkesbury Sandstone: Its Origins and Later Life. Proceedings of the 15th Australian Geological Convention, 'Sandstone City – Sydney's Dimension Stone and other Sandstone Geomaterials'. Held at the University of Technology, Sydney, July 2000. pp. 23-38. ISBN 1 876315 22 9.

3. **Branagan, D.F., 2000b**. Structural Geology of the Hawkesbury Sandstone with Particular Reference to the City Of Sydney and Nearby Areas. Proceedings of the 15th Australian Geological Convention, 'Sandstone City – Sydney's Dimension Stone and other Sandstone Geomaterials'. Held at the University of Technology, Sydney, July 2000. pp. 39-54. ISBN 1 876315 22 9.

4. **Domenico, P.A. and Schwartz, F.W., 1990**. Physical and Chemical Hydrogeology. John Wiley and Sons Inc., New York. ISBN 0-471-50744-X.

5. **Driscoll, F.G., 1986**. Groundwater and Wells – Second Edition. Johnson Division, St. Paul, Minnesota. ISBN 0-9616456-0-1.

6. **Fetter, C.W., 1988**. Applied Hydrogeology – Second Edition. Macmillan Publishing Company, New York. ISBN 0-675-20887-4.

7. **Freeze, R.A. and Cherry, J.A., 1979**. Groundwater. Prentice-Hall Inc. New Jersey. ISBN 0-13-365312-9.

8. **Hatley, R.K., 2004**. Hydrogeology of the Botany Basin. Proceedings of the Mini-Symposium 'Engineering Geology of the Sydney Region - Revisited'. Australian Geomechanics, Volume 39, Number 3. September. pp. 73-91. ISSN 0818-9110.

9. **Johnson, Inc., 1972.** Groundwater and Wells - A Reference Book for the Water-well Industry. Johnson Division, Universal Oil Products Co., Minnesota.

10. **Jolly, P. and Foo, D., 1994**. Investigation, development and management of groundwater resources for water supplies in remote coastal aboriginal communities in the Northern Territory, Australia. Conference Paper *Water Down Under 94* volume 1 – Groundwater/Surface Hydrology Common Interest Papers, pp. 423-428. ISBN 85825 607 X.

11. **McKibbin, D. and Smith, P.C., 2000**. Sandstone Hydrogeology of the Sydney Region. Proceedings of the 15th Australian Geological Convention, 'Sandstone City – Sydney's Dimension Stone and other Sandstone Geomaterials'. Held at the University of Technology, Sydney, July 2000. ISBN 1 876315 22 9.

12. **McNally, G.H., 2000**. Geotechnical Investigation and Reclamation of Sandstone and Shale Quarries in the Sydney Region. Proceedings of the 15th Australian Geological Convention, 'Sandstone City – Sydney's Dimension Stone and other Sandstone Geomaterials'. Held at the University of Technology, Sydney, July 2000. pp. 163-177. ISBN 1 876315 22 9.

13. **McNally, G.H., 2004**. Shale, Salinity and Groundwater in Western Sydney. Proceedings of the Mini-Symposium 'Engineering Geology of the Sydney Region – Revisited'. Australian Geomechanics, Volume 39, Number 3. September. pp. 109-124. ISSN 0818-9110.

14. **NSW Government, 1998**. The NSW State Groundwater Quality Protection Policy. Prepared by the New South Wales Department of Land and Water Conservation, Sydney. Report No. HO/37/98, December. ISBN 0 7313 0379 2. Available on-line at: http://www.naturalresources.nsw.gov.au/water/pdf/nsw_state_groundwater_quality_policy.pdf [accessed 30 June 2006].

15. **Tammetta, P. and Hewitt, P., 2004**. Hydrogeological Properties of Hawkesbury Sandstone in the Sydney Region. Proceedings of the Mini-Symposium 'Engineering Geology of the Sydney Region – Revisited'. Australian Geomechanics, Volume 39, Number 3. September. pp. 93-108. ISSN 0818-9110.

16. **Todd, D.K., 1980**. Groundwater Hydrology – 2nd Edition. John Wiley and Sons Inc., New York. ISBN 0-471-08641-X.

3.0 ACCESSING GROUNDWATER FOR WATER SUPPLY

3.1 Introduction

Because groundwater remains mostly unseen, there is generally little understanding of the potential for it to be used as an alternative water supply. This potential varies throughout the SCCG region, and can only be broadly assessed because of the changes in geological characteristics, and limited data, in many areas.

This chapter outlines the types of uses for which groundwater is accessed. It also broadly describes the two main types of installation ("groundwater work") used in the SCCG region. An indication of the considerations and legal requirements for installing a groundwater work is provided, together with the obligations placed on users of the resource.

Note

All groundwater works for water supply purposes require a licence from DNR.

3.2 Objectives

Objectives

The objectives of the chapter are:

- To clarify the requirements and obligations associated with installing a groundwater work.
- To describe the two main types of groundwater work used in the SCCG region.
- To identify the suitability of particular groundwater works in different geological settings.
- To provide guidance in siting and using a groundwater work in an urban area.
- To describe essential considerations in sampling groundwater for testing of water quality.
- To provide a broad understanding of the potential for, and risks associated with, using groundwater as an alternative water supply.
- To provide a basis for the understanding of groundwater management, described later in the Handbook.

3.3 Groundwater uses in the SCCG region

3.3.1 Irrigation

The use of groundwater by member Councils throughout the SCCG region generally involves the irrigation of public parks, playing fields, gardens and golf courses. Such open space irrigation requires high yields of good quality groundwater, particularly for golf courses, and therefore these applications are primarily found across the coastal sand aquifers. In areas where porous or fractured rocks occur, the groundwater yields may be too low, and the quality not suitable, for such purposes. Large diameter, appropriately constructed and fully penetrating bores are required to maximise the groundwater yield available for such use.

3.3.2 Domestic water supply

Domestic or household use of groundwater is really only affordable and practical in the coastal sand bed aquifer areas of the region. Most domestic use occurs within the Botany Sand Beds aquifer, including suburbs such as Kensington, Pagewood, Rockdale and Kurnell, although areas around Bondi, Rose Bay, and Manly are also suitable.

Commonly, inquiries are received about the prospects for using groundwater to supply intended domestic uses such as garden watering, car and boat washing, cleaning paved surfaces (such as driveways), irrigation of plants and filling swimming pools and spas. Less frequently, other household uses are proposed including toilet flushing, washing and shower use.

Domestic use generally requires low yields of good quality groundwater, and therefore such applications usually only require the installation of a spearpoint. Because only small flow rates are generally required, works that only partially penetrate the aquifers can be used successfully.

In the coastal sand bed areas, spearpoints are in demand as an inexpensive supply for garden watering because frequent irrigation is required to counteract the high infiltration rates. Critically, most domestic users are located in areas of high groundwater vulnerability and are not aware of the potential for the bore water they are using to become contaminated.

3.3.3 Industrial process or cooling water

Historically, many industries were located to the south of Sydney across the Botany Sand Beds aquifer due to the availability of groundwater as a water supply. Large yields of good quality water were required for most industrial purposes. These activities were utilising significant quantities of groundwater throughout the 1960s, 1970s and 1980s, peaking at around 20,000 ML per year. However, due to the increasing awareness of contamination within the sand beds aquifer, many industries reduced their reliance on groundwater, or chose avoid it altogether. Currently, few industries in that area use groundwater from this source.

Elsewhere in the SCCG region, in the porous and fractured rock areas, the yields and quality of groundwater generally preclude industrial application. Large diameter, appropriately constructed and fully penetrating bores are required to maximise the more limited groundwater yield available for use in these areas.

3.3.4 Commercial use

Some areas of the SCCG region include groundwater works licensed for commercial purposes. These are primarily for nursery water supplies, to provide for plant watering, and can be serviced by lower yields than those required for either industrial or irrigation uses. Water supplies for nurseries have been established in the coastal sand bed aquifers and parts of the porous rock (Hawkesbury Sandstone Formation) areas. The localities where commercial uses can be developed are subject to the same constraints as for industrial uses, that is, limitations on either yield or quality, or both. Appropriately constructed, fully penetrating bores are required to maximise the groundwater yield in these aquifers.

3.4 Types of installations

Within the SCCG member Council areas, two main types of water supply installation (“groundwater work”) are used. These are **spearpoints** and **bores**.

3.4.1 Spearpoints

Spearpoints are shallow installations usually reaching no more than 6 metres in depth. They comprise small diameter casings and screens of lightweight construction and are therefore suitable only for areas of soft sediment. Because they are not very robust, and are installed by jetting or pushing into the ground, the areas where they can be used are generally limited.

Spearpoints are installed to shallow depths (i.e. only partially penetrate into the aquifer) and are operated using a surface mounted suction pump (Figure 3.0). Groundwater extraction is reliant on the water table being sufficiently close to the ground surface to maintain suction. The lowering of the water table during drought periods, the deterioration of airtight seals, or the clogging of the wellpoint can all reduce the amount of water that can be pumped. Instances of spearpoints going dry during drought have been reported in the past because the water level has declined below the reach of the suction pump.

These installations usually only deliver low yields in the range 0.3 to 0.5 litres per second (L/sec). Such flow rates are suitable for household use, but are generally too low for other purposes. Where greater yields are required, batteries of spearpoints (multiple installations in lines connected by piping) are sometimes used. Spearpoint batteries are commonly used for coastal village water supplies, but are more likely to be encountered in the SCCG region for the purposes of dewatering of sites for construction purposes.

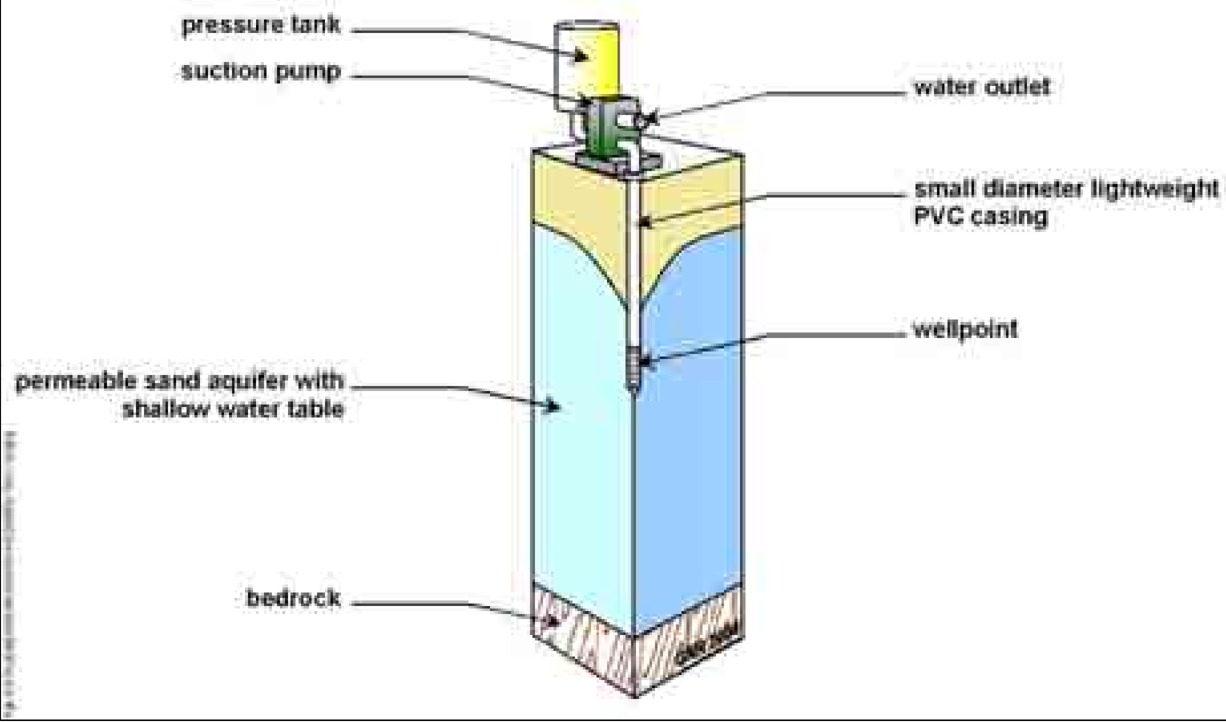

Figure 3.0 Typical construction of a spearpoint installation

Note

Because of their lightweight construction, spearpoints can only be utilised for water supply in the coastal sand bed aquifers (i.e. where properties are underlain by soft sediments and shallow water tables). They cannot be installed in areas where hard rock occurs at shallow depth.

3.4.2 Bores

Bores are more complicated installations than spearpoints because they are designed to maximise the available yield during pumping. They are generally large diameter robust installations that fully penetrate the aquifer (i.e. extend through the entire thickness of the water bearing layer).

Bores typically comprise heavy duty PVC casing and stainless steel screens. Construction usually involves the installation of filter pack material, made up of washed and graded gravel, to surround and support the screens. A bentonite clay seal and concrete sanitary seal are placed above the filter packed interval to prevent contamination from overlying layers or from the ground surface (Figure 3.1).

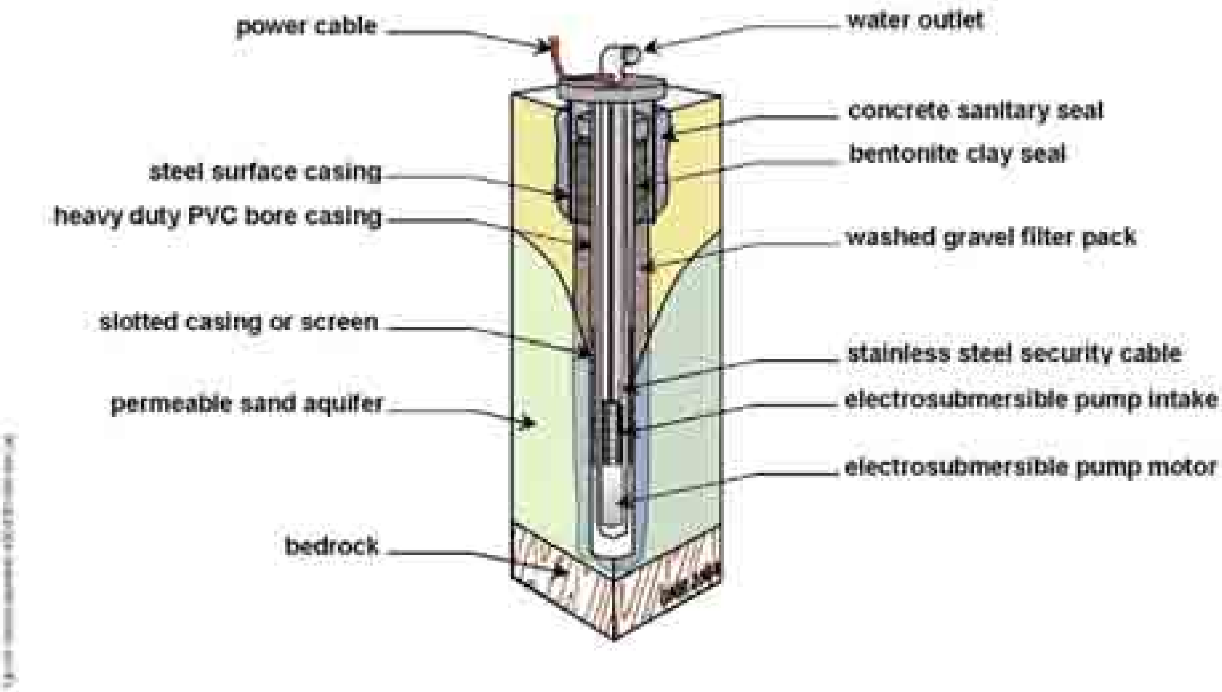

Figure 3.1 Typical construction of an irrigation bore

Because bores are drilled and constructed as two separate processes, they have a wider range of application than spearpoints (which are "drilled" and constructed in the one action). They are also considerably more expensive to install and operate than spearpoints. Bores are not restricted to areas of soft sediment, but can be installed into hard rock, such as the Hawkesbury Sandstone Formation areas of the SCCG region.

The extraction of groundwater from bores is most commonly accomplished by the use of electrosubmersible pumps. The electrosubmersible pump is suspended in the bore at a depth below the water table, allowing the motor to be cooled by the flow of groundwater during pumping. Because the pump does not operate by suction, but drives the groundwater to the surface, bores are not prone to loss of supply as readily as spearpoints. However, clogging of screens may still be an issue, and iron fouling of the pump intake can also reduce yields.

The flow rates provided by bores are dependent on the nature of the aquifer into which they are installed, together with the construction techniques and materials used. In the SCCG region, properly constructed bores in coastal sand bed aquifers may yield in excess of 40 L/sec, whereas bores in Hawkesbury Sandstone might only produce 0.5 to 1 L/sec.

3.5 Requirements for establishing a groundwater supply

In order to establish a bore water supply, there are two essential requirements to be considered initially. These are that the **work itself must be licensed** (i.e. a bore licence must be applied for and obtained by the intended user), and that the driller selected to carry out the installation is a **licensed water bore drilling contractor**.

These requirements have previously been enacted within State legislation under the *Water Act 1912* and will be carried over into the *Water Management Act 2000* when the provisions of that Act have been enabled across the state. To avoid confusion, further discussion of licensing arrangements will be limited to the requirements under the *Water Act 1912*. It is envisaged that later editions of this Handbook will describe the provisions of the *Water Management Act 2000*.

Several obligations apply to both the licensee and the driller, including environmental protection, occupational health and safety, and prevention of pollution (Table 3.0).

Table 3.0 Licensee and driller's obligations when installing a groundwater work.

Licensee obligations	**Drillers obligations**
• A bore licence for the intended purpose has been obtained from DNR.	• A written quotation for the installation of the groundwater work has been provided to the client.
• The class of driller's licence held by the water bore drilling contractor is appropriate for the proposed type of installation.	• A bore licence appropriate for the work has been obtained by the licensee and the conditions outlining the construction have been read and understood.
• Access and clearances for the drilling rig are sufficient in the area selected for the work.	• Clear technical advice on the type of work, site controls and materials to be used have been provided to the client.
• The presence and location of underground or overhead services (e.g. water, gas, electricity) around the site.	• Drilling and constructing the work in accordance with the *Minimum Construction Requirements for Water Bores in Australia - 2nd Edition* (LWBC 2003) and licence conditions.
• Obtaining a written quotation or agreement from the driller indicating the activities to be carried out and the materials to be used.	• Observation of safety requirements during drilling.
• Observing the drilling and construction of the groundwater work from a safe distance and ensuring compliance with the written agreement or quotation.	• Disposal of drill cuttings ("drilling spoil") in an environmentally acceptable manner.
• Forwarding a fully documented and signed copy of the '*Form A - Particulars of a Completed Bore*' to DNR (in some cases the driller may forward a signed copy of the Form A to DNR on behalf of the licensee).	• Controlling discharge of drilling fluids and groundwater to prevent their release off-site.

A basic checklist of these requirements should be used to ensure that appropriate approvals and safeguards are observed prior to, during and following the installation of any groundwater work.

3.6 Considerations in siting and using a groundwater work

3.6.1 Siting a groundwater work

The siting of a groundwater work is not only important in terms of ease of use, but must also account for other site-specific considerations. In particular, important local features such as property boundaries, waterways and waste disposal areas may all have significant bearing on the suitability of a location for a groundwater work.

Frequently Asked Questions: Bore water supplies

Do I need a licence to access and use groundwater?
Yes. State legislation requires that all works connected to a source of underground water and used for water supply, groundwater monitoring, dewatering, or other specified purposes must be licensed. An application must be submitted to the Department of Natural Resources (DNR) and a bore licence obtained for all works (including spearpoints, wells, excavations and other structures) before drilling commences.

Where can I get a bore licence application?
Application forms are available from DNR licensing personnel in your area (look under 'Natural Resources, Department of' in the Business Listings section of your local White Pages).

Why do I need a licence?
Obtaining a licence for your bore allows you to legitimately extract groundwater and use it for the purpose specified on the licence. Carefully read all documentation provided as you will need to abide by the conditions specified for the bore licence. A licence also provides recognition of your claim to a share of the resource and allows DNR to keep you informed should some event make the groundwater in your area unusable.

How much does it cost to get a licence?
Licences issued for domestic or stock purposes (and some other low yield applications) do not attract any fee. Licences for water supply to commercial ventures (including industrial, irrigation, and commercial purposes) attract two fees that are set by the Independent Pricing and Regulatory Tribunal (IPART) and are levied annually. Check with DNR licensing personnel in your area for information on the current fee structures.

If I move, can I use the licence on the property I have just purchased?
No. Currently licences are linked to a particular parcel of land (specified by the Lot number, Deposited Plan number, Parish and County cadastral description on the licence). When you sell your old property you should provide the new owner with the licence and any associated bore records. You will need to apply for a new licence for your new property if there is no bore already installed. If there is a bore on your new property, you should seek any licensing documentation from the previous owner. You will also need to notify DNR licensing personnel of the change in ownership so the bore licence can be amended appropriately.

Who can I get to install a bore for me?
Only licensed water bore drilling contractors are legally allowed to install a work (bore, spearpoint, etc.). You will need to confirm that the contractor holds a class of driller's licence appropriate for the proposed drilling. Licensed water bore drilling contractors (look under 'Boring and/or Drilling Contractors' in your local Yellow Pages) are required to view the bore licence and conditions sheet before drilling commences. Once the bore is completed, they are required to forward to DNR all physical details of the work on a completion report known as a 'Form A - Particulars of Completed Bore'.

What else should I do before having a bore drilled?
You should check that there is sufficient access for the drilling rig on your property. You should also check the location of underground services by checking with council or telephoning 'Dial-Before-You-Dig' (freecall 1100) for advice.

Some Councils require a Development Application to be lodged that covers the construction of a bore. You should check with your local Council what requirements apply and the tasks that need to be undertaken to obtain development consent where it is necessary.

Bore or spearpoint installation checklist

Before drilling commences:

- ☐ Bore licence obtained from the Department of Natural Resources (DNR)
- ☐ Licensed water bore drilling contractor selected
- ☐ Site located and prepared following consultation with driller
- ☐ Underground services locations checked, proposed site is clear of utilities
- ☐ Access to proposed site adequate for drilling rig, or can be arranged
- ☐ Signed written agreement with licensed water bore drilling contractor obtained
- ☐ Driller’s licence viewed, classifications and endorsements appropriate
- ☐ Bore licence conditions read and understood
- ☐ Development consent obtained from Council (where required)

During drilling and construction:

- ☐ Clearance from overhead power lines adequate and maintained
- ☐ Safety precautions around drilling site adequate and observed at all times
- ☐ Log of geological formations intersected during drilling recorded
- ☐ Bore designed and constructed in accordance with *‘Minimum Construction Requirements for Water Bores in Australia - 2nd Edition’*
- ☐ Bore designed and constructed in accordance with licence conditions
- ☐ Techniques and materials used consistent with those in written agreement
- ☐ Groundwater yield and salinity measurements recorded
- ☐ Tailwater (discharge water) controlled on-site and disposed of appropriately
- ☐ Water quality sample collected

After drilling completed:

- ☐ ‘Form A - Particulars of Completed Work’ completed, signed and forwarded to DNR
- ☐ Water quality sample submitted to NATA registered laboratory for testing
- ☐ Drilling waste (soil, rock fragments, muds, foam, etc) disposed of appropriately
- ☐ Pump testing carried out according to *AS2368-1990 ‘Test Pumping of Water Wells’*
- ☐ Bore decommissioned in accordance with *‘Minimum Construction Requirements for Water Bores in Australia - 2nd Edition’* if decision is made to abandon the work

The different hydrogeological settings in the SCCG region have different prospects for groundwater supply and different potential for pollution. The coastal sand bed deposits provide by far the greatest opportunity for groundwater supply in the SCCG region, but also are at the greatest risk of becoming polluted. Domestic users should be aware that bore water can be readily contaminated from a variety of sources in urban areas. As a general rule, the more easily a groundwater supply can be accessed, the greater the potential for contamination.

All efforts should be made to reduce the potential for contamination during the siting of the bore. In this regard, guidelines such as the ***Environment and Health Protection Guidelines: On-Site Sewage Management For Single Households*** **(DLG 1998)**, provide information that can be used to locate an appropriate site for a domestic groundwater work.

3.6.2 Using a groundwater work

The installation of a bore or spearpoint anywhere in the SCCG region should not be considered solely as a response to drought and water restrictions. In most cases the cost of installation and the expense of regular water quality testing means that the groundwater work should be included as a component of a long-term (say 10 year duration) water management plan for a property.

In addition to using the groundwater work only as required, there are significant issues in the ongoing housekeeping on the property. Housekeeping issues relate to the use of chemicals in the vicinity of the groundwater work, particularly fuels, fertilisers, paints and other common potentially contaminating materials. Guidelines such as those prepared by various agencies, such as ***Greywater Reuse in Sewered Single Domestic Premises*** **(NSW Health 2000)** and the ***Citizen's Guide To Ground-Water Protection*** **(USEPA 1990)**, can provide direction in identifying contaminants likely to occur around a property.

Note

DNR advises that groundwater from individual domestic bores or spearpoints in urban areas should never be considered suitable as a drinking water supply. The health risk posed by untreated water from these installations can be significant. DNR also recommends that groundwater should not be used for watering edible produce (i.e. vegetables and fruits), nor for filling swimming pools and spas in an urban area. Any of these proposed uses requires frequent rigorous testing and treatment of groundwater to confirm its suitability for the intended purpose.

3.7 Bore water quality considerations

The testing of water quality is essential in understanding the risks associated with groundwater use. In the urban environments of the SCCG region, the potential for any water source to become contaminated is very high. This applies not only to rivers and streams, but also to rainwater and groundwater.

The range and frequency of testing cannot be broadly applied for all groundwater works in the SCCG region. Various factors, such as the proximity to contamination sources, will dictate more frequent and more rigorous testing regimes at much greater expense. Those areas at less risk of pollution do not require the same level of rigour, and licensees would be subject to unnecessary expense for little return.

The key points to consider when adopting a testing program are:

- A single sample, taken at the time of bore completion, is not sufficient to ensure the ongoing suitability of bore water for an intended purpose. Often a sample taken by the driller during bore development is tested for a minimal range of parameters and is then relied on by the licensee to be representative of conditions for the life of the bore. The results of any sample are specific to the time of collection and do not take into account changes in groundwater quality due to long-term pumping or other outside influences.
- Samples must be collected using appropriate methods and should be transported to a laboratory within specified holding times to meet even basic requirements for sample reliability.
- Specific analytes may require specialised collection and preservation techniques to ensure a representative sample. A sample transported in an old soft drink bottle that is in transit to a laboratory over several days will almost certainly change in water quality from the time of collection, and will not provide results representative of the groundwater.
- The timing of sample collection may have a bearing on the results obtained. Many sampling protocols require the removal of stagnant water from within the bore casing before a sample is taken. Samples collected before this water is removed will differ from those taken later in the process. In a similar way, the frequency of pumping may also affect the results of any tests.
- Although the water being pumped from a bore appears to be visually “clean”, this does not mean that contamination is not present. Many contaminants (both toxic compounds and nuisance constituents) exist in groundwater in a dissolved form that cannot be detected by eye. In some cases, the clarity of the water is directly related to the presence of contaminants.
- Even nuisance constituents, such as salinity, can pose long-term problems in the suitability of pumped water for particular purposes. Continual application of saline water can lead to soil degradation and impacts on plants within the property on which it is used. Other impacts may be generated off-site, through surface runoff or by leaching of salts to the groundwater.

Additional information on the requirements for sampling groundwater to obtain representative water quality data is provided in Section 7.8.

Frequently Asked Questions: Bore water quality

Is the water from my bore "safe"?
With the exception of mains water, any water source in an urban area could be contaminated. This is because of the multitude of potential contamination sources in urban areas, many of which can be carried by or dissolved in water. Groundwater sourced from urban areas typically has a high likelihood of being contaminated. Just because you don't know what is in your bore water doesn't mean that it is "safe".

What shouldn't groundwater be used for?
Groundwater should never be considered suitable as a substitute drinking water supply. Neither should it be used for irrigation of vegetables and fruits, nor for primary contact uses (such as spas and swimming pools) in any urban area without frequent rigorous testing and treatment.

How often should I have the quality of water from my bore tested?
Groundwater quality testing should be undertaken on a regular basis to ensure that the bore water is suitable for use. The quality of bore water in any area cannot be guaranteed. Because groundwater quality can change over time in response to pumping and other factors, it is suggested that you test the quality of the water from your bore on a regular basis, such as every one or two years. More frequent testing will be required if the bore is likely to be affected by saline water bodies, is located near filled or reclaimed areas, or has been installed close to potentially contaminating sources (such as septic tanks or adjoining industrial properties).

Where can I get water from my bore tested?
You will need to have the water tested by a laboratory accredited with the National Association of Testing Authorities (NATA) in your area (look under 'Analysts' in your local Yellow Pages). You should consider using the specialist services offered by environmental or hydrogeological consultants as they can carry out the sample collection for you (look under 'Environmental and/or Pollution Consultants' in your local Yellow Pages). You should not carry out your own sampling unless you know how to collect a sample correctly using the appropriate container for the tests that are to be undertaken. Samples must be chilled, and transported to the laboratory within a certain time after collection. Consultants generally make sure these specific requirements are met as part of any sampling program. They may also provide a short report explaining the results obtained from the laboratory and comparing the data against various water quality criteria.

What can I do to prevent water from my bore becoming contaminated?
Installing a bore and accessing groundwater carries with it an inherent obligation to protect the quality of the resource for yourself and other nearby users. Protecting the resource generally requires good housekeeping practices around the surface fixtures of the bore, avoiding the use of greywater to water the garden, minimising fertiliser application, and storing chemicals safely. You should be aware that any activity on your property may have implications for the quality of water from your bore. In addition, you should only pump the bore as necessary to meet your needs so that impacts from excessive extraction, such as drawing in polluted groundwater from neighbouring areas, are avoided.

What should I do if I think the water from my bore is contaminated?
Have the bore water tested. If you suspect serious contamination, stop using the groundwater for any purpose and make sure the bore is closed down in such a way that no-one else can turn it on again. Contact the Department of Environment and Conservation Pollution Line (telephone 131 555) and inform the Department of Natural Resources licensing personnel in your area (look under 'Natural Resources, Department of' in the Business Listings section of your local White Pages).

3.8 Abandoning a groundwater work

Should a groundwater work (either during drilling or after completion) not deliver the required amount of water, or provides water of too poor a quality for the intended purpose, a licensee may wish to abandon it. Alternatively, an old work that is to be replaced by the installation of a new one nearby must be correctly abandoned (decommissioned) to prevent future groundwater quantity or quality problems.

In some cases, to save costs, bores have been sealed by covering the opening (e.g. welding a plate across the steel support casing), without sealing the cavity beneath. This method of abandonment is inappropriate and will not be endorsed by DNR because:

- The cavity (casing space or void) within the groundwater work can act as a conduit for contaminants to pass from the land surface directly to the groundwater. This can impact on other users or the environment and can have long-term consequences for the groundwater resource.
- The hydrostatic pressure or water levels within the aquifer can be altered by the existence of the void at atmospheric pressure. Where the water levels within nearby works are dependent on hydrostatic pressures, an inappropriately abandoned work can affect the availability of groundwater during pumping. That is, because the pressure is not sufficient to maintain pumping yields, the nearby groundwater works can only be pumped for shorter durations or at lower rates.
- Where multiple water bearing zones are intersected, the void can allow the transferral of groundwater or contaminants between aquifers. This becomes significant where aquifers or aquitards containing saline or contaminated water occur above groundwater resources of high quality. The impacts of the continuing transfer of poor quality groundwater into a high quality resource can become both widespread and long-term.
- The surface components of the work can still pose a hazard to humans or animals.

Spearpoints are sometimes abandoned by disconnecting the pumping apparatus without necessarily removing the in-ground components. DNR does not consider the decommissioning of spearpoints to be appropriately completed unless the casing and wellpoint have also been removed from the ground.

The decommissioning of any work must be carried out to prevent the contamination of groundwater resources, to preclude the transfer of fluids between aquifers, to maintain pressures and water levels, and to eliminate the hazard posed by any surface components. In this regard, guidance on the decommissioning of groundwater works should be sought from the *Minimum Construction Requirements for Water Bores in Australia - 2nd Edition* (LWBC 2003).

3.9 Recommendations

Recommendations

It is recommended that:

- Those wishing to access groundwater as an alternative water supply be directed to familiarise themselves with the requirements and obligations placed on the users of this resource.
- Such interested parties be made aware of and follow the systematic process of licensing and installing a groundwater work.
- Council staff dealing with public or consultants' inquiries familiarise themselves with the *Minimum Construction Requirements for Water Bores in Australia - 2nd Edition*.
- Intending bore water users be made aware of the need for regular water quality testing to provide ongoing reassurance of the suitability of groundwater for a proposed use.
- Councils develop and implement policies to restrict or prohibit domestic / industrial activities with the potential to contaminate groundwater resources (e.g. on-site wastewater disposal) near environmentally sensitive areas or in suburbs with widespread groundwater use.
- Intending bore water users be made aware of the obligation to appropriately decommission a groundwater work if it is to be abandoned.

3.10 Suggested technical and further reading

1. **ARMCANZ, 1997**. Minimum Construction Requirements for Water Bores in Australia. Agriculture and Resource Management Council of Australia and New Zealand, July. ISBN 0 7242 7401 4.

2. **DLG, 1998**. Environment and health protection guidelines: On-site sewage management for single households. New South Wales Department of Local Government, January. ISBN 0 7310 9496 4. Available on-line at: http://www.dlg.nsw.gov.au/dlg/dlghome/documents/information/onsite.pdf [accessed 23 February 2005].

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5. **NSW Health, 2000**. Greywater reuse in sewered single domestic premises. NSW Health. April. Available on-line at: http://www.health.nsw.gov.au/public-health/ehb/general/wastewater/greywater_policy.pdf [accessed 23 February 2004].

6. **Saayman, I.C. and Adams, S., 2002**. The use of garden boreholes in Cape Town, South Africa: lessons learnt from Perth, Western Australia. *Physics and Chemistry of the Earth* 27(11-22): 961-967.

7. **Trojan, M.D., Maloney, J.S., Stockinjer, J.M., Eid, E.P. and Lahtinen, M.J., 2003.** Effects of land use on ground water quality in the Anoka Sand Plain Aquifer of Minnesota. Ground Water, Vol. 41, Issue 4.

8. **USEPA, 1990**. Citizen's Guide To Ground-Water Protection. Office of Water, United States Environment Protection Agency. Report No EPA 440/6-90-004, April. Available on-line at: http://www.epa.gov/safewater/protect/citguid.pdf [accessed 8 January 2001].

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4.0 LEGISLATION, POLICY AND OTHER INSTRUMENTS

4.1 Introduction

This chapter outlines the policies, legislation and other instruments that are relevant to groundwater management in NSW. Each section summarises the responsible agency and powers available under their respective governing legislation.

4.2 Objectives

Objectives

The objectives of this chapter are:

- To describe legislation that is relevant to groundwater management.
- To provide guidance on the application of legislation.
- To outline State Government policies regarding groundwater.
- To describe other planning instruments relating to groundwater management.
- To provide a basis for the understanding of groundwater management, described later in this Handbook.

4.3 Planning framework

Since the circulation of water is so critical to the survival of all living things, laws regarding ownership, rights to access and constraints to water use are necessary. Water is not a common property resource where each individual has equal rights to access and use the resource in whatever way they wish. The State Government has reserved the right to control surface water and groundwater on behalf of the community. By doing so, it aims to ensure that the economic, environmental and social benefits of the use of water are appropriately balanced.

Land use planning legislation and instruments are important measures that can also be used to protect groundwater resources. **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.**

Several NSW authorities (Figure 4.0) are responsible for administering legislation dealing with various aspects of groundwater resources. These are the Departments of Planning, Natural Resources, Environment and Conservation, and Councils.

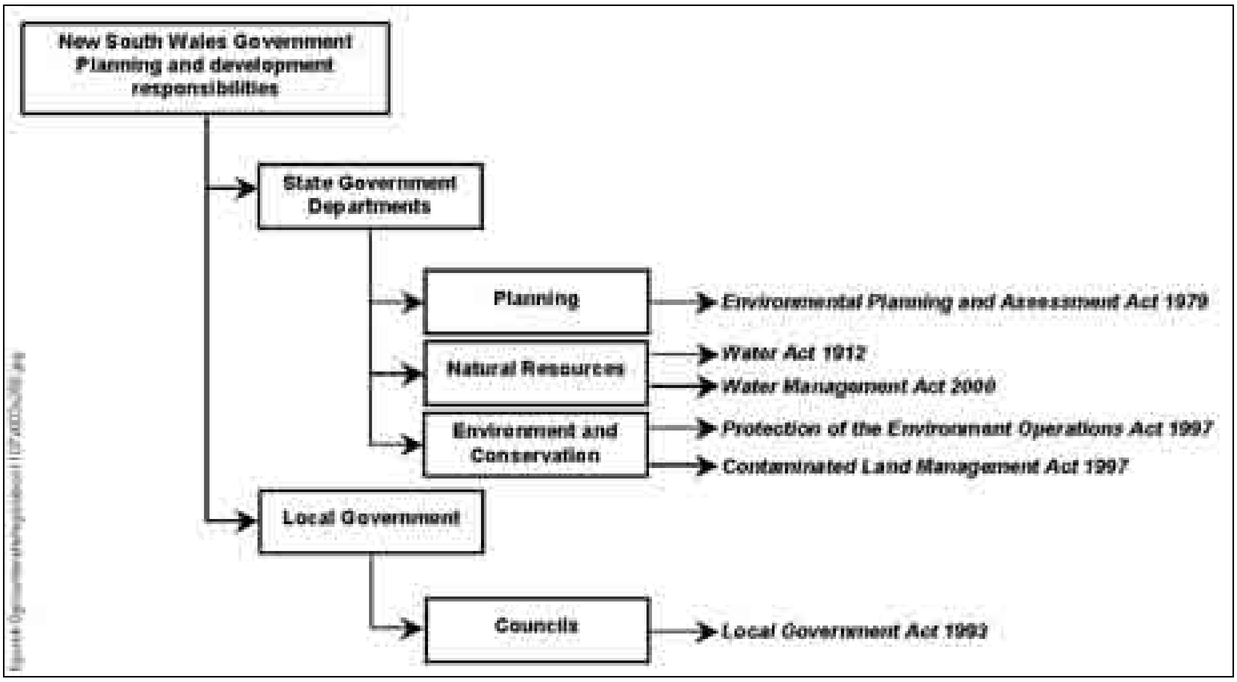

Figure 4.0 Legislation relevant to managing groundwater resources in NSW

4.4 NSW State Government legislation

The following Acts cover different aspects of groundwater management. The *Water Act 1912* and the *Water Management Act 2000* deal specifically with groundwater resources. The *Protection of the Environment Operations Act 1997* prohibits the pollution of all water, including groundwater. The *Contaminated Land Management Act 1997* allows for the regulation of the clean up of contaminated sites, including groundwater that has been impacted by point source pollution. The *Environmental Planning and Assessment Act 1979* requires that groundwater impacts are taken into consideration when new developments are proposed.

4.4.1 Water Act 1912

The right to control, manage and use groundwater in NSW is vested in the Minister responsible for water resources under the *Water Act 1912*. The Minister's management role is largely exercised by DNR. That department, in turn, controls a process to allow private entities and other government agencies access to groundwater resources through a licensing system.

The *Water Act 1912* states that all works connected to a source of underground water and used for water supply must be licensed. A work includes any of the following: bore, well, excavation, shaft, trench, collector system, spearpoint, artesian bore or variations on these basic structures.

In addition, works not used for water supply, but that may have relevance to groundwater management are also required to be licensed. These include test bores

for investigation purposes, monitoring bores and some construction dewatering systems. A new licence is required when it is proposed to enlarge, deepen or alter a bore, or if the authorised purpose for which the groundwater is being extracted is to be changed.

The *Water Act 1912*, provides DNR with powers to manage water resources in the state, including:

- Declaring water shortage zones and refusing access to a resource where it is overcommitted (i.e. placing embargoes on any new applications for groundwater licences within designated areas).
- Requiring a licensee to install a meter, monitor extraction and report usage to the department.
- Requiring a licensee to reduce or cease extraction and disable their bore or pump (where water shortage or contamination impacts on the availability of water for use).
- Requiring a licensee to undertake further investigations to address the scale of impacts associated with groundwater use.
- Requiring a licensee to undertake remedial action where damage has occurred.
- Restricting, suspending or cancelling licences where deemed necessary (i.e. for failing to comply with directives, wastage of water, etc.).
- Issuing penalties for offences such as using unlicensed works or damaging activities.

4.4.2 Water Management Act 2000

The *Water Management Act 2000* was enacted in December 2000 and will supersede the *Water Act 1912* as the legislation covering groundwater access and management. At the time of writing, not all of the provisions of the *Water Management Act 2000* have been enabled. Subsequent editions of this Handbook will discuss the provisions of the *Water Management Act 2000* and how they are to be applied.

The principal objective of the *Water Management Act 2000* is to provide for the sustainable and integrated management of the State's waters for the benefit of present and future generations. The *Water Management Act 2000* introduces measures that will:

- Provide for improved environmental health of the State's waters. This is to be achieved through equitable sharing provisions that require, as the highest priority, water to be available to sustain the environment. The Act also allows for the regulation of activities that threaten waters and their dependent ecosystems.
- Provide for shared government and community responsibility in managing water resources. This is to be accomplished through the establishment of a comprehensive, community-based, planning framework.
- Provide greater economic benefits to individuals and communities by clarifying and strengthening entitlements to access and use water resources. Resources are to be better valued through the establishment of water markets, and improved compliance tools will ensure equitable distribution to individuals and communities.

Once all provisions of the *Water Management Act 2000* have been enabled, the licensing arrangements under the *Water Act 1912* will be rolled over into a different range of authorisations. Under the *Water Management Act 2000* the following licensing provisions will apply:

- **Access licence**. These will be required to extract and use groundwater for activities other than basic landholder rights (i.e. stock and domestic purposes). The access licence defines the share of the water resource that is authorised for use and is not linked to property ownership or landholding. The access licence is the only tradeable component of any authorisation under the *Water Management Act 2000*.
- **Water use approval**. This approval is linked to the property on which the groundwater is to be used. It authorises the use to which the extracted groundwater is to be applied and cannot be traded. A water use approval is not needed where the groundwater is being extracted to meet basic landholder rights.
- **Water supply works approval**. This approval applies to the works required for the extraction of groundwater and authorises their construction. It is linked to a property and cannot be traded. A works approval is required for all installations used to extract groundwater, including those for basic landholder rights.
- **Aquifer interference approval**. This approval covers those activities that intersect groundwater and where impacts resulting from such development may occur on a large scale or significantly affect water quality.

It is envisaged that the powers under the *Water Management Act 2000* will be similar to those exercised by DNR through the provisions of the *Water Act 1912*.

4.4.3 Protection of the Environment Operations Act 1997

The State Government agency that deals with contamination is DEC. That department's powers as a regulatory authority are limited to point source pollution incidents, and controlling **scheduled activities**. Specifically, DEC is responsible for:

- Activities and the premises on which they occur listed in Schedule 1 of the Act ("scheduled activities"). These activities are generally those that have potential to generate significant environmental impacts.
- Those activities carried out by State or public authorities that require an **environment protection licence**. Licences may be issued to control air, noise or water impacts of an activity, or the management of waste products.
- Any other activities for which an environment protection licence is deemed by DEC to be required.

Councils are the Appropriate Regulatory Authority under the Act for the regulation of pollution from all other non-scheduled and non-licensed activities. The *Protection of the Environment Operations Act 1997* provides powers to both Local Government and DEC to protect groundwater from pollution. Other public authorities may also have certain responsibilities under the Act.

The Act sets out various duties, obligations and processes by which contamination incidents can be managed. These relate to environment protection licences, notices and offences, and are broadly categorised as follows:

- **Environment protection licences**. These are issued to regulate the impacts on air and water, control noise and waste management activities. They are reviewed at least once every 3 years and penalties can be applied if non-compliance with the licence conditions occur. Specific requirements associated with the licences require monitoring to assess ongoing impacts, reporting schedules, complaint resolution processes and actions to be taken in the event of a pollution incident. Licences are generally applied to scheduled activities, but can also be required to regulate water pollution from non-scheduled activities. Under the Act, a list of environment protection licences is required to be publicly available.

- **Environment protection notices**. Three types of notice may be issued under the Act - clean up, prevention and prohibition. Clean up notices are applied to remediate pollution incidents, and are issued by the regulatory authority (either DEC, Council or another public authority) for the activity or premises. Prevention notices are also issued by the regulatory authority, and applied to control the environmental impacts of an activity that is being undertaken in an unsatisfactory manner. Prohibition notices can only be issued by the Minister responsible for the Environment, and require that an activity cease until actions have been taken to rectify significant environmental impacts.
- **Environment protection offences**. A three tier regime of offences applies under the Act, ranging from serious breaches, involving wilful or negligent action, to penalty notices. Tier 1 offences apply to waste disposal practices, spills or leaks, and ozone depleting emissions that have occurred wilfully or through negligence and have, or are likely to, harm the environment. Significant financial and other penalties apply to both individuals and corporations who commit offences of this nature. Tier 2 offences apply to all other breaches of the Act and include pollution of land, air, noise and water, failure to notify incidents, emission of offensive odours and unlawful transport of waste. Within this range of infringements, Tier 3 offences may apply where the lesser seriousness of the pollution incident warrants only the issue of a penalty notice (i.e. on the spot fine). Financial penalties apply to Tier 2 and Tier 3 offences.

Any incidents causing or threatening material harm must be notified to the regulatory authority, either Councils or DEC. This **duty to notify** applies where leaks, spills, or escapes of substances have occurred, and an actual impact or the threat of harm exists, either on a property or off-site. The duty to notify applies to the person carrying out the activity, an employee or agent, the employer, or the occupier of the premises on which the incident occurred.

4.4.4 Contaminated Land Management Act 1997

The *Contaminated Land Management Act 1997* regulates the management of contaminated sites. That Act sets out a framework by which DEC can regulate the assessment and clean up of contaminated land if it considers the contamination to be posing a **significant risk of harm** to human health or the environment. Where contamination does not pose a significant risk of harm, regulation is achieved through planning consent authorities (usually Councils) by means of land use planning processes directed by *State Environmental Planning Policy 55 - Remediation of Land* and the **Managing Contaminated Land Planning Guidelines** (refer to Section 4.6.1). The *Contaminated Land Management Act 1997*, the *State Environmental Planning Policy 55 - Remediation of Land* and the Managing Contaminated Land Planning Guidelines form part of an integrated legislative package that deals with the management of contaminated land. Duty to notify obligations also apply under the *Contaminated Land Management Act 1997*.

Powers provided to DEC under the Act allow the agency to:

- Declare a property as an investigation site. Once declared, DEC has powers to order an investigation of the property and surrounds to assess the impacts of the contamination and what further action is necessary. DEC may also take action to minimise risk or harm to the community through notification or education.

- Declare a property a remediation site. The declaration of a remediation site allows DEC to order that remediation takes place, and may specify the manner in which clean up is undertaken.
- Agree to a voluntary investigation or remediation proposal. Where a polluter commits to undertaking voluntary investigations, or remedial actions, DEC has powers to regulate the activities involved.

Those directed to take action are the polluter, where they can be identified, or the property owner, if the polluter cannot be found. If the property owner cannot be located, DEC will direct the notional owner of the site to undertake action. DEC may also require a public authority to undertake investigation or remediation of contaminated land where the pollution is posing a significant risk of harm. Records of sites regulated under the *Contaminated Land Management Act 1997* are to be kept by DEC for current and former investigations or remediation activities.

Under the Act, DEC also regulates the site auditor scheme, develops guidelines for the assessment and remediation of contamination, and maintains the public register of regulated sites. Site auditors accredited by DEC have expertise in the management of contaminated land and act as impartial reviewers of the investigations undertaken, any proposed remediation techniques, or any suggested restrictions applying to the land or groundwater. After reviewing the information provided, site auditors are required to prepare Site Audit Statements, which note any deficiencies, restrictions on activities allowed at the property, or further actions required to complete the process.

4.4.5 Environmental Planning and Assessment Act 1979

Land use planning in NSW is administered by the Department of Planning and Local Government authorities under the *Environmental Planning and Assessment Act 1979*. The planning and development control process under that Act is important in the management of land use and contamination. It aims to ensure that land is not to be put to a use that is inappropriate because of the presence of contamination, and incorporates mechanisms to ensure that:

- Planning authorities consider contamination issues when they are making rezoning and development decisions.
- Land remediation is facilitated and controlled through *State Environmental Planning Policy 55 – Remediation of Land*.
- Councils provide information about land contamination on planning certificates.

The consideration of contamination issues can include the impacts of contaminated groundwater as part of the planning process.

The **Integrated Development Approval Scheme (IDAS)** was installed under the Act to streamline the processing of Development Applications. The scheme applies where a development requires both consent from the planning authority and an authorisation (permit or licence) from a State Government agency. Under the scheme, the Development Application is referred to the agency that regulates whichever aspect of the proposal that requires an authorisation. Some of the commonly required authorisations are as follows:

- Disturbance or destruction of items of indigenous heritage - National Parks and Wildlife Service (DEC).

- Development of aquaculture business - NSW Fisheries (Department of Primary Industries, DPI).
- Dredging or reclamation works - NSW Fisheries (DPI).
- Activities on a site of heritage significance - NSW Heritage Office.
- Development within a mine subsidence district - Mine Subsidence Board.
- Potential for environmental impact or pollution, large scale development or activities near sensitive environmental areas - DEC.
- Activities affecting public roads or other thoroughfares - Roads and Traffic Authority, Department of Planning or Council.
- Using water to carry out the proposed activities - DNR

The agency to which the application is referred then carries out an integrated assessment of the proposal. The assessment provides the combined requirements for each individual permit or licence required for the activity from that agency. The agency, once satisfied that the requirements to allow an authorisation to be issued have been, or can be met, may grant "in principle" approval to the proposed development.

The specific requirements that are to be applied to the development are forwarded to the consent authority as "**general terms of approval**" (**GTAs**). The general terms of approval are not the actual permit or licence, but are the provisions under which such authorisations would be granted. These provisions are included as the conditions of consent under which the proposed development may proceed. Following the granting of approval by the consent authority for the proposed development, the applicant must apply for and obtain the particular permits or licences required.

As part of the IDAS process, the consideration of contamination, protection of groundwater systems and other environmental health requirements can be incorporated into the conditions of consent.

4.4.6 Local Government Act 1993

The *Local Government Act 1993* applies an obligation on Local Government to:

"*properly manage, develop, protect, restore, 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*".

Councils have responsibilities under the Act with some significance to the management of groundwater resources including:

- The regulation of waste management and disposal practices.
- Protection of environmentally sensitive areas.
- Application of standards to the construction, operation and maintenance of various facilities.
- Prevention of contamination and environmental degradation.

4.5. State groundwater policies

The objective for the management of groundwater in New South Wales is to:

"*manage the State's groundwater resources so that they can sustain environmental, social and economic uses for the people of NSW*."

4.5.1 The NSW State Groundwater Policy Framework Document

The NSW Government released the *NSW State Groundwater Policy Framework Document* in 1997, which was aimed at achieving efficient and sustainable management of groundwater resources (NSW Government, 1997). Three component policies were written to support the framework document (Figure 4.1).

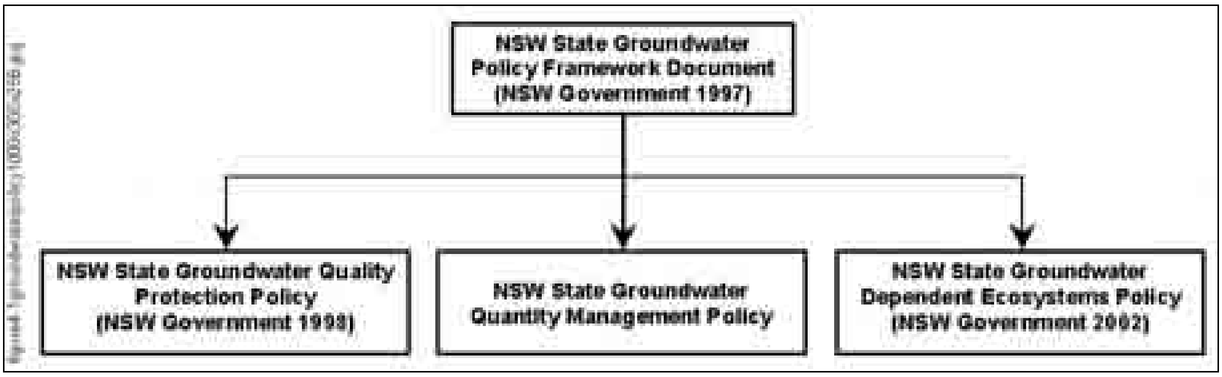

Figure 4.1 NSW groundwater policy framework

The framework document described the following **management principles to provide for the sustainability of groundwater resources:**

- An ethos for the sustainable management of groundwater resources is to be encouraged in all stakeholders. The responsibility for groundwater protection and sustainable use rests with all sections of the community, business and government.
- Non-sustainable resource uses are to be phased out. Those existing activities that are incompatible with the maintenance of groundwater resources and dependent ecosystems will be gradually replaced with sustainable options. Any new proposed non-sustainable activities will not be permitted.
- Significant environmental and social values dependent on groundwater are to be protected. Areas of intrinsic environmental value, special or representative areas, those of unique social or recreational amenity or of cultural importance are to be preserved using specialised management actions.
- Environmentally degrading activities are to be discontinued. Best management practices will be required to promote higher levels of groundwater protection, together with the use of economic instruments to encourage continual improvement.
- Environmentally degraded areas are to be rehabilitated. Clean up of contaminated localities, where practical, will be required to a level that restores the identified beneficial uses of groundwater systems.

- Integration of surface water and groundwater management will be progressed. Depending on the degree of interconnection, the linking of these systems will enable management of business risks associated with water supply, and control over threats due to extraction and use.
- Adaptive management of groundwater resources will be implemented. Improvements in the understanding of groundwater systems, and changes in the values placed on these resources by the community, will lead to refinements in the estimates of resource sustainability and the required levels of protection.
- Groundwater management will be integrated with other land use policies, environmental controls and development planning. The impacts of land use activities on groundwater systems are to be given greater recognition and the controls over activities strengthened to prevent resource degradation.

4.5.2 The NSW State Groundwater Quality Protection Policy

The *NSW State Groundwater Quality Protection Policy* (NSW Government 1998) identified the following principles:

- Maintain the most sensitive beneficial use of a groundwater system. All stakeholders share an obligation to protect a groundwater resource for themselves and other users, including the environment. Degradation of groundwater quality to a lower beneficial use will not be permitted.
- Ensure town water supplies are protected against contamination. The importance of drinking water resources, together with the high cost of providing alternative sources of supply should groundwater become polluted, requires that wellhead protection plans be developed and implemented around production bores.
- Prevent groundwater pollution so that remediation is not required. Once a groundwater resource has been contaminated, the expense and impracticality of clean up may be such that it cannot be restored and becomes unusable. Prevention of contamination provides a more effective management approach.
- The risk posed by a proposed development, and the value of the groundwater resource, shall dictate the level of protection required. The assessment required to demonstrate adequate protection is to be linked to the threat posed by the activity, the vulnerability of the aquifer, and the beneficial use of the groundwater currently and in the foreseeable future.
- Groundwater dependent ecosystems will be protected. This is to be undertaken to maintain intrinsic environmental value, such as threatened species or critical habitat, and the conservation of special areas through the application of buffer zones around ecosystems.
- Ensure the quality of pumped groundwater is compatible with soil, vegetation or any receiving water. The risks associated with using groundwater, that may be naturally high in dissolved mineral concentrations or of different pH to the receiving environment, are to be instilled in all stakeholders. The responsibility for damage or degradation from using groundwater incompatible with the receiving environment rests with the user.
- Rehabilitate degraded areas where practical. The ‘polluter pays’ approach adopted by DEC in the management of contaminated sites shall also be applied where activities have degraded groundwater systems. The ecosystem support functions, and where possible, beneficial uses of the groundwater, are to be restored.
- Consider the cumulative impacts of activities on groundwater quality. The collective effects on groundwater quality from many widespread activities are to be considered in any assessments of environmental impact for new developments.

- Consider the links between groundwater quantity and groundwater quality management. Changes in groundwater flow or extraction are known to have generated adverse impacts in water quality in some areas. The management of both quantity and quality are to be integrated so that the impacts associated with changes in one aspect of the groundwater regime are managed to minimise effects on the other.

4.5.3 The NSW State Groundwater Dependent Ecosystems Policy

The *NSW State Groundwater Dependent Ecosystems Policy* (NSW Government 2002) was specifically designed to protect valuable ecosystems that rely on groundwater for survival. Wherever possible the ecological processes and biodiversity of these dependent ecosystems are to be maintained or restored for the benefit of present and future generations.

The policy guides the decision-making of State agencies, Local Government and landholders in the management and use of groundwater. It influences the type and selection of management activities and resource development opportunities that are supported by the State's resource managers. It sets out management principles to:

- Ensure the most vulnerable and valuable ecosystems are protected. The wide ranges of environmental, social and economic values afforded by groundwater dependent ecosystems are to be identified and maintained. A consistent rapid assessment process shall be adopted to identify ecosystems of value that are at risk.
- Manage groundwater extraction within defined limits thereby providing flow sufficient to sustain ecological processes and maintain biodiversity. A proportion of the renewable groundwater resource is to be preserved for ecological viability. The location, depth, timing, rate of pumping and volume extracted are to be managed to prevent local impacts in the vicinity of ecosystems.
- Ensure sufficient groundwater of suitable quality is available to ecosystems when needed. The pattern of groundwater availability and its quality are as important as the overall quantity that is preserved.
- Ensure the precautionary principle is applied to protect groundwater dependent ecosystems, particularly the dynamics of flow and availability and the species reliant on these attributes. The degree of dependence is not a constant, but varies according to prevailing conditions, the types of species present, seasonal patterns, sensitivity to change and ecological resilience. Protection measures and systematic research are to be applied to address the lack of data relating to those ecosystems where the degree of dependence is unclear.
- Ensure natural patterns of groundwater flow are maintained, pollution is prevented and rehabilitation of degraded areas is undertaken. All aspects of development, water use and land use activities, including groundwater, soils, surface water, vegetation and ecosystem condition, are required to be managed to adequately protect sensitive environments.

4.5.4 The NSW State Groundwater Quantity Management Policy

At the time of writing the *NSW State Groundwater Quantity Management Policy* has not progressed beyond a draft document. However, the principles that are to be described within the policy document have been outlined in the brochure *Advice to Water Management Committees - No. 8 Groundwater Quantity Management* (NSW Government 2001). These principles overlap with the other State Groundwater Policies regarding extraction limits, quality and ecosystems:

- Total groundwater use will be maintained within the sustainable yield of the aquifer from which it is withdrawn. Strategies for the management of groundwater extraction are to be implemented that include mechanisms for any reductions in use for over allocated systems.
- Groundwater dependent ecosystems are to be protected. Specific environmental water provisions shall be incorporated into any plans of aquifer management.
- In currently over allocated systems, total licensed entitlements will be adjusted to within 125% of the available resource for the defined planning period. Further adjustment is to be undertaken in subsequent planning periods to bring the over allocated resources to within sustainable yield limits.
- Groundwater extraction shall be managed to prevent unacceptable local impacts. The local effects of pumping such as aquifer compaction, water quality degradation, changes in flow to groundwater dependent ecosystems and pumping interference between users are to be considered in any licence assessment.
- Artificial recharge will be strictly controlled. Significant issues exist with regard to artificial recharge schemes in protecting the intrinsic water quality of the groundwater and maintaining the permeability of the aquifer.
- Access to groundwater for stock and domestic purposes is considered a basic right for owners of land overlying an aquifer. The exercise of this basic right may be restricted, however, should the cumulative impacts of many extraction points begin to adversely affect the groundwater system.
- A priority of use governs access to the resource. In descending order the priority is water to the environment, basic rights, water utilities and then all other commercial interests (i.e. irrigation, industry, etc.).
- All groundwater extraction for water supply is to be licensed. All groundwater extraction other than for basic rights is to be metered. The reporting of actual usage to DNR is to be implemented to support metering of groundwater works.
- Licensed entitlements in systems that are not embargoed are to be issued on an as needs basis. Applications involving unrealistic volume entitlements will not be granted, but may be offered reduced volumes commensurate with the anticipated demand required by the proposed activity.
- Licensees are obliged to protect the groundwater system for themselves, other users and the environment. There is also an obligation to abide by the conditions placed on the licence.
- Transfers of licensed entitlements may be allowed depending on the physical constraints of the groundwater system. Transfers between aquifers is not permitted.
- Provisions for borrowing against annual allocations may be permitted at times to allow businesses to operate with some degree of surety of supply.
- Future access licences cannot be activated unless approvals for works and use have been obtained.
- Future aquifer interference approvals are required for activities that intersect groundwater. Where groundwater quantity declines due to the aquifer interference activity an access licence will also need to be obtained to authorise the incidental impacts on the resource.

4.6 Other instruments

4.6.1 State Environmental Planning Policy 55 - Remediation of Land

State Environmental Planning Policy 55 (SEPP 55) establishes best practice for managing land contamination through the planning and development control process. Under SEPP55, planning authorities must consider land contamination issues in assessing development and rezoning applications and must assess whether the land is suitable or will be made suitable for its proposed use. In some instances groundwater contamination can make the land unsuitable for a particular use, and therefore management of the contamination may be necessary before the development or rezoning application is approved.

The policy allows clean up of contaminated sites by:

- Making remediation permissible across the state.
- Defining when consent is required.
- Requiring all remediation to comply with standards.
- Ensuring land which is going through the development consent process is investigated if contamination is suspected (e.g. if the site history suggests potentially contaminating land use has occurred in the past).
- Requiring Councils to be notified of all remediation proposals.

4.6.2 Planning certificates

Section 5 of SEPP 55 contains information on the use of Section 149 certificates under the *Environmental Planning and Assessment Act 1979*. In summary, planning certificates under Section 149, Clause 2 must record:

- The land is within an investigation area or remediation site declared by DEC under the *Contaminated Land Management Act 1997*.
- The land is subject to an investigation order or remediation order issued by DEC under the *Contaminated Land Management Act 1997*.
- A voluntary investigation or remediation proposal for a site has been agreed to.
- A copy of a site audit statement for the land is held by Council.
- The existence of a Council policy restricting use of the land.

Council also has the opportunity to include further information of a factual nature about the land on the Section 149 certificate under Clause 5. Such information could include details about groundwater contamination, however this would be included at Council's discretion.

4.7 Recommendations

Recommendations

It is recommended that:

- Council staff and other stakeholders familiarise themselves with the legislation (Acts and Regulations) relating to groundwater through the New South Wales Government legislation (www.legislation.nsw.gov.au) or the Australasian Legal Information Institute website (www.austlii.edu.au).
- Member Councils obtain electronic copies of the NSW state groundwater policy documents from DNR.
- Legislative responsibilities be confirmed by Councils with the relevant state agencies where discrepancies or uncertainties exist on individual sites regarding Councils' management roles.

4.8 Suggested technical and further reading

1. **DUAP and EPA, 1998**. Managing Land Contamination: Planning Guidelines SEPP 55 - Remediation of Land. New South Wales Department of Urban Affairs and Planning and New South Wales Environment Protection Authority. Report 98/65, August. ISBN 0 7310 9005 5. Available on-line at: http://www.planning.nsw.gov.au/assessingdev/pdf/gu_contam.pdf [accessed 29 May 2006].

2. **NSW Government, 1997**. The NSW State Groundwater Policy Framework Document. Prepared by the New South Wales Department of Land and Water Conservation, Sydney. Report No. HO/64/97, August. ISBN 0 7313 0333 4. Available on-line at: http://www.naturalresources.nsw.gov.au/water/pdf/nsw_state_groundwater_policy_framework_document.pdf [accessed 30 June 2006].

3. **NSW Government, 1998**. NSW State Groundwater Quality Protection Policy. Prepared by the New South Wales Department of Land and Water Conservation, Sydney. Report No. HO/37/98, December. ISBN 0 7313 0379 2. Available on-line at: http://www.naturalresources.nsw.gov.au/water/pdf/nsw_state_groundwater_quality_policy.pdf [accessed 30 June 2006].

4. **NSW Government, 2001**. Advice to Water Management Committees - No. 8 Groundwater Quantity Management. Unpublished brochure.

5. **NSW Government, 2002**. The NSW State Groundwater Dependent Ecosystems Policy. Prepared by the New South Wales Department of Land and Water Conservation, Sydney. Report No. HO/10/00, April. ISBN 0 7347 5225 3. Available on-line at: http://www.naturalresources.nsw.gov.au/water/pdf/groundwater_dependent_ecosystem_policy_300402.pdf [accessed 30 June 2006].

5.0 CONSTRUCTION AND DEVELOPMENT

5.1 Introduction

With increased pressures to house more and more people in the SCCG region, and the wider Sydney metropolitan area, development continues to force the change from low- to medium- and high-density housing. Because of this trend and the corresponding increase in reliance on motor vehicles, single or multiple level basement car parks are widely adopted as part of new developments.

The construction of basement car parks, or even simple retaining walls on sloping land, can interfere with groundwater systems by retarding, preventing or diverting flow into situations that become at best a nuisance and at worst a hazard.

This chapter describes the short- and long-term interactions between groundwater and development, the associated issues, and recommendations to address common problems.

The chapter deals primarily with construction that extends into sand and rock aquifers, followed by a discussion of excavation that intercepts hillside groundwater flows. Essentially the first sections differ from the latter in that they deal with circumstances where the lowest point of the excavation cannot be drained by gravity to the adjacent surface drainage system.

5.2 Objectives

Objectives

The objectives of this chapter are:

- To provide developers, Councils, other Authorities and the general public with information on the impacts on groundwater systems from development.
- To minimise impacts of development on existing groundwater regimes.
- To ensure that changes to an existing groundwater regime, as a result of development, do not adversely impact upon other properties or the environment.
- To promote ecologically sustainable development by reducing reliance upon mechanical systems to dispose of or redirect groundwater flows.

5.3 Development assessment

Any Development Application, considered under the *Environmental Planning and Assessment Act 1979*, should include an assessment of the impacts of the proposed activity on groundwater, where the potential for interaction has been identified. However, the interaction between development activity and an existing groundwater system is often overlooked or, more commonly, not understood.

It is necessary, therefore, that geotechnical and hydrogeological matters be considered prior to any consent being issued for construction works associated with the proposed development. Any development proposal that involves construction of permanent structures below the water table, other than pile or footing installation, should be supported by a detailed Geotechnical and Hydrogeological Report. In general, the objectives of such a report should be to demonstrate that the proposed works can be feasibly constructed without adverse impacts to neighbouring properties or the environment, and provide recommendations to address areas of uncertainty or concern.

By undertaking a thorough and well executed site investigation prior to construction, relevant issues can be identified and incorporated into the design and planning for the project. This can help to ensure that the environment and community are not adversely impacted by the development and ultimately gives the developers more certainty in terms of construction costs.

Note

It is the responsibility of the approval authority to ensure that an appropriate level of site investigation is undertaken prior to development approval and that an ecologically sustainable groundwater management system is adopted, both during construction and in the long-term.

When assessing the merits of a development, the following key issues should be addressed by the proponent prior to an approval being issued:

- Site investigation to establish existing groundwater conditions.
- Groundwater management during construction.
- Groundwater management in the long-term.
- Disposal of tailwater.
- Groundwater level monitoring.
- Groundwater quality monitoring.

The following sections will discuss these issues separately in relation to the various aquifer types found in the SCCG region. The hydrogeological characteristics (depth to water, permeability, groundwater quality, etc.) of the different aquifer types have a bearing on the approaches that may be used to successfully construct a development. Because of this variability, the methods and techniques described may not be applicable to all parts of the SCCG region. In particular, the unconsolidated sediments (coastal sand bed and alluvial aquifers), where highly permeable materials and shallow water tables are combined, will require the most stringent groundwater management considerations. For the porous and fractured rocks (sandstone aquifers and shale areas, respectively) groundwater management for proposed developments may be less involved, depending on the local circumstances. A more detailed discussion of the characteristics of these aquifers is provided in Section 2.4.2.

5.4 Construction in aquifers

5.4.1 Site investigation

Where it is intended to construct a development that extends into the existing groundwater regime, it is critical that adequate site investigation is undertaken at an early stage. This is to ensure that:

- The most appropriate groundwater management system is installed.
- The construction is undertaken in a way that minimises its impact on surrounding or adjacent properties, nearby infrastructure and the environment.

If the existing groundwater regime is not fully understood at the design stage, it is unlikely that the most suitable groundwater management system will be installed.

To understand the dynamics of the groundwater system and how it will impact on the development, site investigations need to be undertaken by geotechnical engineering specialists and provide an understanding of the following issues:

- The local hydrogeology (behaviour of groundwater), including flow rates, depth to water, hydraulic gradients and recharge characteristics. The local hydrogeology will largely determine the options available for control of the groundwater during construction and in the long-term. Regardless of the construction methodology, it will be necessary to install monitoring devices so that fluctuations in water level can be measured and recorded before, during and after construction and remedial action undertaken if necessary.
- The presence of contaminated soil or groundwater. Contaminated soil or groundwater, whether generated from within the site or beyond, will require remediation prior to construction commencing. The method and extent of remediation will depend on the nature and source of the contamination, and whether it is moving within the groundwater system. If contamination is only detected after construction has commenced, it can lead to lengthy delays and substantial additional costs.
- The presence of Potential Acid Sulphate Soils (PASS). If not correctly managed, the presence of Potential Acid Sulphate Soils (PASS) can lead to contamination well beyond the boundaries of the site, if exposed during excavation or through variations to the groundwater level during and after construction. Any development that involves excavation into these soils must be undertaken in accordance with DNR guidelines.
- The ambient chemical characteristics of groundwater. In most cases the ambient groundwater quality is relatively benign and not likely to impact on the long-term integrity of the structure. However, in some instances the presence of highly corrosive groundwater conditions will warrant the use of selected building materials that are resistant to chemical and physical attack. It is important that the presence of such conditions are identified and understood prior to construction.
- The proximity of surrounding structures or buildings, their footing systems and soil conditions. Major structures in close proximity to a development site may impose constraints on the methods proposed to manage groundwater during construction. Whilst these constraints (e.g. the maintenance of stable water levels or pore pressures) may be significant for multi-storey buildings on adjacent properties, they could be even more critical in the vicinity of other infrastructure such as road or rail tunnels.

Case Study
Problems associated with soil and groundwater contamination encountered during construction
Source: Wood, et al. 1994.

A historic riverfront mill in the Mid-Atlantic region of the USA was being remodelled as a townhouse development. The project was well under way when it was discovered that the site soils were contaminated with chromium (VI), a carcinogenic hazardous waste. The contamination was found to be present in the area of the building foundations.

An extensive site investigation prompted by the discovery identified three areas of concern: contaminated fill was found beneath the access routes required for the movement of heavy machinery; contamination may have been spread across the surface as a result of the construction activities; and groundwater within a shallow perched aquifer had been affected by the presence of the contaminants.

Stakeholders included the developer, construction company, financial lending institution, environmentalists, community groups, some residents (who were already occupying completed townhouses on part of the site) and environmental regulators. A remediation plan, developed by the stakeholders through consultation, was implemented. All accessible contaminated soil that had been identified was removed and transported to a secure waste facility. Soils potentially contaminated by the construction activity were treated by spraying with a ferrous iron solution.

Treatment of the contaminated groundwater to reduce the concentrations of chromium (VI) was required prior to the resumption of work on the site. The use of a conventional “pump-and-treat” system to bring the contaminated groundwater to the surface for treatment was discounted due to the difficulties and costs generated by the triggering of strict hazardous waste regulations governing its management. In addition, a delay in construction of over a year would have been required to establish, trial and commence operation of the treatment system, which would have had to be maintained as a long-term activity. An alternative in situ treatment technique was approved and undertaken that removed the bulk of the contamination and reduced the health risks posed by the contaminants to the workers. In order to demonstrate the effectiveness of the treatment, groundwater quality monitoring was carried out throughout the remediation works and for a period of two years following completion of the development.

In total, the excavation and disposal of soil cost around $US 1 million. The groundwater treatment system cost a further $US 350,000 but could have been as much as $US 1 million or more had a conventional “pump-and-treat” system been used.

5.4.2 During construction

During construction, groundwater inflows into the basement excavation must be managed such that a safe and stable work site is provided. This will usually involve some form of dewatering around the perimeter of the site, so that the work area is kept dry while construction is being undertaken.

Dewatering is the process of removing groundwater from an aquifer to lower the water table below the lowest level of excavation (Figure 5.0). This allows construction to proceed in safety by limiting the potential for excavation instability (either through wall collapse or floor heave) and preventing waterlogged ground conditions.

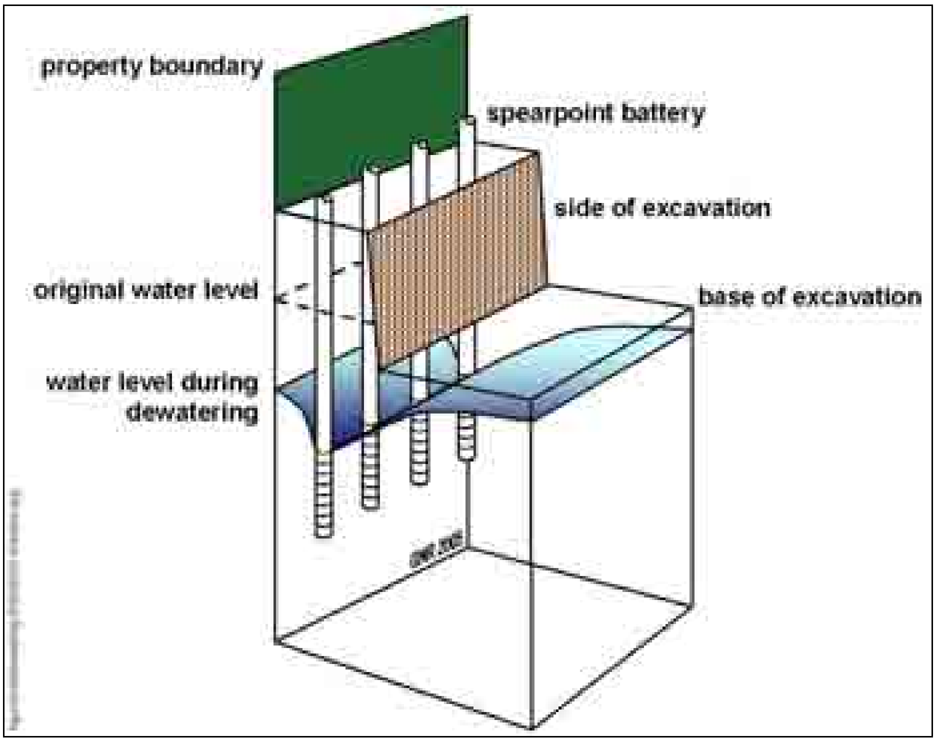

Figure 5.0 Schematic illustration of water table conditions during dewatering from a permeable sand bed aquifer

However, if the dewatering system is not carefully designed, it can lead to a number of adverse impacts on surrounding property and the environment, including:

- Settlement of adjoining structures and environmental impacts resulting from temporary or permanent lowering of the water table beneath the development site and neighbouring properties.
- Saltwater intrusion or inflow of contaminated groundwater resulting from excessive or prolonged pumping.
- Discharge of contaminated water into the public drainage system and waterways or into the groundwater system (if reinjection is employed).

Alteration to groundwater conditions, whether temporary or permanent, may create adverse effects that that are not immediately noticeable at the time of completion, but become apparent in the future. These issues are explored further in Section 5.4.2.

To minimise the potential for these problems, a design that eliminates the need for dewatering should be considered in the first instance in favour of construction methodology that requires large scale removal of groundwater. However, where dewatering is the only viable option, detailed geotechnical investigation and design should precede construction and be followed up with careful monitoring during and after construction. Monitoring is discussed in more detail in Section 5.4.4.

Note

Careful planning of how the groundwater system will be managed during construction is crucial to ensuring that adverse impacts of the development are minimised to an acceptable level of risk. The key elements that must be considered in any design should include:

- The potential for settlement and water seepage.
- Temporary and/or permanent support of any excavation.
- Location and assessment of risk to adjoining properties, including assessment of footing arrangements.
- Design parameters including estimated flow rates, volumes, use of cut-off walls, disposal of groundwater and location of spearpoints for dewatering or reinjection.
- Management of on-site contaminated soils and their appropriate clean up or disposal.
- Options for the disposal of groundwater and site stormwater.
- Maintenance of the existing groundwater regime.
- The potential for contamination of groundwater and the environment due to the dewatering and disposal methods adopted.
- A monitoring program endorsed by the consent authority.
- A contingency plan to deal with unforseen circumstances.

At times, some temporary changes to the groundwater regime will be unavoidable during construction. Potentially, these impacts could extend beyond the boundaries of the development site. Where the geotechnical and hydrogeological investigations can demonstrate that no viable alternative construction techniques are available that can minimise these impacts, and the effects will be within acceptable risk limits, Councils should specify the maximum allowable range of change.

It should be the developer's responsibility to carry out site activities so as to maintain groundwater-related parameters within the range identified by the Council and specified in monitoring and contingency plans.

Case Study

Property Investigation, Eastern Distributor, Sydney.
Source: Commissioners of Inquiry, 2003.

The Minister requested the Chairperson under Section 18(5) of the Environmental Planning and Assessment Act 1979 "to oversee and undertake an independent panel investigation relating to concerns expressed by the local community into alleged damage to property from the construction and operation of the Eastern Distributor". During various stages of the construction and operation of the Eastern Distributor claims of alleged damage were made by property owners. Given the increasing community concern and unresolved negotiations between the construction company and property owners, the Minister believed an independent panel examination of the issues involved would assist in resolving the concerns of the property owners.

The terms of reference required the Panel to determine the cause of the alleged damage to houses and other properties in the vicinity of the roadway, as well as whether the Roads and Traffic Authority (RTA) and its contractors had complied with Condition 41 of the Minister's approval. A list of affected properties, rectification work and estimates of costs was to be compiled where possible. The Chairperson and two appointed specialists constituted the Panel. In total 70 written submissions were received, 63 of which were from property owners, and 19 of them made oral presentations to the Public Hearing. Each of the 59 properties alleged to have been damaged were inspected by the Panel and the report individually addresses each of these properties.

The Eastern Distributor is part of the emerging Sydney orbital road network. Construction work commenced in August 1997 and the main part of the motorway was opened on 19 December 1999. It is 6 km long starting from The Domain. A 1.7 km tunnel passes under William Street and Taylor Square before entering an open lowered roadway section immediately south of Moore Park Road. The roadway passes under Cleveland Street and a further tunnel runs beneath intersections at Dacey Avenue and Todman Avenue before the motorway joins Southern Cross Drive. The Motorway in the area adjacent to Moore Park is largely constructed in a trench, through Botany Sands which overlie clayey sand and Hawkesbury sandstone. Any reduction in groundwater level would potentially result in ground settlement due to compaction of the loose sands as water drains from the soil. Construction of this lowered section of the motorway required dewatering and this is the length of motorway from which about 90 percent of the concerns arose. According to the RTA, dewatering in this section was limited in extent and duration, and proceeded sequentially along this length of the Motorway. Dewatering was discontinued as soon as practicable after completion of each stage of the construction, and the water table allowed to recover naturally. Many parties considered damage to their properties resulted from ground settlement induced by lowering of the water table and/or vibration from construction machinery and traffic.

The Panel found:

1. Construction of the Eastern Distributor had caused damage to 41 properties.
2. The type of damage included major internal and external brick wall cracking associated with settlement, cracking and collapse of plaster ceilings, separation of plaster cornices from walls and ceilings, minor to major wall plaster cracking of a cosmetic nature, separation of door and window frames from masonry walls, and cracking and dislodgment of ceramic tiles.
3. Damage to properties was due to vibration from construction activities, settlement due to groundwater drawdown, or the cumulative effect of vibration and groundwater drawdown.
4. Non-compliance with Condition 41 in respect of 41 properties.
5. The rectification work and the cost to restore buildings damaged by construction of the Eastern Distributor in accordance with Condition 41 cannot be determined in the absence of a geological study of individual sites and a structural analysis of the buildings.

As the extent, type and cost of rectification work could not be determined without detailed investigations of each individual site and structure the Panel's recommendations included that:

a) an appropriately qualified and experienced person or firm be appointed to inspect each of the sites and properties to determine the required rectification work and the cost;
b) the Roads and Traffic Authority and its contractors be responsible for the cost of the investigation and rectification work; and
c) as there is likely to be ongoing minor settlement following rectification work a one-off payment, determined by an appropriately qualified person or firm, be made to property owners by the Roads and Traffic Authority to cover any future repairs.

Dewatering within coastal sand bed aquifers can often require continuous pumping of groundwater for a prolonged period. Groundwater discharge from such dewatering operations is usually directed to the public drainage system and ultimately creeks and other natural water bodies. **Where significant dewatering is required to allow construction to proceed, DNR requires a water licence to be obtained.**

Note

DNR does not endorse developments where permanent, continuous pumping is required to manage groundwater. These are not considered to be sustainable development, and no licence application would be accepted for such a purpose. In such cases, alternatives should be sought to reduce, or ideally eliminate, any reliance on mechanical systems to deal with groundwater inflows into below-ground areas.

It should also be noted that where applicable, temporary dewatering licences issued by DNR have conditions attached that require, following the completion of construction, a report to be submitted to that Department, providing the actual volumes of groundwater extracted, all monitoring records and documentation of any measured impacts associated with the activity. A copy of this completion report should also be retained by Councils.

The installation of a dewatering system is subject to the same requirement as for the establishment of a water supply bore, that is, only contractors licensed through the Driller's Licensing Board are to be used.

5.4.3 Long-term impacts

To protect the integrity of a completed development and minimise its long-term impact, a suitable ground water management system must be installed. Commonly this involves the installation of a subsurface drainage system that collects water from the perimeter of the building, and then pumps it to the stormwater drainage system. However, systems that maintain the equilibrium within the aquifer without the need for pumping are identified by DNR as a more ecologically sustainable solution to groundwater management.

Once constructed and eventually occupied, a building can be expected to last for 50 to 100 years, if not longer. When parts of the building and associated structures have been built below the water table, the system for the management of groundwater around these obstructions must also be robust enough to operate efficiently and effectively for the same period. The method by which the groundwater is controlled in the long-term can have a significant bearing on the size of the environmental footprint that is left behind by the development.

New structures have the potential to cause diversion or damming of groundwater flowpaths in the vicinity of the development that may cause water levels to be altered both up-gradient and down-gradient of the site. Such changes in hydraulic gradient can have the following implications:

- Adverse effects on bearing conditions around the foundations of surrounding dwellings.
- Creation of waterlogging problems on neighbouring properties.

- Impact on flora on adjoining properties.
- Redistribution or spreading of contamination into other areas.

Changes to the groundwater regime can, in some cases, lead to increases in the water table responses to recharge events. This may result in the raising of groundwater levels above those predicted during the design phase. If provision has not been included in the design to allow for the possible range of water table fluctuations, groundwater can potentially overtop outlets, drainage holes or joints in the structure. Typically, openings in the retaining walls such as the junction of precast panels, flood water drainage outlets and unintended fractures, can provide access to rising groundwater levels, resulting in flooding of internal building areas.

The construction methodology that is adopted for the development can have significant consequences in the management responses to these issues. Generally, the building methods that are most commonly used can be categorised as either **tanked** or **sump and pump** construction.

5.4.3.1 Tanked construction

Tanked construction involves fully sealing the basement structure below the water table to prevent the entry of groundwater. Groundwater surrounding the structure is controlled through the provision of subsoil drainage that allows the water to move around and beyond the structure without significant variations to the pre-existing groundwater regime.

5.4.3.2 Sump and pump construction

Sump and pump “untanked” construction involves the collection of seepage water (often continuously) from the perimeter walls and floor of the basement and directing it to an internally located sump or pit. The water collected in the sump is then pumped to the public road or local drainage system.

While sump and pump construction is the most common technique employed for the long-term management of groundwater, it can have a number of adverse impacts, including:

- Settlement of adjoining structures and environmental impacts resulting from temporary or permanent changes in the water table beneath the development site and adjoining properties.
- A legacy of ongoing management and maintenance to preserve the functionality of the system.
- Local flooding problems being created or exacerbated as a result of increased water flows entering the public drainage system during storm events.
- Potential for long-term discharge of contaminated water into the public drainage system and waterways.
- Constant disposal of water from the site creating nuisance flows in kerb and gutter systems. Residents neighbouring the development may note water discharge from the site during dry periods and resolve there is a problem with the development.

The use of tanked construction techniques generally avoids these impacts and while the development will often still rely on some form of pump out system, it will normally only be used to deal with minor stormwater flows collected from entry driveways.

> **Note**
>
> The use of sump and pump systems should only be considered where minor or intermittent seepages are encountered and it is impractical to divert these flows around the structure. Sump and pump systems should only be considered suitable for use in the sandstone areas of the SCCG region, where intermittent (non-continuous) pumping may be sufficient to manage the seepage volumes encountered. They are not suitable for the coastal sand bed areas due to the permeability of these aquifers and the need for generally continuous or semi-continuous operation of any pumps for the life of the development (hence becoming unsustainable development as defined by DNR). Even in the sandstone areas, circumstances may preclude the use of sump and pump systems, particularly where valleys or depressions focus significant quantities or flows of perched groundwater toward a site.

Councils should consider the following requirements as a prerequisite to approving a sump and pump system as a means of groundwater management:

- It can be demonstrated that the volume of groundwater discharged from the site is minimal and will require only intermittent pumping.
- It can be demonstrated that the groundwater is not polluted or contaminated prior to being discharged to the public stormwater drainage system.
- Disposal to the public stormwater drainage system occurs through a direct connection to the piped or below-ground infrastructure to avoid nuisance flows or ponding around the property.
- The owner(s) of the property enter into a Positive Covenant with Council regarding the maintenance and continued operation of the pump and sump system.

Essentially, the use of sump and pump over tanked systems provides a favourable solution for developers due to lower construction costs, however the costs to the community should be measured in terms of long-term maintenance requirements, energy usage and potential environmental and structural implications on adjoining property.

5.4.3.3 Construction materials

Due to the likely aggressiveness of ambient groundwater quality, or the presence of contamination originating from areas up-gradient, the materials selected for construction within the groundwater regime should be appropriate to withstand both chemical and physical attack.

Tanked construction using resistant materials would be considered as the “best practice” approach, particularly in the coastal sand bed areas of the SCCG region due to the pollution potential of these groundwater systems. The materials selected should conform to building codes and have sufficient integrity to withstand aggressive groundwater for the proposed life of the development.

In cases where the exposure of the structure to groundwater may be intermittent or minimal, the use of non-resistant materials might be considered, provided they are otherwise applicable under the relevant building codes. The proponent must demonstrate the materials to be used are sufficiently robust to withstand the anticipated exposure to groundwater for the proposed life of the development.

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.

5.4.4 Disposal of tailwater

5.4.4.1 Impacts of tailwater disposal

Tailwater is the water produced through the action of extracting groundwater during an activity other than for water supply or monitoring. It is commonly produced from dewatering of a site during construction or, in the longer term, from the groundwater management system constructed as part of the development.

The disposal of tailwater is one of the main concerns associated with dewatering activities as poorly managed or inappropriate disposal can result in regular discharge to streets (and, in turn, receiving water) during construction. In such cases, the ongoing discharge into gutters can create issues such as:

- Detrimental ‘downstream’ environmental impacts by potential chemical, physical and/or biological contamination.
- Concern from local residents about the source of the water and the apparent wastage.
- Potential slipping hazards caused by regular wetting.
- Overloading of the drainage network when dewatering occurs during significant rainfall events.
- Impacts on local businesses due to the volumes or appearance of the discharge or the odours generated by degassing of the tailwater.
- Sand or silt deposits when the tailwater is inadequately treated and filtered.

To minimise the potential for these problems, a design that eliminates the need for dewatering should be considered in the first instance in favour of a construction methodology that requires large scale removal of groundwater.

Once the development is completed, the problems associated with the disposal of tailwater will either be eliminated, or will pose ongoing management issues for Councils. Where tanked construction techniques are employed, there is generally no need to collect and dispose of groundwater from a development site. Hence, the use of tanked construction methods should be the preferred option adopted by Councils.

Where sump and pump systems are employed, the disposal of the groundwater seepage from the site can result in regular discharge into the local drainage system or natural waterways or the sewerage system. The regularity of this discharge will be dependent on the magnitude of groundwater inflows into the below-ground structures, the storage capacity of the sump, and any additional inputs from other sources, such as stormwater runoff into basement areas via access ramps or driveways.

The decision on whether to adopt a tanked or sump and pump system should be based primarily on the issues raised in Section 5.4.3. However, the difficulties associated with improper or uncontrolled tailwater disposal provide further justification for Councils to encourage the use of tanked systems.

To minimise the ongoing impacts of sump and pump systems, Councils should consider applying development controls to govern tailwater disposal. Such controls would include a requirement for tailwater disposal piping to be connected directly to Council's drainage system and, possibly, require long-term water quality monitoring of the discharge.

5.4.4.2 Considerations associated with tailwater disposal

Whether during construction or after completion of the development, it is imperative that the tailwater is disposed of in an environmentally sound manner. That is, any disposal that contaminates either surface waters or groundwater is inconsistent with the *Protection of the Environment Operations Act 1997*. Factors to consider in this regard are:

- Seepage water collected from basement car parks may be contaminated with detergents, oils, grease or other hydrocarbons that must be removed prior to disposal. Pollution interception devices such as oil and grease separators should be used to divert contaminants to the sewerage system (under a Trade Waste Licence).
- The physical process of extracting groundwater can alter its chemistry such that it becomes significantly different from the ambient quality within the aquifer. The aeration caused by pumping can generate oxidised forms of compounds that must be accounted for in any proposed disposal option.
- Reinjection of groundwater (Figure 5.1) previously extracted beneath the site may maintain pore pressures and hydraulic support to foundations, but, because of the alterations caused by pumping, can introduce problem constituents to the aquifer. This may be a particular problem where contaminated groundwater is encountered, as the degradation products of some chemicals are more harmful than the original contaminants. The potential for reinjection to contaminate groundwater beneath the development site and adjoining properties should be addressed in any proposal and should not be considered in terms of "only putting back what has been taken out".

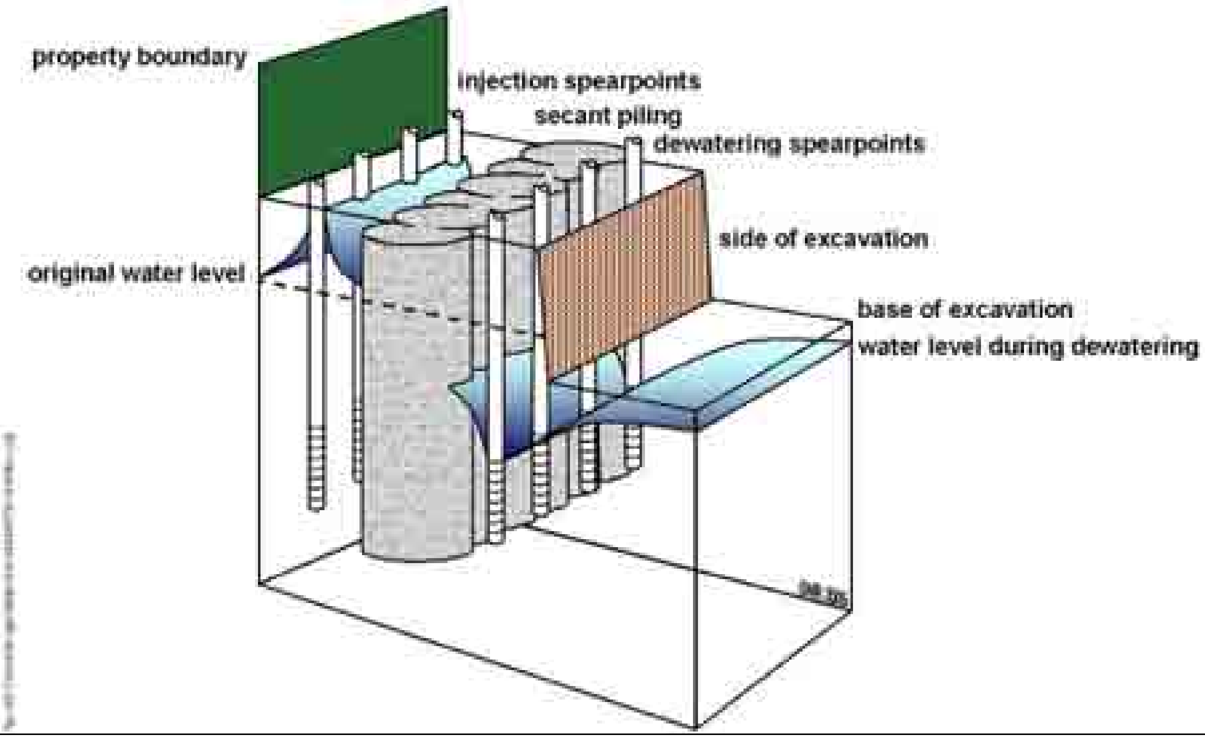

Figure 5.1 Schematic illustration of water table conditions during dewatering with reinjection and engineering controls placed in a permeable sand bed aquifer

5.4.5 Groundwater level monitoring

It is important that during construction and operational phases of a project, the existing groundwater regime is maintained as close as possible to the pre-development condition. In this regard, consideration should be given to the level and flow attributes of the groundwater regime, through appropriate monitoring.

Monitoring measures can assist in preventing immediate or cumulative detrimental effects to the site, surrounding properties, infrastructure and the environment.

In the coastal sand bed areas of the SCCG region, it is particularly important that monitoring of groundwater levels is undertaken **prior to construction** to provide baseline information relating to the undisturbed site conditions and to assist in establishing the method and extent of dewatering that will be required. **During construction**, monitoring can confirm the predictions inherent in the design of the dewatering system, and demonstrate that off-site impacts are maintained within the pre-set acceptable limits. **Following completion of construction,** water level monitoring provides information on the groundwater regime and identifies any major changes that have been brought about by the construction of the building.

It is not appropriate to consider one-off measurements of the standing water level as "monitoring". Single measurements of water level from individual bores do not account for the dynamic nature of the water table. This is particularly the case in the coastal sand bed aquifers, and, although less likely in the sandstone environments, measurements should still be repeated in such areas to confirm the minor magnitude of changes expected. Water level monitoring should be undertaken on a regular basis for a period of six months, from monitoring bores installed at the site and any additional on-site or off-site locations. Reported monitoring results should also include a rainfall hyetograph so as to provide an indication of the sensitivity of the groundwater levels to periods of rainfall.

It is also important to note the potential for variations in the groundwater level through natural causes such as tidal or environmental effects such as rain or drought. Unless adequate monitoring is employed prior to and during construction, these effects can have a significant impact on the integrity of the monitoring results.

In order to provide an understanding of the hydraulic gradient beneath the site, a minimum of three appropriately constructed monitoring bores should be installed. Monitoring from three points across the site allows triangulation of water levels, determination of the hydraulic gradient and interpretation of groundwater flow directions. These installations should be designed to monitor the regional water table in the coastal sand bed aquifers, or the main water bearing zone to be intersected in the sandstone areas.

Where groundwater is likely to only occur as minor seepage from the walls of the excavation, such as the shale environments of the SCCG region, there may be insufficient volumes to provide meaningful monitoring results. In such cases, the requirement for the installation of monitoring bores may be unnecessary. Where monitoring bores are not proposed to be installed, the understanding of the groundwater regime and the impacts of the development need to be clearly demonstrated and documented by the proponent. This is necessary to ensure that diversion or retardation of groundwater flow will not generate off-site impacts and that the amenity of the area surrounding the property is protected.

5.4.6 Water quality monitoring

Depending on the nature of the groundwater beneath a development site, and the disposal practices proposed, water quality monitoring will be necessary to address several attributes, each with specific testing or measurement schedule requirements. Because specific sample collection methods, containers, transport and handling are usually required to obtain representative water quality information, these practices should only be carried out by experienced and trained consultants.

Water quality monitoring is necessary at the design stage to assist in the determination of the most appropriate construction methodology (tanked or sump and pump) and the corresponding groundwater/tailwater disposal method. This will assist in compliance with legislative requirements (particularly the *Protection of the Environment Operations Act 1997* provisions relating to prevention of pollution) and addressing potential impacts on the completed structure after construction.

Sampling for each of these purposes should be carried out at appropriate locations selected by experienced personnel. Initial assessment of the groundwater quality involves one-off sampling of the groundwater from monitoring bores. If the site is to be remediated under the *Contaminated Land Management Act 1997*, additional groundwater sampling from the bores (and other locations) may be required to **validate** any clean up activities undertaken. In the case of tailwater disposal, sampling should also be undertaken at, or as near as possible to, the discharge point.

Analysis of the collected samples should be carried out under documented protocols within specified holding times and at an accredited laboratory.

5.4.7 Existing development

Existing development, particularly older buildings, may incorporate a legacy of design or construction difficulties that allow substantial seepage inflows and require the operation of mechanical systems to routinely remove groundwater from below-ground areas.

Where it has been identified that the activities required to maintain safety in these older structures is causing a nuisance or hazard, steps should be taken to address the problem. Such action might include requiring that the below-ground structure be retrofitted to prevent groundwater inflows.

5.4.8 Reporting requirements

Councils have a responsibility to ensure that the proposed works for a new development does not have an adverse effect on neighbouring property and the environment. Any development proposal involving construction of permanent structures below the water table, other than pile or footing installation, should be supported by a series of detailed Geotechnical and Hydrogeological Reports, prepared at the following stages of the development:

- Prior to development approval.
- Prior to construction.
- During construction.
- Prior to occupation of the development.

5.4.8.1 Prior to development approval

In general, the objectives of the report submitted with a Development Application should be to demonstrate that the proposed works can be feasibly constructed without adverse impacts to neighbouring properties or the environment and provide recommendations to address areas of uncertainty or concern.

Reporting Guidelines Applying to Construction Extending Below the Water Table

A detailed Geotechnical and Hydrogeological Report must be submitted prior to Development Application approval. In general, the objectives of the report should be to demonstrate that the proposal can be feasibly constructed without adverse impacts to neighbouring properties or the environment and provide recommendations to address areas of uncertainty or concern. The report should address the following issues at a minimum:

- Presentation of results of subsurface and groundwater investigations. This includes identification of any soil or groundwater contamination, and interpretation of below-ground site conditions (including the depth to bedrock, soil classification, bearing capacities, depth to groundwater, etc).
- Assessment of existing hydrogeological characteristics and inferred groundwater flow direction. The groundwater regime (flow, level and quality) should be clearly defined.
- Proximity and relevant characteristics of all buildings and structures in the vicinity of the proposed development that may be potentially impacted by the construction works. The key elements that should be considered are the potential for settlement and an assessment of footing arrangements for adjoining buildings.
- Proposed construction methodology, in particular relating to temporary or permanent support of the excavation, and whether dewatering is proposed. Any anticipated changes to the groundwater regime (flow, level and quality) during and following construction should be described and justified where appropriate. Where temporary dewatering is proposed, the report should include estimates of flow rates and volume of groundwater to be extracted, together with details of the design of the dewatering system, reinjection systems (if proposed), and details of any licensing requirements. A bore licence may be required under Part V of the *Water Act 1912*, and an Environmental Protection Licence may be needed for tailwater disposal.
- Proposed groundwater management system for the completed structure. The report should describe and justify measures to be used to maintain the existing groundwater regime throughout the life of the development, such as provision of a passive diversion system around the completed structure.
- Description of the proposed method of tailwater disposal and the management of site stormwater runoff.
- Appraisal of ambient groundwater quality against currently accepted guidelines (note that even though a site may be degraded and groundwater quality may be poor, this does not mean that the least stringent guidelines should be adopted).
- Description of any treatment techniques required to address groundwater quality issues. Note that any disposal of tailwater must comply with relevant approvals and the *Protection of the Environment Operations Act 1997*. That is, it must be demonstrated that treatment, where required, will result in a product that will not pollute surface waters or groundwater during disposal. The requirements of the *NSW Groundwater Quality Protection Policy* also apply in this circumstance.
- Presentation of a risk assessment matrix. This may require individual risk assessment matrices for all of the following; the effects of dewatering, groundwater seepage into the below-ground structure, environmental contamination resulting from poorly planned disposal of tailwater, and effects on the local community in the event of any off-site impacts.
- Details of a monitoring program including schedule of activities, equipment to be used and parameters to be measured. The monitoring plan should also identify acceptable limits to changes in measured parameters such as ground settlement, drawdown of water tables, deflection or movement of retaining structures, vibration, or changes in the quality of the tailwater. It should also define the location of appropriate monitoring sites, recommended hold points (to allow for inspection and certification needs), and exhibit clear linkages to any contingency plans.
- Contingency plans to link monitoring program with triggers to modify site activities and reporting to relevant consent authorities and agencies. The contingency plans should clearly articulate the monitoring triggers and the responsive actions to ameliorate any adverse impacts. Such plans could include details of measures to restore the groundwater regime, additional engineering responses, remedial works and alternative procedures. Particular attention should be paid to management responses to be triggered by the detection of contaminants in the discharge water not previously identified through the site investigation.

Note that the extent to which each of the items is addressed must be determined having regard to the nature of the development, site investigations and sensitivity of the surrounding properties and infrastructure. The author of the report must be satisfied that the objectives and design principles of these guidelines will be met as a consequence of the carrying out of the development and that the information presented is adequate to demonstrate this.

5.4.8.2 Prior to construction

Where applicable, Councils should consider imposing conditions of consent that require the developer to submit the following additional information prior to commencement of construction (that is prior to issue of a Construction Certificate):

- Dilapidation reports.
- Details of dewatering method with licences as appropriate.
- Finalised Implementation Plan incorporating finalised Geotechnical and Hydrogeological Monitoring Program, Contingency Plan and Construction Methodology.
- Further geotechnical and hydrogeological investigations as may be required by special consent conditions or as recommended in the geotechnical and/or hydrogeological report submitted with the Development Application.
- Design Certification from suitably qualified and experienced geotechnical and/or hydrogeological engineers confirming that the design of the new below-ground structure has been undertaken in accordance with applicable standards.

5.4.8.3 During construction

Where applicable, the works on the site should be inspected and monitored in accordance with the Implementation Plan, the Geotechnical and Hydrogeological Monitoring Program and any other recommendations made by the geotechnical and/or hydrogeological engineer.

5.4.8.4 Prior to occupation of the development

Where applicable, Councils should consider imposing conditions of consent that require the developer to submit the following additional information prior to occupation of the development (that is prior to issue of an Occupation Certificate):

- A record of inspections and monitoring as required by the Implementation Plan and Geotechnical and Hydrogeological Monitoring Program.
- Certification from suitably qualified and experienced geotechnical and/or hydrogeological engineers confirming that all works have been undertaken in accordance with applicable consent conditions, applicable standards and the recommendations of the geotechnical and hydrogeological reports.

5.5 Construction on hillsides

Construction on hillsides can be a complex matter that, depending on the nature of the geology and geography of the area, will require varying degrees of investigation and design, particularly relating to the application of best management practices for long-term stability of the land and structures.

This Section confines its discussion to the disposal of groundwater intercepted through the construction of permanent structures; from low retaining walls to large scale excavation for multiple level buildings. The discussion differs from the preceding sections in that it deals primarily with those cases where the intercepted groundwater can be collected and discharged by gravity.

Where suitable groundwater management systems are not installed, the uncontrolled discharge of the tailwater can lead to nuisance flows across footpaths and into street gutters, creating issues similar to those described in Section 5.4.4.1.

It is important that adequate geotechnical and hydrogeological investigation is undertaken as part of the development assessment process so that the quantities of groundwater flow, intercepted by the development, can be estimated and suitable disposal systems designed.

Unless it can be demonstrated that the intercepted groundwater flows will only be intermittent and not cause continuous or regular wetting of the street gutter, Council should consider directing that the disposal system be connected directly to the piped or below-ground stormwater drainage network.

5.6 Suggested development controls

A series of possible development controls have been prepared that deal with those constructions that extend below the water table. Councils are encouraged to adopt the suggested controls either in part or in full to standardise approaches throughout the SCCG region.

5.6.1 Impacts to infrastructure and property

Note

These suggested development controls are broadly applicable to all areas (coastal sand beds, sandstone and hillside environments).

These controls cover both the short-term effects resulting from construction practices involving temporary dewatering and long-term effects resulting from the support and retention of property and infrastructure after construction has been completed.

The applicant must demonstrate, prior to development consent being issued, that there will be no adverse impact on surrounding or adjacent properties and infrastructure:

- As a result of changes in the local hydrogeology (behaviour of groundwater) created by the method of construction chosen.
- From changes to the permanent hydrogeology (behaviour of groundwater) of the surrounding area, created by the nature of the constructed form and groundwater management system utilised.

Where there is the potential for a damming effect created by several consecutive below-ground structures, the following controls are suggested:

- The cumulative impact will require hydrogeological modelling to demonstrate no adverse impact on the surrounding property or infrastructure. The extent of modelling must consider the potential for future development to extend the damming effect and must, as a minimum, extend between street blocks.
- Where below-ground structures are in close proximity to each other (typically less than 3m) ensure no allowance for natural ground flow through these narrow corridors has been included in the design of perimeter or through drainage.

5.6.2 Temporary changes to groundwater levels or flow

Note

These suggested development controls only apply to coastal sand beds or alluvial areas (i.e. unconsolidated sediments).

Temporary groundwater changes are not to exceed the defined limits indicated unless calculations or modelling, based on the results of site-specific field testing, can demonstrate no adverse impact to surrounding properties and infrastructure where a larger variation in level is proposed.

The temporary shadow zone during dewatering should be taken as an area within 20m of the earlier construction, unless site-specific calculations can demonstrate that a different lateral extent should be adopted.

Temporary changes to the groundwater level as a result of construction must be kept within the historical range of natural groundwater fluctuations:

- Where data is limited or unavailable, changes in the level of the natural water table due to construction are not to exceed 0.3m.
- In areas where the construction affects existing development within a shadow zone of an earlier construction, temporary changes in the level of the water table due to the construction are not to exceed 0.15m.

5.6.3 Permanent changes to groundwater level or flow

Note

These suggested development controls only apply to coastal sand beds or alluvial areas (i.e. unconsolidated sediments).

Temporary groundwater changes are not to exceed the defined limits indicated unless calculations or modelling, based on the results of site-specific field testing, can demonstrate no adverse impact to surrounding properties and infrastructure where a larger variation in level is proposed.

Permanent changes to the groundwater level as a result of construction must be kept within the historical range of natural groundwater fluctuations.

- Where data is limited or unavailable the permanent change in the level of the natural water table due to the development is not to exceed 0.2m.
- In areas where the construction affects existing development within a shadow zone of an earlier construction, the permanent change in the water table due to the construction is not to exceed 0.1m. The permanent shadow zone of an earlier construction with full penetrating cut-off walls but without appropriate subsurface drainage should be taken as a distance equal to one building width along the groundwater flow path both in front and behind the earlier construction.

5.6.4 Groundwater management systems

Note

These suggested development controls are broadly applicable to all areas (coastal sand beds, sandstone and hillside environments).

Groundwater management systems shall be designed to transfer groundwater through or under the proposed development without a change in the range of the natural groundwater level fluctuations.

Where an impediment to the natural flowpaths is created as a result of the nature of the construction methods utilised or the bulk of the below-ground structure, artificial drains such as perimeter drains and through drainage may be utilised. These systems may only be utilised where it can be demonstrated that the natural groundwater flow regime is restored both up-gradient and down-gradient of the site, without any adverse effects on surrounding property or infrastructure.

Groundwater management systems:

- Are to be designed to be easily maintained. Council will require a Positive Covenant to ensure the continued functioning and maintenance of the approved groundwater system.
- Shall have a design life of 100 years.

5.6.5 Requirements for construction into aquifers

Note

These suggested development controls are applicable to coastal sand beds and sandstone environments.

The applicant must provide details of the method of construction for any development proposal involving construction of permanent structures below the water table, other than pile or footing installation, prior to development consent being issued. The details provided must be sufficient to demonstrate compliance with the following:

- The basement must be of fully tanked construction and be entirely waterproofed.
- The groundwater management system must not rely on a pump-out system for collection and disposal of groundwater.

Council will consider exceptions to these requirements **only in porous rock areas**, such as where perched aquifers are encountered, and it can be demonstrated that:

- It is impractical to divert the groundwater flows around the structure.
- The volume of groundwater collected and discharged from the site is minimal and will require only intermittent (non-continuous) pumping.
- The groundwater is not polluted or contaminated prior to being discharged to the public stormwater drainage system.

Under no circumstances will construction that relies on pump-out systems be considered in the coastal sand bed areas due to the permeability of these aquifers and the need for generally continuous or semi-continuous operation of pumps (hence becoming unsustainable development as defined by DNR and not acceptable for licensing).

5.6.6 Requirements for construction on hillsides

Note

These suggested development controls are applicable to construction on hillsides.

When structures or retaining walls are constructed adjacent to a property boundary, they must be entirely self-supporting in the event that excavation is undertaken in the adjacent property to the depth of the proposed structure. The retaining walls must be adequate to withstand the loadings that could be reasonably expected on the land in the adjacent property. Where the adjacent property is Council road reserve and includes constructed road or footpath, the expected loadings must include normal traffic and heavy construction and earth moving equipment.

The applicant must provide details of the method of construction for any development proposal involving construction of permanent structures below the water table, other than pile or footing installation, prior to development consent being issued. The details provided must be sufficient to demonstrate compliance with the following:

- All components of the structure, including subsoil drainage, must be located entirely within the property boundary.
- Disposal of collected subsoil water must be achieved through a gravity drainage system.

5.6.7. Tailwater disposal

Note

These suggested development controls are broadly applicable to all areas (coastal sand beds, sandstone and hillside environments).

Where the groundwater management system relies on permanent extraction of groundwater, such as may be used for construction that employs a sump and pump system, the tailwater disposal piping shall be connected directly to Council's piped or below-ground stormwater drainage network. Discharge will not be permitted to any surface drainage systems (e.g. kerb and gutter).

Where Council's existing stormwater drainage network does not extend to the frontage of the development site, the applicant will be required to extend the existing system to the site frontage. Where on-site stormwater detention (OSD) facilities are required to be installed as part of the development, the tailwater must be discharged to those facilities. The design of the OSD facilities must take into account the expected tailwater discharge volumes and quality. The OSD facility must be designed to prevent contaminated or polluted tailwater from discharging to the groundwater system. The tailwater discharge piping must also be connected directly to Councils piped or below-ground stormwater drainage network.

5.7 Recommendations

Recommendations

It is recommended that:

- The existing groundwater regime (flow, levels and quality) is determined prior to construction.
- The groundwater regime is maintained as close as possible to the pre-development condition during construction and operational phases of a project.
- Construction techniques that eliminate the need for dewatering, if possible, should be required by Council.
- Water level monitoring is to be undertaken on a regular basis from the monitoring bores installed at the site and any additional on-site or off-site locations, if necessary.
- For development involving construction below the water table in coastal sand bed aquifers, all DNR information requirements are to be addressed prior to the lodgement of the Development Application.
- For development involving construction into perched aquifers in porous or fractured rock aquifers (sandstone or shale areas), construction techniques that eliminate the need for pumping, if possible, should be required by Council.
- Developers familiarise themselves with the requirements of DNR and Councils relating to construction dewatering.

5.8 Suggested technical and further reading

1. **Anon. 2001**. Dewatering site for development. *Engineers Australia: Civil Edition*, 73(9): 50-51.

2. **Booker, J.R., Carter, J.P. and Small, J.C., 1985**. Prediction of subsidence caused by pumping of groundwater. Conference Paper. *International Association for Hydraulics Research 21st Congress.* Melbourne 19-23 August, pp. 130-134.

3. **Commissioners of Inquiry, 2003**. Annual Report 2001-2002. Office of the Commissioners of Inquiry for Environment and Planning. pp. 12-13. Available on-line at: http://www.coi.nsw.gov.au/report/file/2001-2002.pdf [accessed 21 April 2005].

4. **Ervin, M.C., Benson, N.D., Morgan, J.R. and Pavlovic, N., 2004**. Melbourne's Southbank interchange: a permanent excavation in compressible clay. *Canadian Geotechnical Journal*, 41(5): 861-878.

5. **Stretch, J., 2001**. Excavation retention groutcrete-secant pile wall – a case history 10 Darley Road, Manly. *Excavation Retention, Australian Geomechanics Society (Sydney Chapter) Mini-Symposium.* Milsons Point, 8 August 2001.

6. **Wood, E.A., Crosbie, J.R. and Brown, R.A., 1994**. Construction around contamination. *Civil Engineering* 64(10): 50-53.

7. **Woollahra Municipal Council, 2002**. Guidelines for preparation of Geotechnical and Hydrogeological Reports. Woollahra Municipal Council, September. Available on-line at: http://www.woollahra.nsw.gov.au/WebBlocks/Woollahra2.nsf/WebDocs/WB26887E3E721938D3CA256F3B00120C7F/$file/Geotech&HydrogeologicalReports.pdf!OpenElement [accessed 21 April 2005].

6.0 GROUNDWATER MANAGEMENT IN NEW SOUTH WALES

6.1 Introduction

This chapter is designed to provide guidance for Councils on activities that are considered by DNR to require a licence under Part V of the *Water Act 1912*. The information provided is intended to distinguish those activities that are to be considered through the Integrated Development Approval Scheme (IDAS), with respect to groundwater.

6.2 Objectives

Objectives

The objectives of this chapter are:

- To identify the management approaches used by DNR in regulating groundwater access, use and impacts.
- To describe the information that must be addressed as part of construction dewatering or artificial recharge proposals.
- To assist the determination of applications requiring consideration through the IDAS process.
- To provide guidance in the standards to be considered in the drilling and construction of groundwater works.

6.3 Management of bore construction

6.3.1 Bore licence conditions

Conditions placed on bore licences issued by DNR may indicate standards of construction for groundwater works. Standard conditions apply to all licences issued, dealing with separation distances between bores and other features, control of tailwater discharge, notification of unusual groundwater behaviour and environmental protection measures. Specific conditions may be applied to licences to address hydrogeological settings characteristic of certain areas, prevention of aquifer interconnection, the sealing off of poor quality water, or protection of nearby ecosystems.

Conditions that may be attached to bore licences relating to construction are as follows:

- The construction and completion of the groundwater work.
- The decommissioning of the groundwater work if it is to be abandoned.
- The location of the groundwater work relative to property boundaries.
- Separation distances to other groundwater works.

- The depth of the groundwater work.
- The maximum allowed diameter of the groundwater work.
- The aquifer intervals that may be accessed by the completed groundwater work (restrictions may apply in areas near to sensitive environments or other features).
- The sealing off of aquifers containing poor quality groundwater.

6.3.2 Construction standards for groundwater works

National construction standards exist that apply to water bores in Australia. These were originally produced through the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ 1997) and have since been issued through the Land and Water Biodiversity Committee. The *Minimum Construction Standards for Water Bores in Australia* (LWBC 2003) deal with:

- Administrative requirements. The requirements for drillers to be licensed and groundwater works to be authorised are identified.
- Responsibilities applying to licensees and drillers. These include obtaining the relevant authorisations, access to a cleared drilling site, written contracts, safety issues, and protection of the aquifer.
- Drilling methods.
- Siting a groundwater work.
- Sampling of geological materials and groundwater.
- Aspects of construction. Including types of drilling fluids, ensuring accurate alignment of the hole, casing materials selection, grouting approaches and optimising groundwater entry into the bore.
- Development of the completed work to clean out remnant drilling wastes.
- Disinfection of the work to reduce biological fouling or encrustation.
- Test pumping to assess hydraulic characteristics.
- Recording and reporting of data related to the work.
- Construction of headworks and clean up of the drilling site.
- Decommissioning of works.
- Monitoring bore construction, completion and abandonment.

These standards are to be considered in the construction of any groundwater work in the SCCG region. They are to be applied in addition to any specific bore licence conditions that relate to the construction of the groundwater work. Where the information in the standards is less detailed than those provided as licence conditions, the more stringent requirements of the authorisation are to take precedence.

6.3.3 Driller's licences

In New South Wales, driller's licences are issued by the Driller's Licensing Board, a part of DNR. Driller's licences are endorsed with classifications related to the type of installation the contractor is authorised to construct (e.g. a licence endorsed for spearpoints is not appropriate for drilling in the Great Artesian Basin).

Prior to drilling commencing on any groundwater work, the driller's licence should be viewed to ensure the appropriate endorsement is present for the type of installation proposed.

6.4 Management of groundwater extraction

6.4.1 Bore licences

Under the *Water Act 1912*, bore licences are issued as either perpetual or renewable. In the past, perpetual licences have been issued for stock, domestic and farming purposes. Generally, such uses involve small volume extraction, usually no more than 10 ML per year, and bores are pumped intermittently on an 'as needs' basis. Because of the pattern of use and the small extraction demand, these groundwater works generally have minimal impact on surrounding areas. There are exceptions to this where a large number of groundwater works exist within a small area (i.e. there is a high bore density) and the mutual effects of pumping can overlap.

Renewable licences are applied to all uses other than for stock, domestic or farming. That is, for purposes such as industrial (e.g. sand and gravel washing, cooling or processing), irrigation (e.g. agriculture, horticulture, parks), or commercial (e.g. nursery watering, aquaculture). The applicant must demonstrate a need for the amount of water that has been requested, and this forms the basis for the **licensed entitlement** that eventually may be granted.

The entitlement attached to renewable licences specifies the volume of water that has been authorised for extraction and use on the identified property. The issue and renewal of this category of bore licence attracts two fees that are set by the Independent Pricing and Regulatory Tribunal (IPART); an administrative fee (on issue and renewal), and an annual property entitlement charge (including a base property cost and a price per megalitre of entitlement). These charges are reviewed regularly as part of submissions to IPART on bulk water pricing. The current costs should be confirmed with DNR licensing personnel prior to any licence application being forwarded.

Note

Once all of the provisions of the *Water Management Act 2000* have been enabled, these licence categories will be replaced with different authorisations and approvals. A subsequent edition of this Handbook will describe the application of those authorisations and approvals in more detail.

6.4.2 Conditions applying to use

Conditions that are set on bore licences that relate to the extraction and use of groundwater may include:

- The annual entitlement volume.
- The area over which the water may be applied.
- Any defined yield restrictions to prevent unsustainable extraction.
- The authorised use of the extracted groundwater.
- Any specific monitoring requirements, such as the maintenance of the local water table above identified trigger levels.
- The provision of water quality test results.
- Any specific reporting requirements.

6.5 Management of groundwater impacts

6.5.1 Construction dewatering

6.5.1.1 Information requirements

“In principle” approval may be granted by DNR to the temporary dewatering required for construction where an excavation will intersect the water table. With regard to other possible effects of pumping, Councils may also consider temporary dewatering of a site acceptable provided it can be demonstrated that there are no other feasible construction methodologies available and no adverse impacts will occur on or under neighbouring properties.

Where temporary dewatering is required, the relevant information required by DNR to allow licensing must be provided with the Development Application. By requesting this information early in the approval process, the Council and DNR allow developers to consider alternative designs before the Development Application is submitted. This is significant in areas where serious contamination is encountered during the site investigation process as appropriate treatment and disposal options can be assessed.

Should treatment and disposal of contaminated groundwater not be possible without considerable expense or the risk of alternative contamination being generated, changing the design of the development to avoid areas below the water table may be an option. Similarly, the early detection of potential off-site subsidence impacts can allow appropriate engineering measures to be included during construction, rather than trying to rectify damage after completion.

Councils are encouraged to apply the following requirements for developments that extend below the water table.

Requirements for a temporary dewatering licence

The Department of Natural Resources (DNR) licences dewatering to allow excavation for construction for a temporary period, usually 12 months. DNR has advised that the following information must be provided with any licence application for dewatering purposes, in order for the submission to be processed.

1. The method of construction proposed for that part of the development extending beneath the water table that will preclude the need for any type of permanent dewatering facility or activity.
2. The method of temporary dewatering to be adopted during construction and the types and number of pumping and reinjection installations that will be utilised.
3. An accurate plan, to scale, of the property identifying the location of all groundwater works to be used in the temporary dewatering activity and the location of any discharge or reinjection points.
4. Records of groundwater levels beneath the subject property from at least three on-site locations each with at least three weekly measurements prior to the commencement of dewatering.
5. The amount of lowering of the local water table required to accommodate the excavation necessary for the proposed construction.
6. An estimate of the total volume of groundwater to be extracted, in kilolitres or megalitres.
7. An estimate of the total volume of tailwater that is to be reinjected, in kilolitres or megalitres.
8. An estimate of individual and composite flow rates for all extraction and reinjection installations, in litres per second.
9. An estimate of the duration over which dewatering pumping is to take place, in days, weeks or months.
10. Predictions of the impacts of dewatering pumping on any licensed groundwater users, significant infrastructure such as tunnels or pipelines, or groundwater dependent ecosystems in the vicinity of the site.
11. Laboratory results from the analysis of groundwater quality samples taken prior to the commencement of dewatering to assess the presence of any contaminants and comparison with documented water quality objectives or criteria.
12. An assessment of the potential for salt water intrusion to occur as a result of the dewatering pumping for sites within 250 metres of any foreshore.
13. The method of disposal of excess tailwater (either street drainage to the stormwater system or discharge to sewer under a trade waste agreement) if reinjection is not proposed and written advice from the relevant controlling authority indicating that the proposed means of disposal is acceptable.
14. The compatibility of the tailwater and the intrinsic or ambient groundwater in the vicinity of property if reinjection is proposed, including written advice on:
    - 14.1 The treatment to be applied to the tailwater to remove extant contamination.
    - 14.2 The measures to be adopted to prevent redistribution of contaminated groundwater due to either pumping or reinjection.
    - 14.3 The means to avoid degrading impacts on an identified beneficial use of groundwater.
15. Written advice from a geotechnical professional whether there is any significant risk that the proposed dewatering rates and duration may cause any off-site impacts, such as damage to surrounding buildings or infrastructure, as a result of differential sediment compaction and surface settlement during and following pumping.
16. The proposed monitoring activities to be undertaken prior to, during and for the required period of time following the dewatering pumping to confirm the impact predictions, including:
    - 16.1 Locations and schedules of water levels measurements at site boundaries.
    - 16.2 Locations of settlement monitoring points, if required, and schedules of measurement.
    - 16.3 Locations and schedules of groundwater, tailwater or reinjection water quality sampling.
17. The specific information related to the dewatering activity that is to be provided to the department on expiration of the temporary dewatering licence.

DNR also requires copies of any hydrogeological or geotechnical reports of relevance to the proposed dewatering activity. A separate report is required by DNR at the completion of construction detailing the performance of the dewatering system, in particular describing the amounts and quality of groundwater extracted from the site.

6.5.1.2 Licence conditions

Conditions placed on licences for temporary dewatering activity are similar to those for groundwater extraction, with the exception being that a specific time period over which pumping is allowed is clearly defined, and no entitlement is granted. Specific (non-standard) conditions attached to temporary dewatering licences relate to the disposal of tailwater (the water removed by the pumping operation), the monitoring of water levels and quality and reporting to DNR the quantity and quality of groundwater extracted.

6.5.1.3 Dewatering systems not requiring a licence

Sump pump-out systems are not required to be licensed in the porous or fractured rock areas (i.e. sandstone and shale environments) of the SCCG region provided the pumping operation is not continuous and the groundwater inflows are derived from a perched aquifer of limited extent. Where there is some doubt about the nature of the groundwater system, the proponent should provide evidence to Council and DNR demonstrating that a deep regional aquifer exists beneath the perched aquifer intersected.

If a significant perched aquifer is intersected, or contaminated groundwater encountered, the environmental impacts of using a sump and pump system should be assessed by the proponent and presented to Council. Additional considerations, such as the measures to be implemented to address any potentially adverse effects, should also be documented. If the perched aquifer relates to ecosystems identified as dependent on groundwater (commonly manifested by spring discharge), or supports the amenity of a local area, Council may need to consult with DNR to determine appropriate requirements or restrictions on the development.

In the areas of unconsolidated sediments (i.e. coastal sand bed deposits and alluvium), exemptions to the requirement for a licence are only allowed based on the scale of impacts likely to occur:

- Minimal drawdown below the existing water table. Where drawdown associated with the dewatering operation does not exceed 0.5 metres below the existing water level, a licence may not be required from DNR.
- Very short duration of dewatering. Typically, such short pumping durations are required for the installation of a swimming pool, or the repair of a pipeline or other services. These may not require a licence from DNR due to the limited duration of pumping likely to be undertaken.

Note

Although licences may not be required from DNR under the *Water Act 1912*, responsibilities under legislation dealing with environmental protection and contaminated sites still apply to the development. Council should ensure that developers provide adequate information prior to construction commencing to be able to manage any potential impacts.

6.5.2 Artificial recharge

Artificial recharge structures are usually pits, excavations or retention basins constructed above highly permeable unconfined aquifers. In the SCCG region, artificial recharge is only applicable for areas of unconsolidated sediment (e.g. coastal sand beds deposits or alluvium), and are only likely to be successful in areas underlain by coastal sand beds.

These structures are designed to capture and retain stormwater to promote infiltration into the underlying groundwater system. They are generally most effective in areas where existing groundwater development has depleted the naturally occurring resource and the artificial replenishment of the system can provide an ongoing source of supply. Artificial recharge structures are permanent features that can potentially impact on both quantity and quality characteristics of the groundwater.

Artificial recharge structures are not considered to require a licence under the *Water Act 1912*, unless they intersect groundwater. The exception to this is where local planning instruments have identified that DNR approval is required for the carrying out of such activity (e.g. *Sydney Regional Environmental Plan No 17 -- Kurnell Peninsula*).

6.5.2.1 Impacts to be considered

In all cases where artificial recharge is proposed, there must be a sound understanding of the impacts associated with:

- The increased recharge to groundwater at a time when recharge through other open spaces is also increased (that is, increased recharge during periods of raised water levels) and mitigation measures where adverse impacts may occur.
- The quality of the stormwater being recharged and treatment techniques necessary to ensure the recharge water does not lower the beneficial use of the groundwater (as required by state groundwater policies).
- The water balance, particularly as it applies to areas down hydraulic gradient, that could generate waterlogged surface conditions where the increased recharge cannot be adequately dispersed or discharge is restricted by other urban development.

6.5.2.2 Licence requirements

In cases where an artificial recharge structure intersects a regional water table, a licence is to be obtained from DNR for the structure. A separate licence must be sought from DNR for the groundwater monitoring bores to be used in conjunction with the artificial recharge structure. Conditions associated with the maintenance and monitoring of water levels and quality will be applied to these licences in accordance with the requirements of the *NSW State Groundwater Quality Protection Policy* (NSW Government 1998). Where a planning instrument requires the approval or concurrence of DNR, similar groundwater monitoring requirements will be applied irrespective of the need to licence the recharge structure itself.

Councils are encouraged to apply the following requirements for developments that include proposals for the artificial recharge of groundwater.

6.5.3 Reinjection of tailwater

In contrast to artificial recharge proposals, the reinjection of tailwater into the aquifer from which the groundwater was extracted is generally proposed for limited periods (e.g. weeks or months). Such activity is generally associated with construction dewatering and is undertaken to minimise the impacts of water level drawdown beneath areas surrounding the development site. As such, the dewatering and reinjection of groundwater is carried out for the finite (temporary) period of time during which the basement areas of the building are being constructed.

6.5.3.1 Licence requirements

Because the physical actions associated with pumping can generate changes in chemistry, the water that is to be reinjected will not necessarily be of the same quality as the ambient groundwater. The reinjection of tailwater has implications for the quality of groundwater in an area, together with possible impacts on nearby users or dependent ecosystems. These activities must be considered in the management of the groundwater resource, and, as such, a reinjection system requires a licence under the *Water Act 1912*. The authorisation for a reinjection activity must be applied for and obtained separately from the licence for the dewatering system that is being used.

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.

1. A plan to scale showing accurately the location of the artificial recharge structure, treatment systems and monitoring bores in relation to portion and property boundaries.
2. Details of licensed bores within 1.0km of the property.
3. A comprehensive assessment of the hydrogeological regime operating in and around the site including technical assessment of ambient groundwater flow, flux and quality including detailed water balances for the site under pre-development, construction and post-development conditions.
4. A detailed design of the artificial recharge structure in plan and section indicating the scale of the work, the depth to which it is to be constructed relative to the water table and its position with respect to existing and proposed monitoring bores.
   A discussion of the performance of the artificial recharge structure including estimated inflow stormwater quality, proposed treatment processes and methods of application, predicted contaminant reduction efficiencies, and recharge pond water quality.
5. A plan of monitoring that includes the location, depth and construction of existing and proposed groundwater monitoring bores to comply with property boundary water quality objectives, a schedule of sampling including location, analyte list and frequency of testing, and trigger levels at which remedial action is to be undertaken.
6. Management plans indicating amelioration methods to be put in place should any part of the disposal network fail to perform as predicted, measures to ensure that the groundwater quality at the property boundary meets water quality objectives, and remediation actions should groundwater contamination occur.
7. A maintenance plan for the artificial recharge structure, the treatment systems and the monitoring network outlining the measures to prevent contamination of groundwater.
8. A management plan for the site and surrounds that indicates the type of development that will be allowed on-site with regard to pollution potential of the businesses or operations and the vulnerability of the aquifer.
9. Details of the types of contaminating or potentially contaminating industries that will be prevented from purchasing into the final development.
10. An outline of the annual reporting of groundwater quality and recharge structure performance to be undertaken following construction including interpretation of any trends and tabulation of data.
11. The individual or entity who will hold the licence and have responsibility for all ongoing management, maintenance and reporting associated with the development and stormwater disposal system.

DNR also requires any artificial recharge system to comply with the spirit, objectives and principles of the NSW Groundwater Quality Protection Policy, specifically the requirements of Appendix D - Groundwater Protection Levels.

6.5.3.2 Licence conditions

Conditions specific to a reinjection system licence relate to the quality of the water being returned to the aquifer. In most cases, licence conditions will require testing to ensure the provisions of the *Protection of the Environment Operations Act 1997* are met. There may also be a requirement for water quality treatment prior to reinjection, to prevent contamination of groundwater and to comply with the *NSW State Groundwater Quality Protection Policy* (NSW Government 1997) protection principles, specifically the preservation of an identified beneficial use.

In all cases, water quality shall be considered in comparison with the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000). Where the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* do not document limits for particular components, alternative criteria must be used. Other guidelines that can be applied might include the *Australian Drinking Water Guidelines* (NHMRC/NRMMC 2004) or the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999).

6.5.4 Aquifer storage and recovery

6.5.4.1 Areas of application

Aquifer storage and recovery (ASR) schemes are designed to capture water from a secondary source (such as wastewater or stormwater) and distribute it into suitably permeable aquifers for later retrieval. These groundwater management approaches are generally applied to locations where large, permeable geologic formations exist at shallow to moderate depth, and that contain water of poorer quality than the stormwater.

In the SCCG region, such proposals are only applicable to the porous rocks (i.e. sandstone aquifers), because the fractured rock environments (i.e. shale areas) are generally of too low a permeability to be considered. In areas of unconsolidated sediments, proposals to increase recharge to groundwater are not strictly aquifer storage and recovery schemes. In these areas, such activities are considered to be artificial recharge schemes and are controlled as described in Section 6.5.2.

In the SCCG region, ASR is unlikely to be successful, due largely to the geologic and hydrogeologic settings in the area. In general, the permeability of the porous rocks are too low to allow the injection of large volumes of water over very short timeframes (as would be required if stormwater is to be used). In addition, the problems of bore fouling, water quality treatment and necessarily low injection rates, generally preclude this approach as anything other than a very expensive, and ultimately impractical, water management option.

6.5.4.2 Licences and conditions

Should an ASR proposal be suggested, the requirements of state legislation and policies would need to be addressed as for an artificial recharge scheme. Licences would be required for all separate aspects of the proposal, including injection, retrieval and monitoring bores. Conditions placed on these licences would regulate the bore construction methods, environmental protection measures, monitoring requirements and reporting arrangements. In this regard, any ASR proposal would need to demonstrate that impacts would not degrade the beneficial use or other quality characteristics of the groundwater.

6.6 Groundwater resource management

6.6.1 Sustainable yield and local impacts

The management of groundwater in NSW occurs at two different levels: resource management and access management. **Resource management** deals with the determination of sustainable yield and its application to the total groundwater development allowed for an aquifer. **Access management** applies at a local scale and involves the protection of dependent ecosystems, the prevention of pumping interference and the preservation of groundwater quality.

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.

Several methods of determining the recharge to aquifers have been undertaken by DNR throughout the state. The assessment methodologies used are dependent on the type of data that is available for each groundwater system, ranging from an estimate of recharge using scientific principles to calibrated and validated numerical models. The simplest method, requiring only minimal data, is the recharge formula approach. Sustainable yield estimates derived using this method are determined according to the area of the aquifer, the long-term average annual rainfall and the amount of infiltration that is likely to contribute to groundwater.

These are broad scale estimates that apply to each individual aquifer, or GWMA, as a whole in order to allow management of licensed entitlements (Figure 6.0). They provide DNR with a ceiling value beyond which bore licences will no longer be issued within a defined groundwater system. Sustainable yield estimates are refined as more data becomes available, or when significant management issues become apparent.

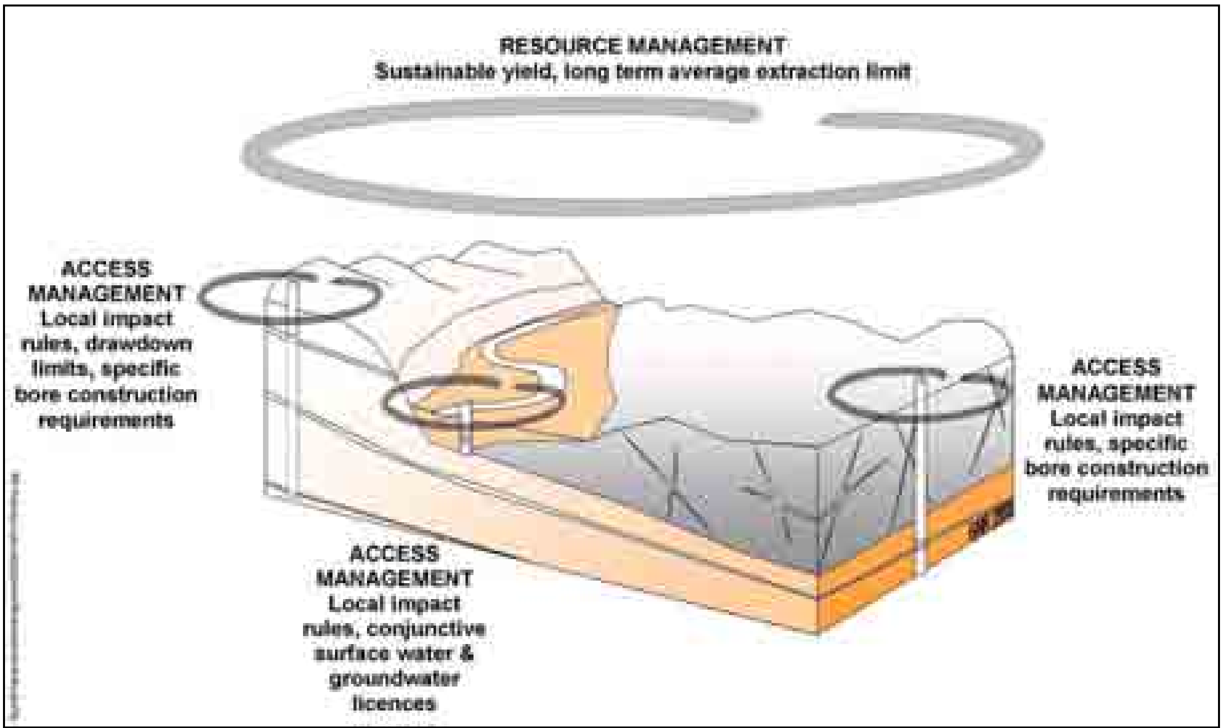

Figure 6.0 Schematic illustration of groundwater resource management components

Groundwater development usually occurs preferentially, that is, bores are installed in particular areas of aquifers that favour water supply, where groundwater is the only available source, or where land is not taken up by National Parks or other reserves. Such focussed development of the resource can lead to adverse impacts on the local scale (known as "hot spots"), even when the entitlements issued for the system are well below the sustainable yield. These **local impacts** are managed by DNR through specific rules that regulate pumping schedules, water levels and flow rates, thereby minimising impacts on surrounding users and the environment. Local impact rules may also specify particular restrictions on groundwater use in areas where significant dependent ecosystems exist, particularly if threatened or rare species have been identified. Further detail on the assessment of groundwater dependent ecosystems is provided in Chapter 8.

6.6.2 Decommissioning of bores

Abandoned groundwater works can pose a threat to a groundwater system by acting as a conduit for contaminants to reach the water table, if they are not decommissioned correctly. In order for these potential contamination sources to be managed, and so that the resource is protected, **any abandoned or disused groundwater works should be decommissioned according to the *Minimum Construction Standards for Water Bores in Australia* (LWBC 2003), or otherwise as endorsed by DNR.**

Should variation on the decommissioning procedures outlined in the *Minimum Construction Standards for Water Bores in Australia* (LWBC 2003) be proposed, it must be clearly demonstrated to DNR that:

- The alternative decommissioning methodology will provide the equivalent level of protection to groundwater resources as that indicated in the standards.

- Materials used, if different to those described in the standards, will be appropriate for the long-term protection of the resource, and will not degrade to contaminate the groundwater, or allow other contaminants entry.
- Any physical hazard posed to the public by the surface exposure of the bore will be negated by the alternative method.
- The alternative decommissioning methodology will not adversely affect hydrostatic pressures or water tables in the vicinity of the bore.

DNR is to be advised of any decommissioning procedure undertaken on an abandoned or disused groundwater work to allow completion of licensing documentation.

6.6.3 Water quality objectives

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000a) note that the guidelines reported are applicable to both surface water and groundwater. This is because the environmental values that are to be protected by the application of the guidelines generally apply to systems existing above-ground.

The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000a) provide water quality criteria appropriate for the protection of ecosystems, recreation and aesthetic values, and industrial and irrigation uses of groundwater. These guideline values are readily applied and cover many inorganic and organic contaminants.

In cases where the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ 2000a) do not provide water quality criteria relevant to a particular parameter, other guidelines are generally considered. These typically include:

- The *Australian Drinking Water Guidelines* (NHMRC/NRMMC 2004). These include a range of parameters typically encountered in raw water (from either surface water or groundwater sources) and also considerations dealing with water supply systems and chemicals used in disinfection.
- The *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999). This includes schedules dealing with soil and groundwater investigation levels, sampling, laboratory analysis, health risk assessments and investigation levels, groundwater and environmental risk assessments, exposure scenarios, community consultation and environmental auditors.
- Other state or international guidelines (e.g. WHO 1998).

Note

The criteria provided in these guidelines are to be considered as water quality objectives, and should be used in the assessment of analytical results. In areas where contamination exists, the application of these objectives is obvious in ensuring groundwater is cleaned up to a prescribed level. However, where the ambient groundwater quality is better than the objectives, their application is less apparent. **The *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* require that the ambient water quality is not allowed to degrade to the levels of the objectives in such cases**. This is also consistent with the state groundwater policy considerations regarding the preservation of beneficial uses of groundwater, and the principles of the *Guidelines for Groundwater Protection in Australia* (ARMCANZ/ANZECC, 1995).

The criteria published in the guidelines are to be applied according to the use of the groundwater, or the possible receiving environment impacts. For example, groundwater discharge to stormwater might require the application of the most stringent criteria amongst Ecosystem Protection or Recreation and Aesthetics categories, depending on the possibilities for exposure to the water. In contrast, groundwater to be reinjected might be required to meet Ecosystem Protection or Raw Water criteria.

The water quality objectives may be applied by DNR across the full extent of an aquifer, or be linked to a beneficial use category for defined areas, depending on the ambient groundwater quality. Beneficial use mapping has not been completed for the SCCG region, however it is envisaged that this may be carried out by DNR in the future as required.

6.6.4 Management of pumping impacts on quality

In areas where groundwater availability has been affected by quantity depletion or quality degradation, DNR can use its powers under the *Water Act 1912* to regulate access and use. Such powers have been utilised in response to the recent investigations into groundwater contamination of the Botany Sand Beds aquifer in the SCCG region.

Within an area of the sand beds where DNR has been advised that significant serious contamination exists, all licensed groundwater users have been issued notices under the *Water Act 1912* to cease pumping and disable their works. Unlicensed users in the area have also been advised not to use groundwater. The establishment of this “Extraction Exclusion Area” has been undertaken to prevent pumping impacts on the groundwater clean up activities being carried out by Orica under a notice issued by DEC. In addition, prevention of groundwater extraction in the exclusion area provides a measure of human health protection to landholders.

Other areas that are likely to have been affected by industrial land use activities have been regulated by DNR under an embargo. The embargo applying to the Botany Sand Beds aquifer prevents further development of the groundwater resource beyond existing levels. This was carried out to control extraction so that any potential contaminants in the groundwater would not be redistributed by widespread pumping.

Case Study
Management of access to a contaminated groundwater resource, Botany Sand Beds aquifer.

The Botany Sand Beds aquifer is an unconfined aquifer system divided into three management zones defined as the northern zone, western zone and the southern zone. The aquifer comprises highly permeable windblown sands, and water tables are generally very close to the surface, making the groundwater resource **extremely** vulnerable to contamination.

The northern zone has been identified as the most used and the most under threat of the three management zones. Groundwater in the northern zone of the aquifer supports processing for industries such as paper manufacturing, chemical and petrochemical industries, the watering of parks and other open spaces, and widespread domestic extraction. As a result of historical manufacturing activities, and poor site management practices over parts of the aquifer, there is a legacy of serious groundwater contamination.

DNR exercised powers under the *Water Act 1912* to embargo a large area in the northern zone and regulate further groundwater development. Under the embargo, no new bore licences are to be issued, however existing licensees were not affected. That is, no increase in groundwater development will be allowed within the defined area whilst the embargo is in place. As part of the process, licensed water bore drilling contractors known to operate in the area were advised by DNR of the embargo and the restrictions that applied.

In order to facilitate the clean up of the contamination originating from the Orica (formerly ICI Australia) properties, and protect users in the vicinity, an Extraction Exclusion Area has been delineated. All licensees within that area have been advised not to use the groundwater until further notice.

6.7 Recommendations

Recommendations

It is recommended that:

- Council staff and other stakeholders familiarise themselves with licensing requirements under the *Water Act 1912*.
- All groundwater works for **water supply** are to be licensed.
- Councils to encourage known or identified unlicensed users to apply for and obtain a bore licence from DNR.
- Councils to confirm with DNR what groundwater extraction **other than for water supply** requires licensing.
- Information requirements for dewatering or artificial recharge prepared by DNR be addressed by developers prior to a Development Application being lodged.

6.8 Suggested technical and further reading

1. **ANZECC, 1992**. Australian Water Quality Guidelines for Fresh and Marine Waters. Australia and New Zealand Environment and Conservation Council. National Water Quality Management Strategy Report. November. ISBN 0 642 18297 3.

2. **ANZECC / ARMCANZ, 2000a**. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. National Water Quality Management Strategy Report No 4. October. ISBN 09578245 0 5. Available on-line at: http://www.mincos.gov.au/pub_anzwq.html [accessed 9 June 2004]

3. **ANZECC / ARMCANZ, 2000b**. Australian Guidelines for Water Quality Monitoring and Reporting. Australia and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand. National Water Quality Management Strategy Report No 7. October. ISBN 0 642 19562 5. Available on-line at: http://www.mincos.gov.au/pub_agwq.html [accessed 9 June 2004]

4. **ARMCANZ, 1997**. Minimum Construction Requirements for Water Bores in Australia. Agriculture and Resource Management Council of Australia and New Zealand, July. ISBN 0 7242 7401 4. Available on-line at: http://www.dse.vic.gov.au/web/root/Domino/vro/vrosite.nsf/pages/water-access-gwater-bores [accessed 11 May 2004].

5. **ARMCANZ / ANZECC, 1995**. Guidelines for Groundwater Protection in Australia. Agriculture and Resource Management Council of Australia and New Zealand and Australia and New Zealand Environment and Conservation Council. National Water Quality Management Strategy Report No 8. September. ISBN 0 642 19558 7. Available on-line at: http://www.affa.gov.au/corporate_docs/publications/pdf/nrm/water_reform/guidelines-for-groundwater-protection.pdf [accessed 10 May 2004].

6. **Department of Infrastructure, Planning and Natural Resources, 2003**. NSW Drillers Licensing – Drillers Licence Compliance Management Guidelines (unpublished controlled document).

7. **LWBC, 2003**. Minimum Construction Requirements for Water Bores in Australia, Edition 2 - Revised September, 2003. Land and Water Biodiversity Committee, September. ISBN 1 9209 2009 9. Available on-line at: http://www.nrme.qld.gov.au/water/pdf/bore_aust/mcrwba.pdf [accessed 15 June 2004]

8. **NEPC, 1999**. National Environment Protection (Assessment of Site Contamination) Measure 1999. National Environment Protection Council, Service Corporation. ISBN 0-642-32312-7. Available on-line at: http://www.ephc.gov.au/pdf/cs/cs_measure.pdf [accessed 25 June 2004].

9. **NHMRC / ARMCANZ, 1996**. Australian Drinking Water Guidelines. National Health and Medical Research Council and Agriculture and Resource Management Council of Australia and New Zealand. National Water Quality Management Strategy Report No 6. ISBN 0 642 24462 6. Available on-line at: http://www.mincos.gov.au/pdf/nwqms/aust_drinking_water_guidelines.pdf [accessed 9 June 2004].

10. **NHMRC / NRMMC, 2004**. Australian Drinking Water Guidelines. National Health and Medical Research Council and Natural Resource Management Ministerial Council. National Water Quality Management Strategy Report No 6. ISBN 186496118X. Available on-line at: http://www7.health.gov.au/nhmrc/publications/pdf/awgfull.pdf [accessed 11 April 2005].

11. **Smith, D.I., 1998**. Water in Australia – Resources and Management. Oxford University Press, Melbourne. ISBN 0 19 553704 1.

12. **WHO, 1998**. Guidelines for safe recreational water environments: Coastal and fresh waters. Draft for Consultation. Report EOS/DRAFT/98.14. World Health Organization, Geneva. Final (2003) version available on-line at: http://whqlibdoc.who.int/publications/2003/9241545801.pdf [accessed 27 July 2004].

7.0 GROUNDWATER QUALITY AND CONTAMINATION

7.1 Introduction

Groundwater quality is naturally different from that of surface water bodies, due to the materials through which it moves and the time taken for it to migrate between recharge and discharge locations. It is often of variable salinity and acidic pH, with high concentrations of dissolved metals (particularly iron and manganese) and some measure of hardness.

This chapter is intended to summarise the typical characteristics of groundwater, identify sources and types of contaminants that can affect its suitability for use, and outline measures to protect the quality of the resource.

7.2 Objectives

Objectives

The objectives of this chapter are:

- To summarise the characteristic inorganic parameters usually found in groundwater.
- To outline the background to the development of beneficial use classifications for groundwater.
- To provide an overview on the common types of potential groundwater contaminants.
- To identify the contamination characteristics of acid sulphate soils.
- To indicate the management requirements associated with on-site wastewater disposal.
- To provide guidance on the water quality attributes that may be considered when carrying out groundwater monitoring.

7.3 Typical groundwater quality characteristics

The quality of groundwater is affected by the type of material through which it flows and the period of time over which it resides in an aquifer. The dissolved inorganic constituents of groundwater are commonly (Driscoll 1986):

- Major Components - cations (calcium, magnesium and sodium), anions (bicarbonate, sulphate and chloride), dissolved silica.
- Minor components - boron, carbonate, fluoride, iron, nitrate, potassium, strontium.
- Trace components – aluminium, arsenic, barium, beryllium, bromide, cadmium, chromium, cobalt, copper, lead, lithium, manganese, nickel, phosphate, selenium, zinc, and others.

Commonly, groundwater exhibits several characteristic quality attributes: variable salinity; low pH; dissolved metals; and a degree of hardness. This section briefly discusses the general characteristics of naturally occurring groundwater quality, and its beneficial uses, as it applies to the SCCG region. More detail on the types of contaminants that may impact on groundwater quality is provided in subsequent sections dealing with pollution from specific areas of urban environments.

7.3.1 Salinity

Salinity is usually a result of elevated concentrations of sodium and chloride, although other salts may also contribute. The salinity of groundwater is usually expressed in units of parts per million (ppm) or milligrams per litre (mg/L) of total dissolved solids (TDS). A similar measurement, electrical conductivity (EC), defines the ability of the fluid to transmit an electrical current. Values of EC are commonly reported in microSiemens per centimetre (µS/cm).

The salinity of groundwater may be modified by the presence of salts stored within rocks at the time of formation (connate salts), by those brought into an aquifer through recharge, particularly in coastal areas (cyclic salts), or by the products of rock weathering. Salinity may also be generated within coastal aquifers by the intrusion of salt water from the ocean under certain hydraulic conditions (such as induced through pumping). Similar salt water intrusion may occur where an aquifer containing saline groundwater is separated from an underlying high quality groundwater resource by a leaky aquitard. Under heavy pumping, hydrostatic pressures in the underlying aquifer are reduced and the saline water may be induced to drain downward through the aquitard.

Because the measurement of salinity can be accomplished readily by the use of hand-held meters, many drillers provide this data to DNR following completion of a bore. Whilst the frequency and accuracy of calibration of these meters may be questionable, they are generally robust and it is expected that the measurements recorded would be reasonably accurate. An error of 100 mg/L or 100 µS/cm would not be significant in most cases.

Prior to the widespread acceptance of the use of these meters by drillers, salinity was usually recorded as a descriptive term or defined within a set range. These terms and ranges were approximate definitions based primarily on taste descriptions. A rough outline of the terms and ranges is given in Table 7.0.

Table 7.0 Approximate salinity levels based on descriptive terms and ranges reported to DNR.

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 80 - 500 mg/L	"Excellent" "Good"
"Slightly salty"	"501 - 1000 ppm"	Acceptable drinking water based on taste	500 - 800 mg/L 800 - 1000 mg/L	"Fair" "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)

Salinity limits the use of groundwater by adversely affecting plants and animals, breaking down soil structure and increasing salt loads in surface runoff and subsurface flow. Levels in excess of 1,000 mg/L are unsuitable for most uses due to the corrosion of pipework, impacts on vegetation and degradation of soil properties resulting from water of that salinity.

7.3.2 pH

The measurement of pH is an indicator of the acidity or alkalinity of water. A pH value of 7 indicates neutrality, that is, the concentration of hydrogen (H^+) and hydroxide (OH^-) ions are equal. Water with pH less than 7 is said to be "acidic", whereas levels above 7 are termed "alkaline". For comparison, lemon juice (2.2 - 2.4) and vinegar (3.0) are strongly acidic, drinking water varies (6.5 - 8.0) and seawater (8.3) is alkaline (Driscoll 1986).

Groundwater most commonly occurs under reducing conditions, where the limited oxygen present is consumed by chemical and biological activity. As a result, reductions in pH occur and values less than 7 are commonly encountered.

7.3.3 Dissolved metals

In groundwater, dissolved metals are generally represented by high iron and manganese levels, particularly in areas where porous and fractured rock aquifers occur. The elevated concentrations are generated by the leaching of iron and manganese from the rock mass over extended periods of time. As the groundwater generally occurs under reducing conditions, these elements remain in soluble form and only precipitate once the water becomes oxygenated.

High iron concentrations can also occur in relation to acid sulphate soils, once disturbance occurs. These soils are generally associated with unconsolidated sediment aquifers such as alluvial systems in estuarine areas, or coastal sands. These sediments, deposited under marine or estuarine conditions, commonly contain iron sulphides (predominantly pyrite, but also small quantities of arsenopyrite) that remain in stable solid form provided reducing conditions are maintained. When allowed to oxidise, either through pumping that lowers the water table or physical disturbance, such as excavation, the pyrite breaks down to produce sulphuric acid, dissolved iron and dissolved aluminium. Some dissolved arsenic may also be produced.

7.3.4 Hardness

The hardness of groundwater predominantly results from the presence of dissolved calcium and magnesium salts, usually carbonates. Hardness is a measure of the effect of water on the ability of soap to form suds. It can cause scaling problems in pipework and heating systems due to the nature of the dissolved salts. This characteristic of groundwater is usually described in terms of "carbonate hardness" and "non-carbonate hardness".

Carbonate hardness is that generated by the combination of calcium and magnesium cations with carbonate and bicarbonate anions. This is the most common and major component of hardness. Non-carbonate hardness is the product of the combination of calcium and magnesium cations with the minor anions of sulphate, chloride and nitrate. The non-carbonate hardness can be determined by subtracting the carbonate hardness from the total hardness.

7.3.5 Typical contamination indicators

Some highly saline groundwater has been found in association with contamination. Both chloride and sodium are components of many contaminants and can increase the salt load to a groundwater resource substantially if spills or releases occur.

Extremes of pH in groundwater may also be generated by the presence of contamination or by acid sulphate soil disturbance. Commonly, contamination provides additional media for biological and chemical reactions that generate hydrogen as a by-product resulting in very low pH values. Alternatively, alkaline extremes of pH (very high values) may also occur due to the influence of contaminants.

Imbalances in the ionic content of groundwater may also be indicative of contamination. For example, elevated levels of nitrate, above the trace levels usually encountered, may suggest excessive use of fertilisers.

7.3.6 Typical groundwater quality in the SCCG region

In the SCCG region, the salinity of groundwater can vary considerably from that of near rainwater to a level that would damage plants if applied. Typical salinity values for the coastal sand aquifers are near to those for rainfall, due to the direct relationship between groundwater and that source of recharge. Groundwater in coastal sand aquifers typically has salinity levels of less than 500 mg/L.

In the porous rock aquifers, residence times are very long and the groundwater has flowed a considerable distance through the sandstone before reaching the SCCG region. As a result, the salinity of groundwater is much higher in the sandstone and may range from around 500 mg/L (in areas where local recharge may contribute fresh water) to in excess of 1,500 mg/L.

No salinity data is available for the fractured rock aquifers (Wianamatta Group shale) in the SCCG region. Further west, in the Western Sydney region, such aquifers contain groundwater with salinity levels in excess of 5,000 mg/L. In those areas, the groundwater is unusable for almost all purposes, and the elevated salinity can pose significant problems for buildings and infrastructure. The hazard posed by saline groundwater seepage from fresh and weathered shales in the Western Sydney region has been addressed by the Western Sydney Regional Organisation of Councils (WSROC). Should saline groundwater issues be of concern for those Councils in the SCCG region where Wianamatta Group shale outcrops, then advice should be sought from WSROC. The list of additional internet resources provided at the end of this Handbook can be used by Councils to seek out further information.

The other inorganic characteristics of groundwater (pH, dissolved metals and hardness) are expected to be encountered at fairly typical levels. Dissolved iron is likely to be problematic, and it is anticipated that the pH of groundwater would be slightly to moderately acidic.

7.4 Beneficial use of groundwater

The ambient quality of the groundwater in an aquifer is used by DNR to define **beneficial use** categories for the resource. Beneficial use (also called 'environmental values' in the *Guidelines for Groundwater Protection in Australia*, ARMCANZ/ANZECC 1995), is the intuitive value of the groundwater in supporting a variety of economic purposes and environmental attributes. Broadly, 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.

The beneficial use of groundwater resources is recognised within *Guidelines for Groundwater Protection in Australia* as being of different values in different areas, both between and within aquifer systems. This recognition is predominantly based on the fact that natural influences may alter groundwater quality (for example dissolution of salts from rocks of marine origin), rather than the impacts of contaminating activity. Those guidelines also allowed for the modification of the five basic classes, and the establishment of special categories, to provide specific locally focussed objectives on which to base groundwater protection approaches.

DNR previously adopted the five basic categories with the intention of linking **water quality objectives** to each class. However, it should be noted that the 'raw water for drinking water' category (ANZECC 1992) was based on guidelines that have since been superseded (ANZECC/ARMCANZ 2000a). DNR has suggested that this category be renamed 'raw water' as there is an inherent assumption that some level of treatment must be applied to make groundwater of this class suitable for most uses.

The consideration of future worth of a resource as an integral part of long-term protection inherently requires continuing improvement in groundwater quality. That is, locations where groundwater quality has been impacted due to past activity should not be considered as degraded and lacking any potential to recover. Over time, many of the contaminants commonly present in groundwater systems will be removed through natural processes, such as flushing or biodegradation. Such improvement can only be achieved with the following:

- Successful application of groundwater remediation measures (where clean up is required).
- Adequate management measures in place requiring the remove of contaminated source material (usually soils).
- Environmental controls on activities to prevent ongoing contamination.
- Exclusion of new potentially polluting activities from inappropriate locations.

Above all, where a beneficial use has been determined for a resource, land use practices with the potential to impact on groundwater quality are to be controlled. In accordance with the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000a), no impacts shall be permitted that degrade the ambient groundwater quality to the level of the water quality objectives for the beneficial use class selected.

7.5 Groundwater contamination

7.5.1 Sources of contamination

Contamination is typically categorised as pollution arising from either point or diffuse sources. **Point source** contamination derives from locations that are of limited areal extent, such as individual sites or properties, where pollution is concentrated. **Diffuse ('non-point') source** contamination is derived from contaminants at much lower concentrations than is the case for point sources, that are distributed broadly over much larger areas. Examples of point source contamination include landfills, dumps, waste disposal areas, intensive agriculture (e.g. cattle feedlots or piggeries) and cemeteries. Diffuse source contamination can arise from broad scale agricultural practices (e.g. fertiliser or pesticide use), urban runoff or the deposition of atmospheric pollutants.

7.5.2 Types of contaminants

Many contaminants are derived from industrial and commercial activities that take place in urban areas (DEP 2001). These include contaminants from both point and diffuse sources, and can range from nuisance constituents to extremely hazardous compounds. Contaminants that may be encountered in urbanised environments include:

- 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.

It is considered unlikely that all of these contaminants will be found at a given site. The occurrence and concentrations that may be found in groundwater will vary depending on:

- The vulnerability of the groundwater system.
- The location and nature of the contaminant source.
- The physical attributes of the chemicals or compounds (that determine how readily the contaminant will pass into and move with the groundwater).
- The residence time of the contaminants in the soil or groundwater.
- The hydraulic characteristics of the aquifer (which will dictate the dispersion of the pollutants once they reach the water table).

However, even in areas seemingly unaffected by contamination or pollution, groundwater quality may be impacted. A range of contaminants have been identified in groundwater from sources commonly distributed throughout urban environments (Table 7.1).

Table 7.1 Contaminants in groundwater derived from various sources common to urban environments

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

Planning guidelines (DUAP and EPA 1998), developed in support of the State Environment Planning Policy No 55 (SEPP 55), identify many contaminants associated with industrial land that can be commonly also found on residential properties.

7.5.3 Assessment of groundwater contamination

Any site in an urban environment is likely to be affected by contamination in some way, either through the soil, surface water, rainfall or groundwater. This is particularly the case in areas that were previously used for industrial activities. Localities where past site activities may not have been adequately controlled (e.g. coastal scrub reserves that were subject to illegal dumping and later rezoned as residential land) may contain many unknown types and sources of contaminants. Because of this, any proposed development should consider the potential for contamination early in the approval process. Further discussion of the importance of groundwater contamination assessment as part of the Development Application process is provided in Section 5.4.

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.

7.5.4 Automatic triggers for notifying groundwater contamination

DEC have recently completed a draft of the guideline document *Contaminated Sites: Draft Guidelines for the Assessment and Management of Groundwater Contamination* (DEC 2004). Those guidelines are currently being finalised for publication following receipt of comment from interested parties. In accordance with those draft guidelines, groundwater contamination is automatically indicated as being present where:

- Non-aqueous phase liquid (chemicals that exist in an immiscible phase when released to the environment) contaminants are identified at a site.
- Contaminants in groundwater are known, or are likely, to be migrating offsite at concentrations exceeding adopted and endorsed groundwater quality criteria (or objectives).

These instances automatically require the regulatory authority to be notified of the existence of the groundwater contamination. Where the regulatory authority has not been clearly defined, DEC should be notified in the first instance.

Later editions of this Handbook will further detail the application of the DEC Guidelines for the Assessment and Management of Groundwater Contamination once they have been applied in practice.

7.6 Acid sulphate soils

The occurrence of Acid Sulphate Soils (ASS) in coastal areas is a common phenomenon. ASS contains iron sulphides (mostly pyrites) and when they are exposed to the air they can generate large amounts of sulphuric acid. New South Wales has about 600,000 hectares of acid sulphate soils along its coastline (Naylor, et al. 1998). These soils formed naturally over the last 10,000 years, and are safe unless disturbed (i.e. excavated, drained or otherwise exposed to oxygen). When iron sulphides have been exposed to oxygen, they become very acidic (i.e. with a pH less than or equal to 4) and can contaminate groundwater.

In the past, large scale drainage of coastal flood plains for flood mitigation, urban expansion and agriculture has exposed significant areas of ASS . This disturbance has generated acidic water (through the generation of sulphuric acid) together with elevated concentrations of, typically, aluminium, iron and arsenic. The discharge of acidic ‘slugs’ of water into streams, rivers or estuaries, have resulted in major fish kills in rivers along the NSW coast.

The potential for the disturbance of ASS should be considered as part of the assessment of any proposal sited within the risk zones mapped by DNR. Areas likely to be at risk can be delineated using the acid sulphate soils risk mapping undertaken along the NSW coastline and accessible through the Natural Resource Atlas. Further detail about the mapping and its limitations is provided in Chapter 9.

7.7 Wastewater irrigation and disposal

With continuing drought conditions, many households are looking to alternatives to mains water for, in particular, garden watering. Some on-site wastewater disposal schemes have also been suggested in areas of the SCCG region serviced by sewers.

The irrigation or disposal of wastewater (either treated sewage effluent or greywater) poses a risk to both human health and the environment, if carried out without appropriate protection measures. Both the *Environment And Health Protection Guidelines, On-Site Sewage Management For Single Households* (DLG 1998) and the *Greywater Reuse In Sewered Single Domestic Premises* (NSW Health 2000) provide guidance for the protection of human health.

The *Environmental and Health Protection Guidelines, On-Site Sewage Management For Single Households* also clearly indicate the environmentally sensitive areas that are major constraints to on-site wastewater management. These include:

- Potable aquifers.
- Areas with vulnerable groundwater.
- Drinking water catchments.
- Wetlands, sand dunes, alluvial flats, sensitive vegetation.

Specific groundwater constraints on wastewater management include the distance to a groundwater work used for domestic water supply, the vulnerability of the aquifer, its associated level of protection, and the distribution of groundwater works in the surrounding area.

The *Greywater Reuse In Sewered Single Domestic Premises* guidelines indicate that the inappropriate reuse of greywater may also lead to disease episodes where shallow spearpoints are used for domestic water supply in nearby areas. **These guidelines require that greywater must be contained within the confines of the premises on which it was generated and applied**. **Irrigated greywater is not to be permitted to escape beyond the confines of the premises**, as this can cause harm to the surrounding environment (NSW Health 2000).

At a minimum, any development proposal suggesting on-site wastewater irrigation or disposal must be consistent with the guidelines and clearly demonstrate the following (NSW Health 2000):

- Prevention of public health risk.
- Protection of lands.
- Protection of surface waters.
- Protection of groundwater.
- Conservation and reuse of resources.
- Protection of community amenity.

Note

Unless treatment to meet the ambient groundwater quality is proposed, any on-site system should be considered as a potential point source of contamination and be assessed accordingly. Further, DNR considers greywater irrigation to be inconsistent with the preservation and sustainable management of resources in areas of high groundwater vulnerability, widespread groundwater use (including domestic and other purposes), and where the level of protection applied to an aquifer is significant.

In the SCCG region, the areas that are considered by DNR to be inappropriate for wastewater irrigation are the coastal sand bed deposits and alluvium. These localities are of high groundwater vulnerability, and generally have a high density of groundwater works (predominantly for domestic use). The proposed irrigation with greywater, or the on-site disposal of wastewater in these areas should not be supported by Councils.

The primary threats to groundwater and the environment occur through the physical and chemical contaminants that are entrained in wastewater. There is widespread knowledge in the community about the contaminants in sewage effluent, however the understanding of the potential contaminants in greywater is not so well known. This lack of knowledge has been highlighted in a recent survey by the Alternative Technology Association (ATA 2005). The typical contaminants in greywater are outlined in Table 7.2.

Table 7.2 Common contaminants in greywater

Source	Typical components	Hazardous or problem contaminants	Comment
Bathroom (hand basin water, shower water, bath water).	Soap, shampoo, hair dyes, toothpaste, cleaning chemicals, particulates	Thermotolerant coliforms, bacteria, viruses, selenium.	Not to be stored for later use. Good hygiene practices after application (e.g. thorough hand washing) should prevent most health impacts.
Laundry (washing machine wash water, rinse water).	Soap powders, liquids, particulates, bleaches	Sodium, phosphate, boron, surfactants, ammonia, nitrogen, suspended solids, lint, turbidity, oxygen demand, sodium hydroxide, sodium hypochlorite, sodium carbonate, sodium perborate, viruses.	Not to be stored for later use. Good hygiene practices (e.g. thorough hand washing) after application should prevent most health impacts.
Swimming pools and spas (backwash water).	Pool chemicals	Micro-organisms, oils, hair, lint, pool chemical residues, sodium hypochlorite.	Not normally used as greywater. Not recommended for use as greywater.
Kitchen (sink water, cooking water).	Detergents, cleaning agents, nutrients, particulates	Food particles, oils, fats, thermotolerant coliforms.	Not to be reused nor diverted from sewer under any circumstances.

Source: modified from NSW Health 2000, Patterson 1999

7.8 Groundwater sampling and monitoring

7.8.1 Sampling considerations

Note

Specific advice should be sought from appropriately qualified and experienced environmental consultants in selecting the sample collection, handling and analysis techniques suitable for particular sites.

7.8.1.1 Obtaining representative samples

The objective of collecting a groundwater sample is to obtain a representative analysis of groundwater quality. Collecting a groundwater sample is a complex process and should be undertaken by qualified personnel. Sampling not undertaken by appropriately qualified or experienced personnel can result in poor quality assurance and quality control, which in turn can lead to an underestimation or overestimation of the concentrations of constituents. The analytical results from testing samples that have not been properly collected or handled cannot be relied on to provide representative information about the groundwater that was sampled.

Representative sample results may not be readily achievable under certain conditions because many factors can alter the characteristics of a sample. Effects such as changes in temperature and pressure may alter the concentrations of constituents resulting in misleading results. Samples collected from any groundwater source should be kept cool in an insulated container (such as an esky) during transit from the site to the laboratory.

7.8.1.2 Constraints

In some cases, it is impractical to completely flush out a bore (as is generally required) when collecting a sample. The disposal of moderate volumes of potentially contaminated groundwater from sampling sites is a key constraint, particularly in urban areas. Alternative methods, such as “low flow” sampling, require specialised equipments and precise operation by experienced personnel to obtain representative samples.

Where groundwater contamination may be of concern, personnel undertaking the sampling should have adequate Personal Protective Equipment (PPE) such as disposable overalls, gloves and even gas masks, and be trained in its use. In certain cases there may also be specific requirements that are needed to protect the health of the general public, including pedestrian control barriers or security fencing. Good on-site hygiene is also required to prevent health impacts and avoid affecting sample results.

Decontamination between sampling sites is also critical when sampling in areas having potentially contaminated groundwater. It is usually recommended that sampling commence at the least contaminated site and then proceed to the most contaminated to minimise the potential for failure of decontamination procedures. Decontamination generally involves washing of sampling equipment with phosphate-free detergents and rinsing with deionised fresh water.

7.8.1.3 Selection of water quality parameters for testing

At a minimum, testing should be carried out for general water quality parameters:

- Cations.
- Anions.
- pH.
- EC.
- TDS.
- Inorganic components (e.g. metals, heavy metals).
- Organic compounds (e.g. petroleum-based products).
- Nutrients (e.g. nitrates).
- Microbiological organisms.

Any other contaminants suspected of being present in the groundwater (based on an appraisal of current and past land use activities in the vicinity, or from other sources of information) should also be included in the analyte list. A suggested general analytical suite that Councils could use to develop tests appropriate for sites in their Local Government Area is provided below.

Suggested general groundwater quality analytical suite

This general analytical suite is only broadly representative of commonly encountered contamination and does not account for the influences of local factors (such as local pollution sources). Because specific contaminants may occur in some areas, the analyte list included may need to be expanded to account for local environments. It may also be necessary to undertake more detailed sampling and analysis if the presence of contaminants is identified in preliminary testing. Specialist advice on the testing regime required for specific sites should be sought from suitably qualified and experienced environmental consultants.

All of the analytical results should be compared against recognised water quality criteria, guidelines or objectives to determine the significance of the concentration levels. Any results above recognised water quality criteria, guidelines or objectives should prompt follow up sampling in the first instance and more comprehensive management actions if repeated high concentrations are detected.

Physical parameters	Alkalinity, electrical conductivity (EC), pH, redox potential (Eh), total dissolved solids (TDS), total hardness
Major anions	Sulphate ($SO_4^{=}$), chloride (Cl^-), bicarbonate ($HCO_3^{=}$)
Major cations	Calcium (Ca^+), magnesium (Mg^{++}), 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.

7.8.2 Monitoring considerations

Where ongoing sampling is required to monitor changes in groundwater quality over time or to manage contamination, the requirements for representative and accurate results becomes more critical. Poor sampling or handling may be identified in anomalous results for one sample round, but may just as likely be misinterpreted as deteriorating groundwater quality. This is particularly the case where an unsound practice, such as inadequate decontamination, is repeated continually for a sampling event at several sites or over several rounds.

Monitoring should be undertaken using bores with adequate security and using documented procedures that can be repeated at every site visit. Site-specific sampling protocols should be prepared and should specify the analytes to be targeted, the sampling equipment, collection method, decontamination measures and the checks required to ensure results are comparable over time as investigations progress (quality assurance).

Note

It is not appropriate to consider once only sample collection and analysis as “monitoring”. Single tests do not account for changes in the groundwater quality associated with pumping impacts or other off-site influences.

7.9 Contaminated site investigations

Contaminated site investigations require the services of specialist environmental consultants, most of whom are members of the Australian Contaminated Land Consultants Association (ACLCA). Not all environmental consultants can conduct contaminated site investigations, so care should be taken if selecting a company from sources such as local telephone directories or the Yellow Pages. Alternative resources, such as the ACLCA website (http://www.aclca.asn.au) or the DEC website (http://www.environment.nsw.gov.au) provide contact details of consultants experienced in contaminated site work and accredited by the NSW Site Auditor Scheme, respectively.

Section 105 of the *Contaminated Land Management Act 1997* provides DEC with the powers to make or approve guidelines for purposes related to the objectives of that Act. The *National Environment Protection (Assessment of Site Contamination) Measure 1999* is one of the guidelines approved by DEC in accordance with Section 105 of the *Contaminated Land Management Act 1997*. Any contamination investigation should be consistent with the approaches described in the *National Environment Protection (Assessment of Site Contamination) Measure 1999* (NEPC 1999a) and the attached schedules. Contaminated site investigation reports should include:

- Clearly documented links to the *National Environment Protection (Assessment of Site Contamination) Measure 1999* and its schedules, together with any state guidelines appropriate to the study (e.g. NSW EPA 1994, 1999 and DEC 2004).
- Clearly identified details of the water quality criteria used, their source and application, and relevance to the site in question.

- Comprehensive information on the ambient groundwater quality in the vicinity of the site, including areas up hydraulic gradient and down hydraulic gradient, where possible.
- Documentation describing the sampling protocols, laboratory accreditation, quality assurance and quality control checks used in the assessment.
- A tabulation and map of groundwater users in the vicinity of the site that could potentially be affected by contaminated groundwater.
- Suggested methods of clean up that might be used to address the contamination in either soils or groundwater. Note that the removal of contamination is generally required to prevent the degradation of the beneficial use of groundwater in accordance with the *NSW State Groundwater Quality Protection Policy* (NSW Government 1998).
- Any other details of the contamination or site that could have a bearing on the groundwater system.

7.10 Assessment of groundwater quality for particular purposes

Because of the different water quality requirements for various end uses of groundwater, it is not possible to fully define all parameters and guidelines that must be met. This is exemplified in the change in approach from the *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 1992), which provided set criteria relevant to various beneficial uses, to that utilised in the subsequent *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000a), which provides a range of possible values. This change in approach illustrates a recognition that strict water quality criteria may not apply in every instance, and that modifying factors, both natural and human-induced, may affect the limits and degree of environmental protection.

With regard to the application of water quality criteria to groundwater to assess its suitability for an intended purpose, there are several considerations that must be addressed:

- Frequency of sampling. An understanding of the degree and speed at which groundwater quality can change in the different hydrogeological settings is necessary so that an effective water quality monitoring program can be designed.
- Potential contamination sources in the area of the bore. The requirements that might apply to a bore in an industrial area will almost certainly differ to those applied to one in a residential neighbourhood. The frequency and range of analytes tested will be dictated by the types of contaminants that might be present, and limitations on use may also become apparent.
- Ambient groundwater quality. In some areas the quality of the groundwater that can be accessed may already have been altered or degraded by natural processes (e.g. saline seepage from marine shale areas), rendering it unfit for the intended use.
- Surficial characteristics of the area of application. In many instances the application of groundwater may affect the productive capacity of the land on which it is used. This is an apparent consideration in areas where groundwater has a high salinity, but may not be recognised where individual ions may affect soil structure (e.g. sodium). The impacts of runoff from the site on neighbouring environments may also be a consideration.
- The requirements of the proposed end use. For irrigation use, the salt tolerance of vegetation species will be a primary consideration. In the case of industrial purposes, the potential for clogging, fouling and scaling may instead be the significant factor.

In order for adequate assessment of the suitability of groundwater for a particular purpose, a property-wide water balance study should be undertaken. This is generally best achieved through the commissioning of a multi-disciplinary consultancy firm (including water engineering, hydrogeological, environmental and soils staff) that can apply professional knowledge to all aspects of water movement around a site. Such a study should not only include consideration of alternatives sources of supply, but should also include possible reuse options, soil suitability for irrigation, improvements in application methods, demand reduction measures and water quality constraints. In potentially contaminated areas, consideration may also need to be given to the possibility of human and environmental health impacts associated with the use of the groundwater.

Any study should consider groundwater analyses against the water quality criteria described in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC/ARMCANZ, 2000a). The analyte list provided in Section 7.8 could be used as a first pass assessment of groundwater quality for most purposes.

Care should be taken in selecting consultants to design or conduct groundwater sampling programs or site water balances from local telephone directories or the Yellow Pages. Qualified and experienced consultants are required for such tasks so that all aspects of proposed water management measures are dealt with appropriately. The International Association of Hydrogeologists (IAH) website (http://www.iah.org.au) provides contact details of consultants experienced in hydrogeology, although not necessarily in all components of site water management.

7.11 Recommendations

Recommendations

It is recommended that:

- 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.
- Groundwater samples be collected, handled and transported to the laboratory under site-specific documented sampling protocols and in accordance with Australian Standards.
- Quality assurance and quality control checks be included in any sampling and monitoring program.
- Monitoring be undertaken using appropriately designed bores of sound construction and with adequate security to prevent tampering.
- 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.

7.12 Suggested technical and further reading

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8.0 GROUNDWATER DEPENDENT ECOSYSTEMS (GDES)

8.1 Introduction

Groundwater dependent ecosystems represent a vital yet poorly understood component of the natural environment and include communities of plants, animals or other organisms. Groundwater carries a range of dissolved nutrients and organic matter that is often essential to these ecosystems.

Ecosystems are threatened by human pressures such as the extraction of groundwater and changes in land use or management. These pressures may in turn affect the availability, quantity and quality of groundwater to dependent ecosystems (NSW Government, 2002). Hence these pressures can change the structure, function and/or composition of the ecosystem or sensitive species may be eliminated completely. The major pressures on groundwater dependent ecosystems include:

- Commercial, urban, industrial or domestic contamination.
- Changes in land use, particularly from native vegetation to agriculture or forestry.
- Salinisation.
- Activation of acid sulphate soils in coastal areas by drainage, dredging or groundwater extraction.
- Clearing of wetland or riparian vegetation and draining and filling wetlands.
- Weed infestation.
- Dewatering or water resource development related to mining activities.

The value of groundwater dependent ecosystems can be measured by their age, biodiversity (flora and fauna), as an indicator of river health, cultural significance (for indigenous Australians), recreation and tourism.

8.2 Objectives

Objectives

The objectives of this chapter are:

- To outline the importance of considering groundwater dependent ecosystems in land use planning.
- To outline the significance of different ecosystem types and the different degrees of dependence on groundwater.
- To identify listed threatened species in the SCCG region.

8.3 Types of Groundwater Dependent Ecosystem

The significance of groundwater in sustaining dependent ecosystems was first described in Australia within four categories (Hatton and Evans 1998): terrestrial vegetation, base flow in streams, aquifer and cave ecosystems, and wetlands. These were later expanded to include marine and near shore environments, and terrestrial fauna (SKM 2001).

The significance of these groundwater dependent ecosystems is:

- **Terrestrial vegetation**. Forests and woodlands often develop a permanent or seasonal dependence on groundwater, by extending deep tap roots well below the land surface to reach the water table. Conversely, where the water table is shallow and permeable soils exist, this reliance on groundwater may be significant in maintaining the diversity of species forming a particular ecological community. Any impacts on terrestrial vegetation can also affect animal species dependent on the habitat provided by plant communities for survival.
- **Base flow in streams.** The saturated base of a river or stream can afford a supply of water even after that in the surface channel has ceased to flow. Exchanges between surface water and groundwater (base flow) occur within a part of the river bed known as the 'hyporheic zone'.
- **Aquifer and cave systems.** The typical example of this category is the karst or limestone caves found in the central west areas of the state. Other, less obvious species that are dependent on groundwater include micro-organisms and minute invertebrates that exist within the saturated pore spaces of an aquifer ('hypogean' ecosystems).
- **Wetlands.** These include lowland and upland wetlands and hanging swamps. Many wetlands have developed in areas that were originally waterlogged due to the discharge of groundwater at the land surface, and have therefore progressively become reliant on continuing seepage.
- **Estuarine and near-shore marine ecosystems.** Various coastal aquatic ecosystems are included in this category, with the most apparent being mangroves and seagrasses. Evidence suggests many seagrass environments are heavily reliant on the nutrients and other constituents transported by groundwater, together with the lower salinity discharge generated from that source.
- **Terrestrial fauna.** The species assemblage reliant on groundwater dependent vegetation includes fauna that rely on the habitat formed by the plant communities. In places where critical habitat depends on groundwater for survival, the faunal assemblage associated with those environments would be impacted should any change in water supply occur to the plant community.

If the availability of groundwater is reduced by drought or over-use, or water quality within an aquifer deteriorates, it is likely that the above dependent ecosystems will come under threat. These ecosystems may include species, communities and populations recognised under the *Threatened Species Conservation Act 1995*, the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* or even the *Fisheries Management Act 1995*. These legislative instruments require that Councils, developers and community groups consider threatened species, communities and populations when development is proposed.

8.4 Degree of dependence

The dependency of ecosystems can be classified into five types (Hatton and Evans, 1998):

- **Entirely dependent**, in which slight changes in the groundwater regime about a threshold may have dire results.
- **Highly dependent** where moderate changes to the groundwater regime may have major effects on ecosystem distribution, community health or the diversity of species.
- **Proportionally dependent**, in which ecosystem characteristics vary correspondingly to changes in the groundwater regime.
- **Opportunistically dependent**, where reliance on groundwater is limited to seasonal or climatic variations (such as during the dry season or in drought) but under prolonged conditions could detrimentally affect ecosystem characteristics.
- **Not apparently dependent**, in which the likelihood is that groundwater is not a significant source of supply. In this category the lack of groundwater dependence is not definitively known, but is strongly suspected.

The changes in groundwater regime that have significant effect on dependent ecosystems include the attributes of flow (or flux), level, pressure and quality (SKM, 2001). The flow or flux attributes of the groundwater regime relate to the rate and volume at which groundwater is supplied or otherwise available to ecosystems. Level relates to the depth to water and the interrelated spatial location of discharge areas for ecosystems situated in the vicinity of unconfined aquifers. Pressure applies to ecosystems associated with confined aquifers and relates to the potentiometric head within the aquifer and the flow characteristics generated at discharge locations. Quality is an immediately apparent factor that impacts on groundwater dependent ecosystems and relates to variations in intrinsic groundwater quality and contamination of aquifers as a result of anthropogenic activity.

Such changes to groundwater attributes may have variable impact on ecosystems, largely due to the dependence of the plant and animal communities on that source of supply. It is therefore critical that the degree of dependence of an ecosystem is assessed, so that the potential impacts can be identified, and actions taken to prevent or mitigate such effects.

8.5 Threatened species

Threatened species that exist or have previously been sighted within the SCCG region are listed under the *Threatened Species Conservation Act 1995*, the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* or the *Fisheries Management Act 1995*. Some of these are endangered ecological communities, comprising a variety of plants that are unique in their combination, or contain individual species at risk of extinction, or both. Other threatened species are animals, reptiles or birds that are becoming restricted in range due to land use changes, or are migratory species reliant on particular habitats for parts of their life cycle.

The *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* provides an indication of the numbers of ecological communities, threatened and migratory species recorded by Local Government Area (Table 8.0).

Table 8.0 SCCG member Council listings under the *Environment Protection and Biodiversity Conservation Act 1999*.

LGA	Ramsar wetlands	Threatened ecological communities	Threatened species	Migratory species
Botany Bay	1	1	33	24
Hornsby	1	1	56	25
Leichhardt	1	nil	16	9
Manly	1	1	37	26
Mosman	1	nil	37	25
North Sydney	1	nil	36	26
Pittwater	1	nil	45	26
Randwick	1	1	32	26
Rockdale	1	nil	33	25
Sutherland	1	1	48	30
Sydney	1	nil	35	26
Warringah	1	nil	49	26
Waverley	1	1	33	26
Willoughby	1	nil	25	9
Woollahra	1	nil	34	26

Note: All LGAs listed as being within 10 km or in same catchment as Ramsar-listed Towra Point Nature Reserve.

Specifically, the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* identifies the following within the SCCG region (DUAP 2000):

- The Towra Point Nature Reserve as a declared Ramsar wetland (wetland of international environmental significance).
- Eastern Suburbs Banksia Scrub and Cumberland Plain Woodland as listed ecological communities.
- Migratory species under the Agreement between the Government of Australia and the Government of Japan for the Protection of Migratory Birds in Danger of Extinction and their Environment (JAMBA).
- Migratory species under the Agreement between the Government of Australia and the Government of the People's Republic of China for the Protection of Migratory Birds and their Environment (CAMBA).

Various threatened species and threatened ecological communities exist within the SCCG region that are listed under the *Threatened Species Conservation Act 1995* (Table 8.1). Aquatic reserves under the *Fisheries Management Act 1995* have also been declared within member Council areas.

Table 8.1 SCCG member Council listings under the *Fisheries Management Act 1995* and the *Threatened Species Conservation Act 1995*.

LGA	Aquatic reserve	Endangered ecological community	Other features of significance	GDE types
Botany Bay		Eastern Suburbs Banksia Scrub, Sydney Freshwater Wetlands	Botany wetlands (Eastlakes)	Wetlands, terrestrial vegetation
Hornsby		Cumberland Plain vegetation, Swamp Oak Floodplain Forest		Terrestrial vegetation
Leichhardt		Cumberland Plain vegetation		Terrestrial vegetation
Manly	Cabbage Tree Bay, North Harbour	Eastern Suburbs Banksia Scrub		Terrestrial vegetation
Mosman				Terrestrial vegetation
North Sydney				Terrestrial vegetation
Pittwater	Barranjoey Head, Narrabeen Head	Sydney Freshwater Wetlands, Swamp Oak Floodplain Forest, Pittwater Spotted Gum Forest		Wetlands, terrestrial vegetation
Randwick	Bronte-Coogee, Cape Banks	Eastern Suburbs Banksia Scrub, Sydney Freshwater Wetlands	Lachlan swamp (Centennial Park)	Wetlands, terrestrial vegetation
Rockdale		Sydney Freshwater Wetlands, Cumberland Plain vegetation, Swamp Oak Floodplain Forest, Kurnell Dune Forest	Rockdale wetlands (Scarborough Park, other reserves)	Wetlands, terrestrial vegetation
Sutherland	Towra Point, Boat Harbour, Shiprock	Sydney Freshwater Wetlands, Cumberland Plain vegetation, Swamp Oak Floodplain Forest, Kurnell Dune Forest, Sutherland Shire Littoral Rainforest	Towra Point Nature Reserve (Kurnell)	Wetlands, terrestrial vegetation
Sydney				Terrestrial vegetation
Warringah	Long Reef	Sydney Freshwater Wetlands, Swamp Oak Floodplain Forest		Wetlands, terrestrial vegetation
Waverley		Eastern Suburbs Banksia Scrub, Sydney Freshwater Wetlands		Wetlands, terrestrial vegetation
Willoughby				Terrestrial vegetation
Woollahra		Sydney Freshwater Wetlands		Wetlands, terrestrial vegetation

Threatened species listed under the *Threatened Species Conservation Act 1995* include various native plants (*Darwinia spp.*, *Acacia spp.*, *Wahlenbergia spp.*) and various fauna (Gang-gang Cockatoo, Green and Golden Bell Frog, Little Tern, Little Penguin and Koalas).

The abovementioned ecological communities and species all may have significant dependence of groundwater and should be considered as part of any development assessment. These listed threatened species and communities require a Species Impact Statement (SIS) as part of the development proposal. A Species Impact Statement is required for any activity that may have a significant effect on critical habitats or listed threatened species or communities. Information specific to any development site relating to groundwater dependent ecosystems should be clearly documented in the SIS and should consider the types of environments, the likely dependence, and potential impacts.

8.6 Desktop assessment of GDEs

The NSW Government has published a rapid assessment methodology for identifying and attributing a value to GDEs (NSW Government 2002), based on the work conducted by the Nature Conservation Council of NSW. The methodology comprises eight steps as follows:

- **Identify geographical area.** The area defined in this step can relate to an aquifer or parts thereof, or may be linked to the development of a planning instrument (i.e. the area might be delineated by an LGA or suburb boundary).
- **List GDEs present**. Ecosystems known, or considered likely, to occur in the defined area are listed. These are tabulated according to location, type of GDE, and type of groundwater system. Any information gaps should also be recorded at this stage.
- **Assess the vulnerability of GDEs**. Each ecosystem is to be assessed based on it's vulnerability to quantity depletion (i.e. over extraction), quality impacts (i.e. contamination) and other threatening factors. The degree of dependence on groundwater is to be assessed, and the nature of that dependency is to be recorded (e.g. seasonal, permanent, opportunistic).
- **Assess the value of the ecosystems.** Factors such as the ecological values of biodiversity and species assemblages should be considered. The social and economic values of the groundwater system for water supply, as a recreational or tourism component, its cultural importance or its worth in maintaining local amenity are also to be considered. Priorities for action can then be decided.
- **List management tools to be used.** Regulatory and non-regulatory tools should be identified that can be applied to the protection of the GDEs. These might include risk assessments, land use restrictions or applying special conditions to bore licences.
- **Prioritise management actions.** Cost-benefit analyses should be undertaken to establish the most effective management tools and options to protect the GDEs identified in the area.
- **Implement management actions.**
- **Review process and outcomes.**

The framework by which the rapid assessment methodology can be applied is illustrated in Figure 8.0. This methodology can be used to provide initial assessment of GDEs in a given area and could provide additional information for any SIS, where required for a development.

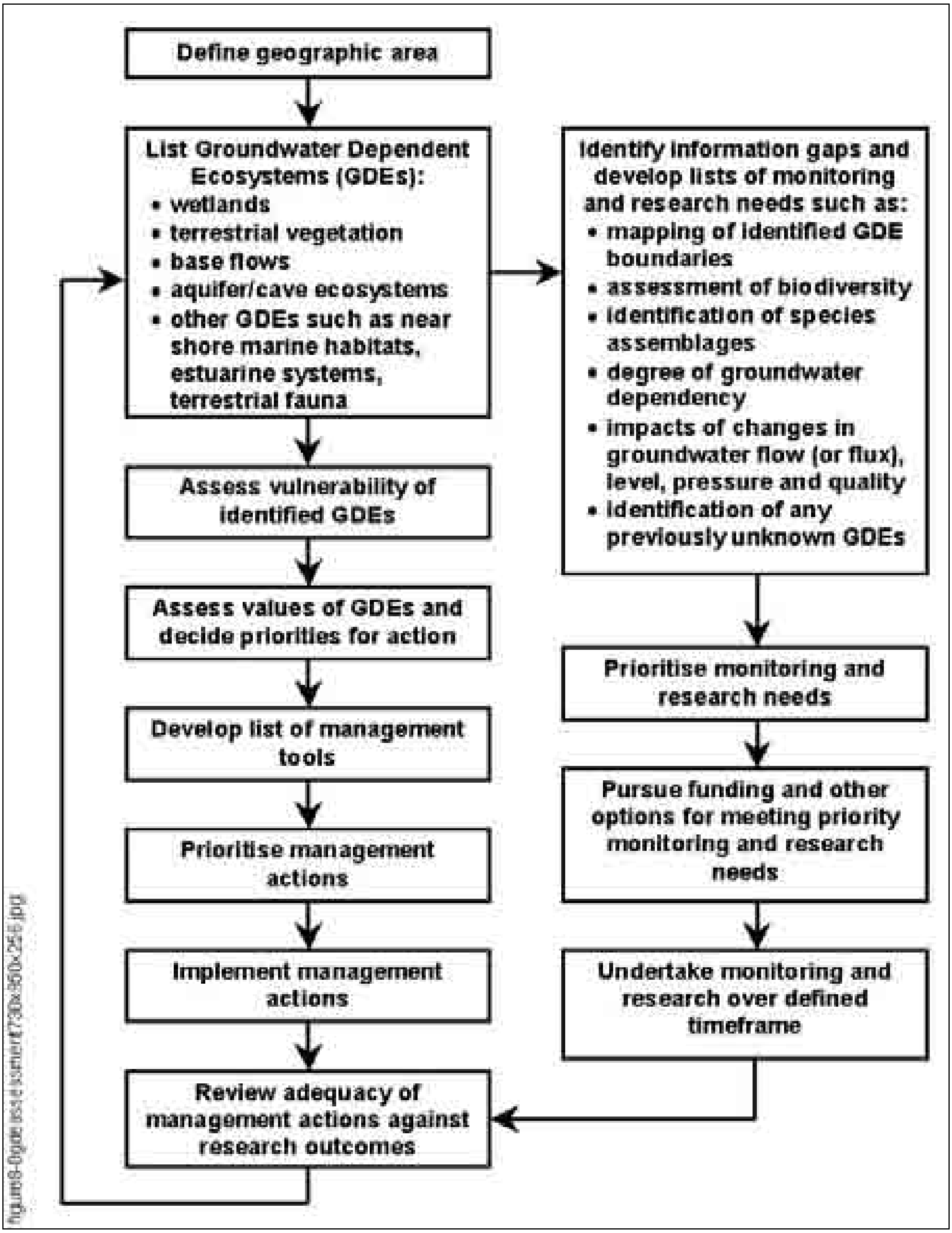

Figure 8.0 Rapid assessment methodology for identifying and valuing GDEs

8.7 Recommendations

Recommendations

It is recommended that:

- Councils adopt the GDE rapid assessment methodology as a requirement for proposed development in the vicinity of environmentally sensitive areas, including aquifers of high groundwater vulnerability.
- Councils confirm or update the range of listed threatened species under the Threatened Species Conservation Act 1995, the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 or the Fisheries Management Act 1995.
- Councils require that developers give greater consideration to the state groundwater policy documents (particularly the *NSW State Groundwater Dependent Ecosystems Policy*) when proposing a development so as to improve the level of information provided to Councils and state agencies for assessment.

8.8 Suggested technical and further reading

1. **ARMCANZ/ANZECC, 1996**. National Principles for the Provision of Water for Ecosystems. Agriculture and Resource Management Council of Australia and New Zealand and Australia and New Zealand Environment and Conservation Council. Occasional Paper No 3. Available on-line at: www.deh.gov.au/cooperation/anzecc/pubs/ecosystems.pdf [accessed 11 May 2004].

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4. **Hatton, T. and Evans, R., 1998**. Dependence of Ecosystems on Groundwater and its Significance to Australia. Land and Water Research and Development Corporation. Occasional Paper No. 12/98. ISBN 0 642 26725 1. Available on-line at: http://www.lwa.gov.au/downloads/PR980270.pdf [accessed 11 May 2004].

5. **Natural Heritage Trust, 2003**. Report on the national workshop on groundwater dependent ecosystems: policy and management. CGS Report No. 106, 16-17 June 2003, Melbourne.

6. **NSW Government, 2002**. The NSW State Groundwater Dependent Ecosystems Policy. Prepared by the New South Wales Department of Land and Water Conservation, Sydney. Report No. HO/10/00, April. ISBN 0 7347 5225 3. Available on-line at: http://www.naturalresources.nsw.gov.au/water/pdf/groundwater_dependent_ecosystem_policy_300402.pdf [accessed 30 June 2006].

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9. **SCCG, 2001**. Model DCP and Resource Folder, Protecting Sydney's Wetlands. Sydney Coastal Councils Group Inc, Sydney. Available on-line at: http://www.sydneycoastalcouncils.com.au [accessed].

9.0 HYDROGEOLOGICAL MAPPING

9.1 Introduction

Hydrogeological maps have been historically utilised to illustrate groundwater flow directions, water levels, and quality. The introduction of Geographic Information Systems (GIS) has allowed the rapid development and revision of hydrogeological maps. This, in turn, provides an opportunity for both spatial and temporal analysis of groundwater data.

Most of the pertinent aspects of groundwater systems mentioned in previous chapters can now be accessed through the Community Access to Natural Resource Information (CANRI) program internet site - the **NSW Natural Resource Atlas**. This program collates the environmental maps and data prepared by the following agencies:

- NSW Department of Natural Resources.
- NSW Department of Environment and Conservation.
- NSW Department of Lands.
- NSW Department of Primary Industries.
- NSW Department of Planning.
- Australian Museum.
- NSW Office of Information and Communications Technology.
- NSW Local Government and Shires Association.
- Murray Darling Basin Commission.
- NSW Premier’s Department.
- NSW Treasury.

This chapter describes the principles used to develop the different types of hydrogeological maps and, where available through the NSW Natural Resource Atlas, briefly describes the steps in generating them.

9.2 Objectives

Objectives

The objectives of this chapter are:

- To outline the methods used to generate the different hydrogeological maps.
- To identify the limitations of the data used.
- To provide guidance in the preparation of different hydrogeological maps through the NSW Natural Resource Atlas internet site.
- To provide a staged approach to the assessment of groundwater-related conditions in a given area.

9.3 Groundwater condition assessment process

9.3.1 Staged assessment process

In order to adequately assess proposals provided as part of a Development Application not referred to DNR through the IDAS process, Council staff need to be aware of the local groundwater conditions and the potential for adverse impacts to occur (both on the environment and on the development). The most effective and rapid approach currently available is to screen the area of a proposed development against the pertinent groundwater data maintained on statewide databases (that is, a **screening assessment**).

The SCCG has previously obtained groundwater data on CD-ROM for the member Council areas from DNR. This is of considerable value in being able to utilise GIS layers developed by member Councils in conjunction with the groundwater data provided to tailor approaches for the different hydrogeological settings.

Note

The CD-ROM data is only current for the time at which it was produced. The SCCG and member Councils will need to regularly update the information by requesting new data dumps from DNR information personnel. This should be carried out at least annually to keep track of ongoing groundwater resource development.

Following an initial screening of the area around a property, a preliminary appraisal of the Development Application can be made. Should the application not adequately address various aspects of the surrounding environment, further detail should be sought from the proponent. If a reasonable attempt has been made to assess environmental impacts according to those identified in the screening process, then a more detailed **data assessment** can be undertaken. This could involve Council staff utilising the groundwater data provided on CD-ROM to identify standing water levels, indicative salinity and the potential for any nearby users to be affected.

9.3.2 Screening assessment

The mapping capability of the NSW Natural Resource Atlas should be utilised to initially screen the locality of a proposed development. The intent of such screening should be to rapidly identify any potential groundwater constraints that may apply to the development and any significant impacts that may arise from the proposal.

The NSW Natural Resource Atlas provides four main products that can be of use in the assessment of groundwater-related issues applying to a development: an acid sulphate soil map layer, bore distribution layer, groundwater availability layer and groundwater vulnerability layer (Figure 9.0). The generation of maps from these layers, the methodology by which they were developed and the limitations of the data used are described in following sections.

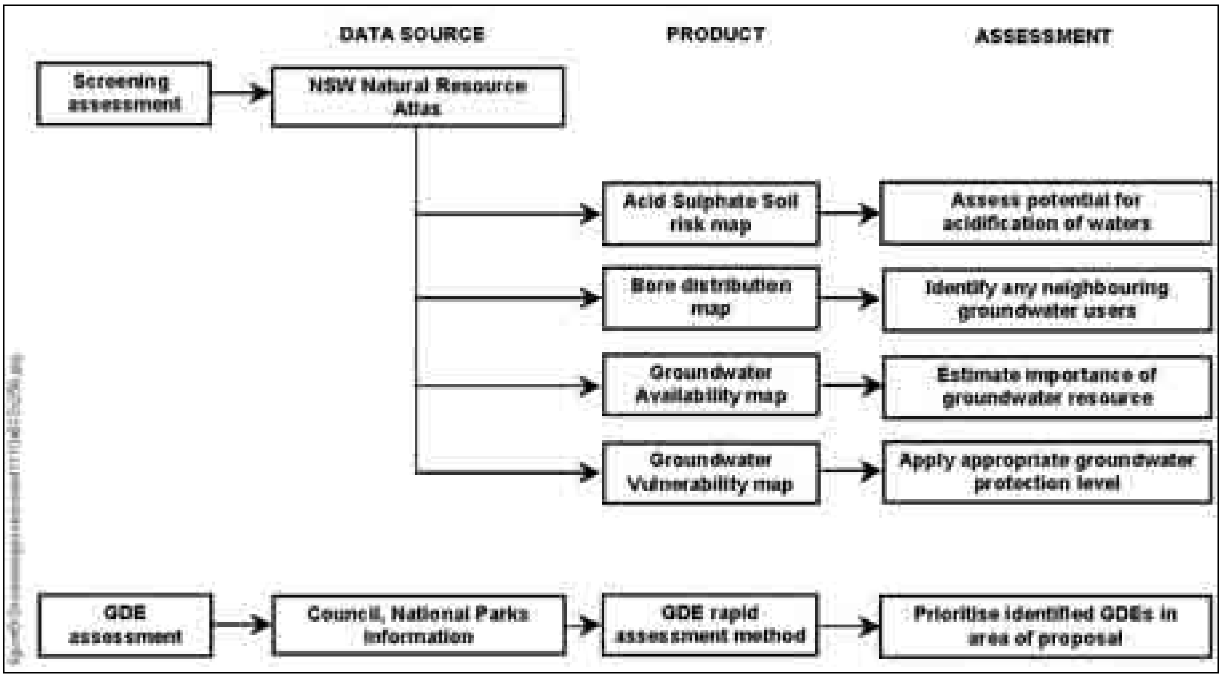

Figure 9.0 Screening assessment framework

Note that currently there is no GDE layer in the NSW Natural Resource Atlas. To accommodate the existence of GDEs in the vicinity of a proposal in the SCCG region, it is suggested that the rapid assessment methodology outlined in Section 8.6 be carried out as part of the screening process (if not already undertaken for the respective member Council LGA in which the development has been proposed).

The NSW Natural Resource Atlas is accessed as laid out below.

STEP 1. Open the Natural Resource Atlas internet site at: www.nratlas.nsw.gov.au. This opens the New South Wales Natural Resources Atlas home page, illustrating the entire state.

STEP 2a. Select a region from the state map to narrow the area of interest as illustrated below. All of the SCCG member Council LGAs fall within the "Sydney Metro" region marked on the map.

STEP 2b. Alternatively select the "Sydney Metro" option from the drop-down list.

9.3.3 Data assessment

The data assessment process should be undertaken where potential environmental impacts are identified from the screening assessment. Site-specific groundwater information provided as part of a Development Application should be compared against any local data derived from the GIS layer. Where there are significant discrepancies between the conditions reported for the site and those indicated from the CD-ROM information, DNR should be consulted for advice.

The information that can be utilised from the CD-ROM is outlined in Figure 9.1. The advantage of this data source is that it can be used to derive a localised assessment of any given proposal in a format that can be combined with other management information developed by Councils. However, as noted above, the currency of the data needs to be constantly checked and verified to confirm the existing level of groundwater development.

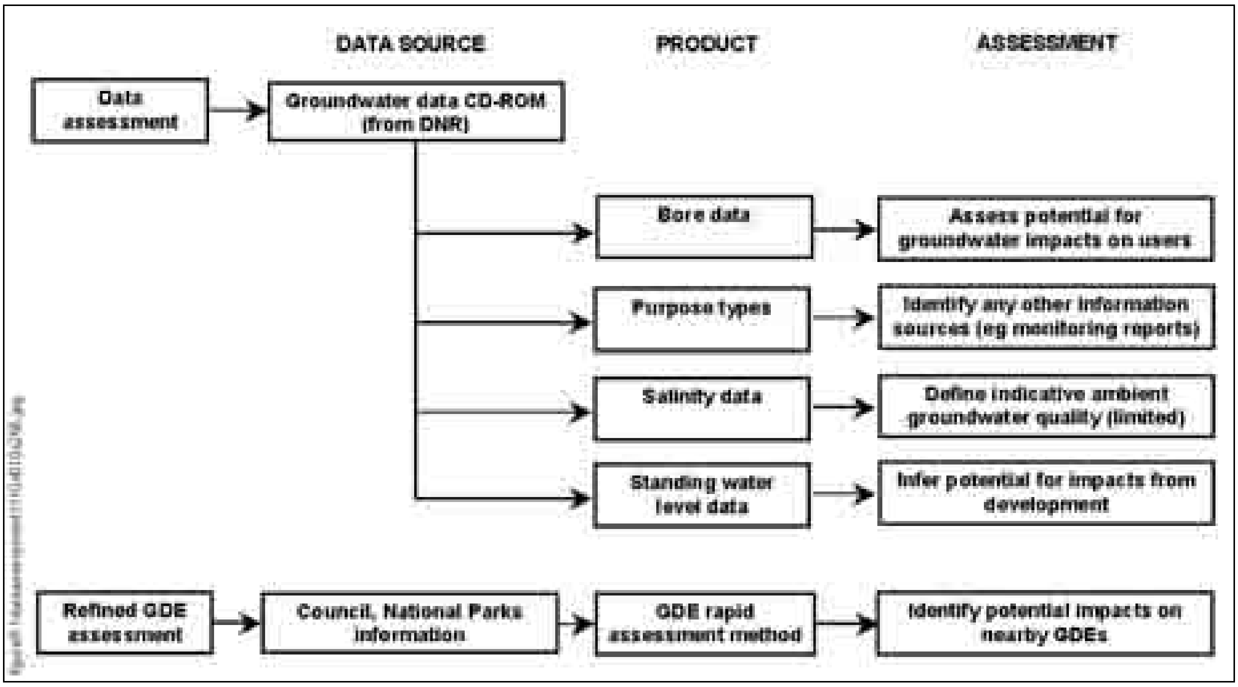

Figure 9.1 Data assessment framework

In general, the information that is of most use are the physical details, such as the bore locations, standing water level records and salinity of the groundwater. These can be used to develop a local picture of the groundwater conditions that can be compared against those reported in the Development Application documentation. The purpose types reported also may be used to assess whether additional information may be available to further understand the groundwater system. For example, a nearby site with numerous monitoring bores may have been reported on to Council previously, and those reports could be used to assess ambient groundwater quality, pollution potential and the existence of contamination in the area.

Other aspects that can also be considered are yield (used to infer the relative permeability of the aquifer), geology (can provide indicative vulnerability in areas not already mapped) and water bearing zone depth (whether the impacts of the proposed development will reach the level at which nearby users could be affected).

9.4 Acid sulphate soil risk mapping

9.4.1 Methodology

The acid sulphate soil risk maps prepared for the NSW coastal areas were developed from geomorphic principles, that is, the identification of particular landforms understood to contribute to the generation of acidic leachate. Originally, 120 hard copy maps were prepared based on the distribution of Holocene sediments along the coastline and estuarine areas. These hard copy maps were generated from a process of landform identification and interpretation of acid sulphate soil processes up to an elevation of 10 m relative to Australian Height Datum (AHD). Areas of Holocene sediments with the potential to generate acid sulphate soil conditions at elevations above 10 mAHD have not previously been identified in NSW.

First pass mapping was carried out using stereoscopic interpretation of 1:25,000 scale aerial photographs for the coastal area. Landforms up to elevations of 10 mAHD were mapped at the same scale and overlaid on the interpreted maps. One to four soil samples were then collected from selected sites where **acid sulphate soils (ASS)** or **potential acid sulphate soils (PASS)** were suspected to occur. In total, some 1,600 samples were tested for acid sulphate soil characteristics, including total actual acidity (TAA) and total potential acidity (TPA).

Four classes were distinguished based on geomorphological origins and used to develop the first edition maps. These were categorised as either High or Low Probability, and then further subdivided based on the depths at which ASS and PASS might occur. The first edition maps were constructed using very conservative assumptions about the potential for ASS to occur within the elevation limits selected. A second edition of the maps replaced the term “Probability” with “Risk”, and were modified based on improved understanding of the geomorphic conditions under which ASS might be developed. These second edition maps reduced the mapped areas in the Low Risk category, because these were found not to extend as far inland as initially assumed (Naylor, et al. 1998).

9.4.2 Data limitations

Due to the limitations of the sampling equipment, no soil samples were collected from areas above 4 mAHD elevation. The mapped areas located at elevations between 4 and 10 mAHD were classified based on scientific principles regarding geomorphological origin and the potential for remnant acid sulphate materials to exist. In areas with a paucity of information, data was transferred across from surrounding landforms with similar geomorphological settings.

The accuracy of the maps is limited to the scale at which they have been prepared. Application of these maps to define small areas at magnified scales is inappropriate and should not be used as a substitute to site-specific investigations.

9.4.3 NSW Natural Resource Atlas approach

The steps used in generating an acid sulphate soil risk map by means of the NSW Natural Resource Atlas are outlined below.

STEPS 1 and 2 outlined in previous section.

STEP 3. From the "Choose a topic" list on the right hand side of the screen, select "Land" and then "Soils map".

STEP 4. Select the "Edit" tab to remove the soil profile data and other unnecessary information layers.

STEP 5. Uncheck all layers apart from "Base map", "Major rivers", "Acid sulphate soils risk maps of Coastal NSW", and desired base features then use the "Apply" button to draw the new map.

STEP 6. Select the zoom in button in the "Map tools" list to focus the map on the area of interest.

STEP 7. Click and drag a box around the area of interest.

STEP 8. The area of interest should then be displayed. The scale and other map features should be modified if necessary to further define the locality.

9.5 Bore distribution mapping

9.5.1 Methodology

The information used to generate the bore distribution maps is extracted from the DNR databases that retain records of groundwater works and licensing details. Specifically, these databases are the Groundwater Data System (GDS) and the Licensing Administration System (LAS). The LAS database includes information relating to the property on which the groundwater work has been installed (e.g. geographic coordinates, cadastral information). The GDS database includes physical information relating to installed groundwater works (e.g. drilling depth, date of construction, water bearing zone intersections, lithologies encountered). This information is received by DNR in separate stages during the licensing process (Figure 9.2).

The collation of licensing information commences with the receipt of an application by DNR. At this stage, cadastral property details are obtained, typically including the lot number, deposited plan (DP) number, Parish name and County name.

Once the groundwater work has been installed and the 'Form A – Particulars of Completed Bore' has been received by DNR, the physical information recorded for the work is entered into the GDS. In most cases this information will include drilled depth, depths at which water bearing zones were intersected and a drillers log of the strata through which drilling occurred. In more recent works, more detailed information is usually included, such as salinity measurements, yields and development techniques.

It should be noted that the information retained on the GDS database may not necessarily reflect the actual number of works in the ground at any one time. This is because of a lag time between the issue of a licence, the installation of a work, the reporting of completion and, finally, database entry. Lag times will be extended during drought periods when licensed water bore drilling contractors are exceptionally busy, but would normally be expected to be of the order of six months.

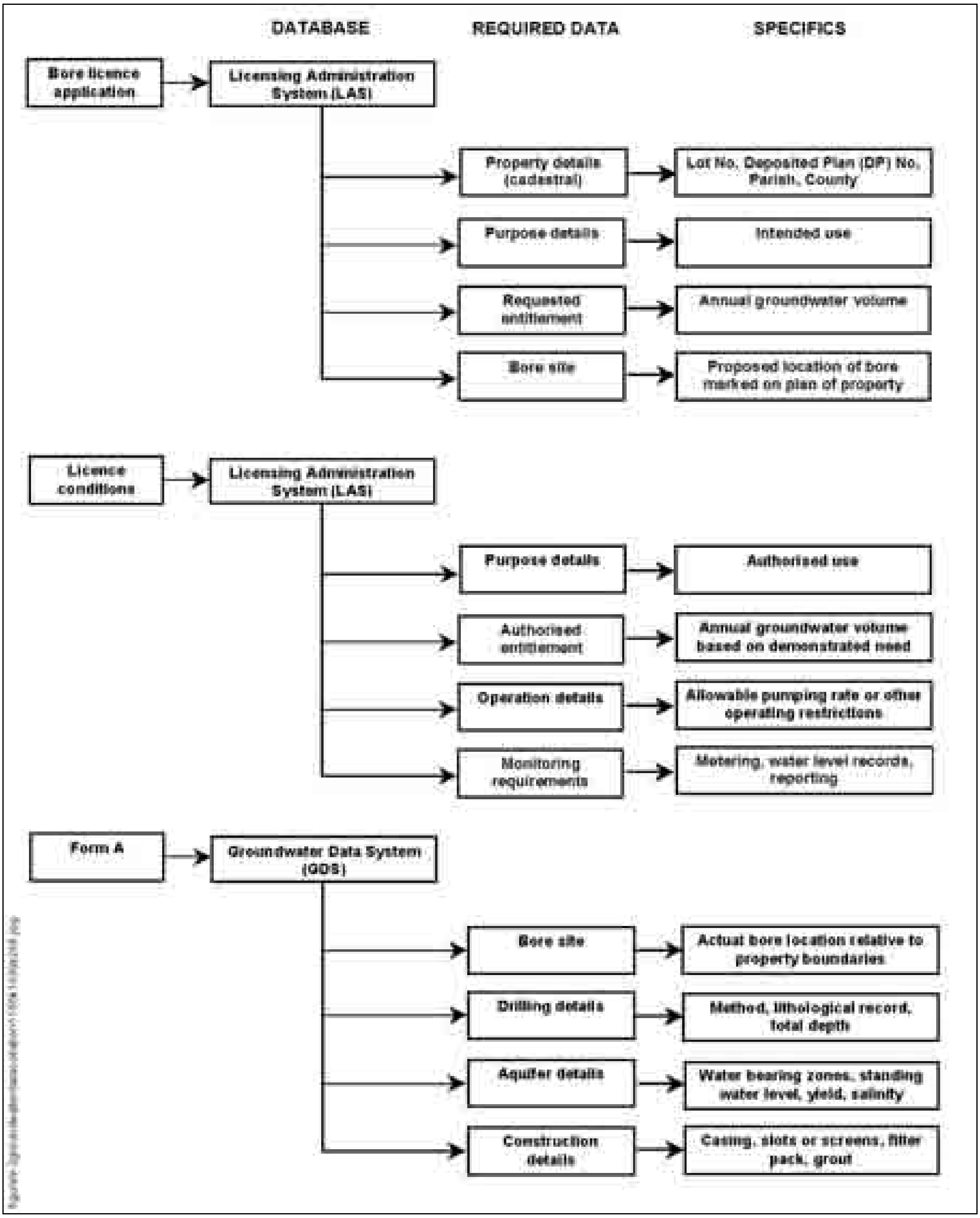

Figure 9.2 Schematic framework of data collation into the LAS and GDS databases

9.5.2 Data limitations

Every aspect of a groundwater work is specific to the location and time of completion, and does not take into account variations in hydrogeological regimes either spatially or temporally. Works identified in a region may have completion dates ranging over a period of years, often over a period of decades. Any measurements associated with the works may also be subject to changes that might have occurred in the period between the completion of one work and the installation of another nearby. Works separated by long distances may have little relevance to each other, particularly where geological changes intervene between them. Because of this, the hydrogeological information recorded for individual groundwater works should not be considered absolute.

Whilst many registered groundwater works may be depicted for a particular location, the data recorded for these installations may be minimal. Similarly, drilling undertaken before the widespread use of rotary percussion rigs may be limited to shallow or moderate depths (which was governed by the limitations of the drilling technologies available at that time). Hence, an area may have numerous registered groundwater works, but may have little physical information on which to interpret the hydrogeological setting. In addition, as individual works are generally constructed by different contractors, the data provided reflects subjective interpretation, may vary in accuracy and may be incomplete, depending on the skill and diligence of the driller in recording physical characteristics.

The lithologies recorded on completion reports vary depending on the skills of the driller in identifying rock types. In some cases, the lithologies encountered during drilling are indicated as being “rock”, “fractured rock” or “weathered rock”. These crude descriptions do not allow a full and thorough assessment of the aquifer material that has been intersected, nor does it allow correlation of these rock types across a larger area. In many respects, this renders the other data provided for that bore unusable.

The data recorded for particular works may also be limited by the depth drilled. This is particularly the case with monitoring bores that, on many occasions, do not extend below depths of 3 to 4 metres. Similarly, older works such as shallow, hand dug wells may have only reached depths to around 6 metres and descriptive information for these works may be sparse.

Other factors affect, particularly, the information available through the GDS relating to monitoring bores. The reasons for the lack of information are:

- Most monitoring bores are drilled under the supervision of an environmental scientist, hydrogeologist or geologist. These professionals take on the responsibility of recording a detailed geological log during drilling, focussed on the characteristics of lithologies that might have a bearing on contaminant distribution. Because of this, many drillers logs are not completed on the Form A (and therefore are not available through the GDS), but refer to the particular consultant’s reports that contain the detailed geological information.
- Monitoring bores are always installed for specific purposes other than water supply. The information recorded for water supply bores is usually focussed on delineating a groundwater resource, whereas monitoring bore records typically detail soil types and ground conditions. Generally, the information recorded for monitoring bores does not relate to the groundwater resource that might be expected in an area, particularly where deep aquifers are present.

9.5.3 NSW Natural Resource Atlas approach

The process for assessing the bore distribution in a particular area is as follows:

STEPS 1 and 2 outlined in previous section.

STEP 3. From the "Choose a topic" list on the right hand side of the screen, select "Inland waters" and then "Groundwater map".

STEP 4. Use the zoom in button in the "Map tools" list to focus the map on the area of interest.

STEP 5. Click and drag a box around the area of interest.

STEP 6. Select the information button in the "Map tools" list.

STEP 7. Click on a bore symbol to interrogate the database for completion details of the groundwater work.


Feature Details

Groundwater Works Summary

Figure 9.3 Typical work summary report downloaded from CANRI Natural Resource Atlas website

9.6 Groundwater availability mapping

9.6.1 Methodology

The mapping of groundwater availability as undertaken by DNR was generally focussed on the highest beneficial use aquifer in an area, regardless of the vertical location in the geological sequence in which it occurred. Where an aquifer with poor quality groundwater overlies a high quality resource, the availability mapping provides information only on the latter. The reason for this is that it simplifies complex hydrogeological settings into a single, readable information layer.

In the SCCG area, the shallow fractured rocks (shales) would be overlooked as a groundwater target on the availability maps in favour of the underlying porous rocks (sandstones). In contrast, the coastal sand bed aquifers, where they overlie deeper porous rocks (sandstones), would be mapped preferentially because they represent a resource with greater potential for use.

Groundwater availability maps provide broad categorisations of the likelihood of aquifers providing an alternative water supply option. They are divided into broad geologic settings of unconsolidated sediments, porous rocks and fractured rocks, and then further categorised according to yield and salinity data retained within the GDS database. General salinity ranges as indicated below are applied to delineate the suitability of different areas for groundwater supply (Table 9.0). A yield threshold is also applied to distinguish highly prospective areas from those with low groundwater supply potential.

Table 9.0 Groundwater availability salinity classification.

Total Dissolved Solids (TDS)	Descriptive classification	Implied suitability for use
< 500 mg/L	"fresh"	Suitable for stock, domestic and irrigation purposes as well as municipal use.
501-1500 mg/L	"marginal"	Suitable for stock, domestic and some irrigation purposes.
1501-3000 mg/L	"brackish"	Stock water, suitable for dairy cattle, beef, cattle, horses and sheep.
> 3000 mg/L	"saline"	Limited stock use.

Source: Krumins, et. al. 1998

Availability mapping relevant to the SCCG region is currently limited to that conducted for the Hawkesbury-Nepean Catchment (HNCMT and DLWC 1997a). The mapping conducted for the Hawkesbury-Nepean Catchment overlaps parts of the Local Government Areas of Hornsby, Pittwater and Warringah. Other parts of the SCCG region have not yet been mapped.

For the Hawkesbury-Nepean Catchment groundwater availability mapping, a yield threshold of 1.5 L/sec was utilised (Krumins, et al. 1998). This yield threshold is approximately equivalent to 1,200 gph or slightly over 0.1 ML/day. The resultant map identified five categories of groundwater availability: fresh, high yield (i.e. above 1.5 L/sec); fresh, low yield; marginal low yield; brackish low yield; and saline low yield.

Indicative groundwater availability classifications can be derived by considering the level of groundwater development in a particular area. In general, areas with high bore densities suggest the presence of available groundwater supplies, whereas sparsely drilled localities might indicate low availability in terms of yield, quality, or both.

9.6.2 Data limitations

The accuracy of the maps is limited to the scale at which they have been prepared. Application of these maps to define small areas at magnified scales is inappropriate and should not be used as a substitute to site-specific investigations.

Groundwater availability maps are also limited by the date of production, as they have been generated from data available at that particular time. Such data availability is restricted not only by the density of groundwater works on which an area is delineated, but also on the quality (i.e. descriptive term versus measurement) and type of information (i.e. level of completion) that was recorded. As additional information becomes available, the boundaries and accuracy of the maps could be subject to change.

9.6.3 NSW Natural Resource Atlas approach

The process for assessing groundwater availability in a particular area is as follows:

STEPS 1 and 2 outlined in previous section.

STEP 3. From the “Choose a topic” list on the right hand side of the screen, select “Inland waters” and then “Groundwater map”.

STEP 4. Select the "Edit" tab to add the groundwater availability information layer.

STEP 5. Uncheck all layers apart from the "Groundwater availability 1995-2002" and any other desired base features then use the "Apply" button to draw the new map.

STEP 6. Use the zoom in button in the "Map tools" list to focus the map on the area of interest.

STEP 7. Click and drag a box around the area of interest.

STEP 8. The area of interest should then be displayed. The scale and other map features should be modified if necessary to further define the locality.

9.7 Groundwater vulnerability mapping

9.7.1 Methodology

The concept of groundwater vulnerability was developed in the 1960s and is based on the fact that the environment provides varying degrees of groundwater protection against the infiltration of contaminants into the subsurface. This is in contrast to groundwater availability mapping, which deals with below-ground conditions, because the focus of vulnerability assessments is at the land surface. The varying protection afforded to groundwater resources is due to the changing physical features between individual areas. The spatial variability of such protection, or lack thereof, made the vulnerability concept amenable to describing pollution potential by means of maps.

Regardless of the area considered by vulnerability mapping, the significant factor is that the zones within maps represent the groundwater pollution potential relative to each other. The assigned vulnerability categories do not reflect absolute values but indicate areas of risk, allowing vulnerable aquifers to be given greater priority.

The vulnerability mapping carried out by DNR to date and with relevance to the SCCG region has been applied to the Hawkesbury-Nepean Catchment (HNCMT and DLWC 1997b). This mapping utilised the DRASTIC methodology (Aller, et al. 1987). The methodology was developed by the National Water Well Association (NWWA) and the United States Environmental Protection Agency (USEPA) as a relative evaluation tool.

DRASTIC comprises seven parameters to define hydrogeological settings, specifically: **D**epth to water, **R**echarge (in net terms), **A**quifer media, **S**oil media, **T**opography (as % slope), **I**mpact of the vadose zone and **C**onductivity (hydraulic). For the Hawkesbury-Nepean Catchment mapping, aquifer media and vadose zone impacts were considered most important, followed by hydraulic conductivity and depth to water table, then recharge and soil type and, finally, topography (Rumpf, et al. 1998). Weightings were applied to each of these attributes to reflect this hierarchy.

The value of the DRASTIC index for each individual area reflects the susceptibility of groundwater at a given location to pollution. The higher the DRASTIC index value, the greater the risk of contamination of groundwater. The assumptions inherent in the DRASTIC methodology are four-fold: firstly, that the contaminant is introduced at the ground surface; secondly, that the contaminant is flushed into the groundwater by precipitation; thirdly, that the contaminant has the mobility of water; and lastly, that the area evaluated is 100 acres (40.5 hectares) or larger.

It is important to note that groundwater vulnerability maps are designed only as a guide and do not give a precise indication of pollution potential at a particular site. Because the preparation of the maps necessarily involves the simplification of complex geological and hydrogeological situations into broad physical settings, they are not intended to replace an environmental impact assessment. Instead, these maps were intended for use as a tool by planners, developers and regulating agencies to guide the location of potentially polluting activities so as to minimise the risk to groundwater resources.

In general, the vulnerability of the different geological settings can be summarised as indicated in Table 9.1.

Table 9.1 Indicative groundwater vulnerability classification for aquifers of the SCCG region.

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

Alternative vulnerability mapping methodologies have been described (Foster, et. al. 2002, Berardinucci and Ronneseth 2002, International Association of Hydrogeologists 1994), however these are likely to generate similar results to the modified DRASTIC approach used by DNR.

9.7.2 Data limitations

The accuracy of the maps is limited to the scale at which they have been prepared. Application of these maps to define small areas at magnified scales is inappropriate and should not be used as a substitute to site-specific investigations. In addition, groundwater vulnerability maps represent the relative pollution potential for defined areas larger than the assumed size (40.5 hectares). Therefore, smaller areas within the mapped zones may be at lesser or greater risk than indicated by the vulnerability category applied (e.g. where a direct threat of contamination exists or changes in the geologic setting vary over short distances).

Groundwater vulnerability maps are also limited by the date of production, as they have been generated from data available at that particular time. The factors used in the vulnerability assessment necessarily simplify complex hydrogeological settings, thereby placing heavy reliance on the accuracy of information used. Parameters such as depth to water are derived as composite values from works records received over many years, and could be subject to error from changes occurring within intervening periods. Similarly, the parameter of hydraulic conductivity could be refined based on additional information obtained since the maps were produced.

9.7.3 NSW Natural Resource Atlas approach

The process for assessing groundwater vulnerability in a particular area is as follows:

STEPS 1 and 2 outlined in previous section.

STEP 3. From the "Choose a topic" list on the right hand side of the screen, select "Inland waters" and then "Groundwater map".

STEP 4. Select the “Edit” tab to add the groundwater vulnerability information layer.

STEP 5. Uncheck all layers apart from the “Groundwater vulnerability maps” and any other desired base features then use the “Apply” button to draw the new map.

STEP 6. Use the zoom in button in the “Map tools” list to focus the map on the area of interest.

STEP 7. Click and drag a box around the area of interest.

STEP 8. The area of interest should then be displayed. The scale and other map features should be modified if necessary to further define the locality.

The Hawkesbury-Nepean Groundwater Vulnerability Map Notes (Rumpf, et al., 1998) identify the level of groundwater assessment required of proposed developments based on the vulnerability category identified. These requirements are provided in Table 9.2.

Table 9.2 Assessment requirements based on groundwater vulnerability classification for the Hawkesbury-Nepean Catchment.

Vulnerability Classification	Groundwater Assessment Requirements
Low	**Groundwater Contamination Assessment Report** A desk study is required to identify the concerns and potential risk to groundwater or the environment and the need for any further action to be presented in the Development Application. A standard format hydrogeological report would most likely result.
Low Moderate	**Site Investigation With Monitoring** A potential risk is indicated by the vulnerability map requiring site investigation and groundwater monitoring. The extent of work should involve a limited amount of site investigation, soil and water sampling and testing, definition of flow systems and reporting, in addition to a desk study.
Moderate	**Detailed Site Investigation and Monitoring** For moderately high vulnerability areas, or where the previous levels of investigation indicate a demonstrated risk to groundwater, a detailed groundwater site investigation is required. The work should include an ongoing monitoring program, details on the protection design factors, (natural attenuation, physical barriers, etc.) in addition to the previous levels of investigation.
Moderately High	**Demonstrated Groundwater Protection System** The risk to groundwater, as demonstrated by the vulnerability map, is an area in which contamination to groundwater cannot be tolerated. The work should include a desk study, detailed site investigation, and implementation of an on-going monitoring program, as indicated above. In addition, the protection design system incorporating natural attenuation, hydraulic barriers, physical barriers etc., needs to be demonstrated, to be effective. The proposal will need to include a feasibility plan for a clean up, in addition to a detailed monitoring and ongoing assessment program.
High	**Demonstrated Remedial Action Plan/Prohibition** This classification identifies the area as having a potential risk so great as to warrant a demonstrated remedial action plan. The work should include a desk study, site investigations, ongoing monitoring, plus a demonstrated remedial action plan for clean up, which analyses the effectiveness of the remediation approach in achieving designated water quality criteria. The financial capacity of the responsible party to enact the plan should also be evaluated. In the event that the risk to groundwater is unacceptable, an activity may be banned by the responsible authority.

Source: Rumpf, et al. 1998

Councils are encouraged to apply similar groundwater assessment requirements to potentially polluting developments proposed for sites in their respective Local Government Areas.

9.8 Recommendations

Recommendations

It is recommended that:

- Council staff familiarise themselves with the NSW Natural Resource Atlas as a tool for rapid screening of groundwater conditions in the area of a proposed development.
- Councils develop GIS layers of the groundwater data provided by DNR as an overlay to allow more detailed assessment of local impacts from proposed development.
- Council staff be made aware of the limitations of data being used and the requirement in all cases of proposed development for site-specific information to be collected and reported.
- SCCG and member Councils develop standard screening procedures, in consultation with DNR, to carry out rapid assessment of proposed developments.
- Councils adopt the assessment requirements, based on groundwater vulnerability classification as applied to the Hawkesbury-Nepean Catchment, and require developers to address these as part of the Development Application process.
- Councils identify sensitive environmental areas within their LGAs and provide this information to DNR as a composite GIS layer to assist in setting "buffer zones" for groundwater management.

9.9 Suggested technical and further reading

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2. **Berardinucci, J. and Ronneseth, K., 2002**. Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater. British Columbia Ministry of Water, Land and Air Protection, June. ISBN 0-7726-4844-1. Available on-line at: http://wlapwww.gov.bc.ca/wat/reports/aquifer_maps.pdf [accessed 7 April 2005]

3. **Fedra, K., 1993**. Integrated Information Systems for water resources management. *Watercomp '93: 2nd Australian Conference on Computing for the Water Industry Today and Tomorrow*. Melbourne 30 March – 1 April, pp. 277-289.

4. **Foster, S., Hirata, R., Gomes, D., D'Elia, M. and Paris, M., 2002**. Groundwater Quality Protection - A Guide for Water Utilities, Municipal Authorities, and Environment Agencies. Report No 25071. The World Bank, Washington DC. September. ISBN 0-8213-4951-1. Available on-line at: http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/2002/12/14/000094946_02112704014826/Rendered/PDF/multi0page.pdf [accessed 16 February 2004].

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7. **International Association of Hydrogeologists, 1994**. Guidebook on Mapping Groundwater Vulnerability. Vrba, J. and Zaporozec, A. (eds). International Contributions to Hydrogeology, Volume 16. Verlag Heinz Heise GmbH, Hannover. ISBN 3 922705 97 9.

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9. **Murray, K and Rogers D., 1999**. The evaluation of groundwater vulnerability in an urban watershed. Conference Paper Water '99 Joint Congress: 25th Hydrology and Water Resources Symposium and 2nd International Conference on Water Resources and Environment Research. Brisbane, 6-8 July 1999, vol 2 pp. 877-883.

10. **Naylor, S.D., Chapman, G.A., Atkinson, G., Murphy, C.L., Tulau, M.J., Flewin, T.C., Milford, H.B., Morand, D.T., 1998**. Guidelines for the use of Acid Sulfate Soil Risk Maps – 2nd Edition. New South Wales Department of Land and Water Conservation. Sydney. ISBN 0 7347 5134 6.

11. **Reynders, A., 1994**. Protection of shallow groundwater resources by means of aquifer vulnerability mapping. Conference Paper, *Water Down Under 94* volume 1 – Groundwater/Surface Hydrology Common Interest Papers, pp. 631-636. ISBN 85825 607 X.

12. **Rumpf, C., Bradd, J. and McKibbin, D., 1998**. Hawkesbury-Nepean Catchment Groundwater Vulnerability Map, Map Notes. New South Wales Department of Land and Water Conservation. Report No CNR 97.040, December. ISBN 0 7347 5004 8.

13. **Verma, M. and Tickell, S., 1994.** Hydrogeological mapping in the Northern Territory. Conference Paper, *Water Down Under 94* volume 1 – Groundwater/Surface Hydrology Common Interest Papers, pp. 383-388. ISBN 85825 607 X.

10.0 GLOSSARY

The glossary presented here has been compiled from various sources to assist in the understanding of technical hydrogeological descriptions. The definitions provided are not rigorous, but are designed to foster the understanding of concepts amongst those untrained in the hydrogeology field. To facilitate this, similar or related topics have been grouped under one heading, and alternative names or uses are included in parentheses.

Abstraction – the process of withdrawing groundwater from an aquifer, usually by pumping.

Acidity – the concentration of free hydrogen ions in solution below pH 7 which increases in corrosivity with decreasing pH.

Aeolian – fine-grained sediments deposited following transport by wind action.

Alkalinity - the concentration of free hydrogen ions in solution above pH 7.

Alluvium - refers to particles of minerals or rock that has been transported by a river and deposited usually temporarily at points along the flood plain of a river. Alluvium is commonly composed of sands, clays and gravels.

Anion – a negatively charged ion in solution.

Annulus – the space between installed casing and the wall of the hole in which it is placed.

Aquiclude – a body of soil or rock through which virtually no groundwater can be transmitted.

Aquifer - a body of saturated rock or soil containing a system of interconnected voids from which significant (economic) quantities of groundwater may be abstracted.

Aquitard – a saturated body of soil or rock of low permeability, through which some transmission of groundwater may occur.

Archaean – an eon of geologic time (see Precambrian, see Eon).

Artesian – an aquifer with a piezometric surface at an elevation above the land surface, which allows groundwater to flow without the need for pumping.

Basalt - fine-grained dark rock of volcanic origin with high percentages of iron and magnesium.

Baseflow (Base Flow) – the part of stream discharge not attributable to direct runoff from precipitation but usually derived from the release of groundwater from storage.

Bore – a work that is constructed with a lining of tubing, usually steel or PVC, which allows the inflow of groundwater for the purposes of abstraction or monitoring.

Cainozoic – an era of geologic time extending from approximately 65 million years ago to the present and including the Tertiary and Quaternary Periods (see Era).

Cambrian – a period of geologic time between around 600 and 500 million years ago (see Period).

Carboniferous – a period of geologic time extending from around 350 to 270 million years ago. This period is commonly subdivided into Mississippian (350 to 310 million years) and Pennsylvanian (310 to 270 million years) (see Period).

Casing – the tubing installed into the ground to allow access to groundwater.

Cation – a positively charged ion in solution.

Clay - sedimentary grains having a particle size of less than 1/256 mm in diameter. It comprises a similar mineralogy to that of silt but differs in terms of plasticity. Unlike silt, clay becomes sticky when mixed with water and the particles can be moulded or rolled into forms that hold their shape. This feature is called plasticity.

Clustered Bores – a multiple bore installation comprising adjacent piezometers drilled and screened at varying depths to intersect different aquifers or aquifer levels.

Colluvium – sediment deposited at the bottom of a cliff or slope.

Confined Aquifer – an aquifer contained by an overlying, relatively impermeable layer, which induces complete saturation at greater than atmospheric pressure. Groundwater will rise to a level above the confining layer if the aquifer is penetrated.

Conglomerate – a sedimentary rock comprising cemented gravels and cobbles.

Construction dewatering (Dewatering) – the extraction of groundwater to lower the naturally occurring water table and provide an unsaturated area within which excavation and construction may proceed without significant impacts from seepage or hydrostatic pressures.

Cretaceous – a period of geologic time between approximately 135 and 65 million years ago (see Period).

Development – the removal of fine particles from the aquifer immediately surrounds a groundwater installation and the simultaneous induced compaction of filter media in the annulus around the casing. Development is commonly accomplished using airlifting, surging or jetting within the casing.

Devonian – a period of geologic time extending from approximately 400 to 350 million years ago (see Period).

Drawdown – the induced lowering of the water table or potentiometric surface by the action of abstracting groundwater from an aquifer.

Electrical Conductivity (EC) – a measure of the ability of water to conduct an electric current between immersed electrodes. The value measured relates to the nature and amount of salts present in the sample and increases with increasing concentration. Usually quoted in microSiemens per centimetre (μS/cm), EC may be approximated from the relationship: EC (μS/cm) = TDS (mg/L) / 0.68; where EC is not directly measured (see Total Dissolved Solids).

Eluvial – material resulting from the weathering of a consolidated sediment or rock that has not been transported from the site of formation.

Eocene – an epoch of geologic time between approximately 60 and 40 million years ago (see Epoch).

Eon – the largest geologic timeframe subdivided into Eras.

Epoch – the smallest subdivision of the geologic time scale applied primarily to the most recent past from around 65 million years ago to the present. Subdivisions of Periods prior to the 65 million year mark are commonly described as Upper, Middle and Lower.

Era – a geologic timeframe smaller than Eons and subdivided into Periods.

Evaporation – the loss of water from an exposed surface induced by the action of solar radiation.

Evapotranspiration – the loss of water from an area of land through the transpiration of water by plants and evaporation from the soil.

Excavation – a work of any dimension larger than about one metre in diameter which is usually unlined but is constructed to a depth that intersects groundwater.

Fluvial, Fluviatile – having originated by deposition within riverine environments (see Alluvial).

Geological Time Scale – the subdivision of millions of years of geologic time into Eras, Periods and Epochs, allowing the interpretation of stratigraphic relationships between rocks.

Gneiss/Schist – metamorphic rock comprising coarse alternating bands of quartz, mica and silicate minerals.

Granite – coarse-grained plutonic rock comprising quartz and silicate minerals of varying colour.

Gravel - In general, gravel refers to sedimentary grains having a particle size of between 2 and 4 mm. The term is applied to grains that are larger than coarse sand but finer than pebbles.

Gravel Pack, Filter Pack – graded sand or gravel placed in the annular space of a groundwater installation to protect the screens or slotted casing adjacent to selected aquifer horizons.

Groundwater (Ground Water) – water contained within the voids and spaces in rocks or soils.

Head (Hydraulic Head, Static Head) – the energy contained within a column of water resulting from elevation or pressure. The static head is the height at which the surface of a column of water could be supported against the action of atmospheric pressure.

Holocene – an epoch of recent geologic time including the last 10,000 years (see Epoch).

Hornfels – a medium or fine-grained metamorphic rock formed when magma intrudes cooler sedimentary mudstone or shale. The heat and pressure of the intrusion causes a change in composition to form this denser, harder rock.

Hydraulic Conductivity (K) - the rate of horizontal groundwater flow through a unit area (1 x 1) of an aquifer under a unit hydraulic gradient ($\delta h / \delta l = 1$). Hydraulic conductivities are reported as m/day [L/T]. Values commonly range between 0.02 and 40 m/day for unconsolidated sand aquifers, less than 0.5 m/day for sandstone, and below 0.0001 m/day for clays or shale (see Hydraulic Gradient).

Hydraulic Gradient – the slope of the water table or potentiometric surface. The hydraulic gradient is determined from the decline in groundwater level (δh) at two measuring points divided by the distance between them (δl).

Indurated – the hardening of a layer of soil through the application of heat or pressure, or by cementation.

Infiltration – the process by which water at the land surface passes into the soil and descends through the unsaturated zone.

In situ – literally “at the site”.

Jurassic – a period of geologic time extending from around 180 to 135 million years ago (see Period).

Limestone - a sedimentary rock formed by biological activity and chemical precipitation. It consists largely of calcite crystals. Most are made up of broken shells and fragments of skeletons, especially those that lived in the sea. Igneous rocks form by the cooling and solidification of magma.

Mesozoic – an era of geologic time between approximately 230 and 65 million years ago and including the Triassic, Jurassic and Cretaceous Periods (see Era).

Metasediments – all metamorphosed sedimentary rock such as slate and quartzite.

Miocene – an epoch of geologic time between approximately 25 and 12 million years ago (see Epoch).

Mudstone – Mudstone is the result of grains of clay having been deposited layer upon layer, compacted by the weight of overlying material and cemented together over millions of years to form a hard rock. They are similar to shales but lack the feature of a layered structure.

Nested Bores – a groundwater installation comprising a single large diameter hole containing multiple piezometer casings screened at varying depths to intersect different aquifers or aquifer levels. The construction of nested bores requires the accurate placement of individual filter packs and bentonite seals to isolate each of the aquifers intersected.

Observation Bore – an installation constructed for the purpose of monitoring variations in parameters such as water levels and pressure changes, usually during a pump-out test.

Ordovician – a period of geologic time extending from around 500 to 440 million years ago (see Period).

Palaeocene – an epoch of geologic time between approximately 65 and 60 million years ago (see Epoch).

Palaeochannel – an river channel or drainage line incised into an ancient land surface that has been subsequently infilled by the deposition of younger sediments.

Palaeozoic – an era of geologic time extending between around 600 and 230 million years ago and including the Cambrian, Ordovician, Silurian, Devonian, Carboniferous and Permian Periods (see Era).

Perched Aquifer (Perched Water Table) – an aquifer in which infiltrating water remains separated from an underlying main body of groundwater, with an unsaturated zone existing between the two. Usually perching occurs due to the presence of an intermediate impermeable or low permeability layer. Where the perched aquifer is unconfined, a perched water table exists.

Period – a geologic timeframe smaller than Eras and subdivided into Epochs.

Permeability – the relative ease with which a porous medium can transmit a fluid.

Permian – a period of geologic time between approximately 270 and 230 million years ago (see Period).

pH – a measure of the acidity or alkalinity of water. It is related to the free hydrogen ion concentration in solution: pH = 7 is neutral; pH < 7 acidic; pH > 7 alkaline.

Piezometer – a pipe in which the elevation of the groundwater level can be determined.

Pleistocene – a epoch of geologic time between approximately 2 million and 10,000 years ago (see Epoch).

Porosity – the percentage of a rock or soil that is represented by open voids or spaces.

Precipitation – the transfer of water from the atmosphere to the land surface, predominantly as rainfall, but also includes dews, frosts, mists, snow, sleet, hail and fog.

Production Bore – a bore from which abstraction of groundwater may take place, either through pumping or artesian flow.

Pump-out Test (Pumping Test, Test Pumping) – a test conducted in a production bore or other installation using a pump to abstract groundwater. May be used to estimate the hydraulic characteristics of the aquifer or bore. Commonly involves the use of a production bore in association with observation bores.

Quartzite – metamorphosed sandstone with a glassy appearance when fractured.

Quaternary – a period of geologic time between approximately 2 million years ago and the present (see Period).

Recharge – the addition of water, usually by infiltration, to an aquifer's saturation zone.

Recovery – the rate at which the water level in a pumped bore rises once abstraction has ceased.

Residual Drawdown – the difference between the original standing water level measured prior to pumping, and the depth to groundwater at a given instant during the recovery period following the cessation of pumping.

Rhyolite – volcanic rock of varying colour with similar composition to granite.

Salinity – the total soluble mineral (dissolved solids) content of water (see Total Dissolved Solids).

Sand – sedimentary mineral grains deposited by wind or water action having a particle size of between 1/16 and 2 mm diameter. The grains are made up of predominantly quartz and can include other minerals such as feldspars, mica, glauconite and iron oxides.

Sandstone – sedimentary rock formed predominantly from consolidated quartz sand where the grainsize is typically between 1/16 and 2 mm.

Saturated Zone – the part of a body of soil or rock in which the voids and spaces are filled with water.

Screen, Slotted Section – a section of casing, usually steel or PVC, with apertures or slots cut into the tubing to allow groundwater to flow through. Screen usually refers to machined sections with openings that can be sized appropriate to the aquifer matrix and filter pack grading.

Shale – sedimentary rock comprising consolidated silt and clay.

Silurian – a period of geologic time between approximately 440 and 400 million years ago (see Period).

Silt - Silts are sedimentary grains having a particle size of between 1/256 and 1/16 mm diameter. It is almost always deposited by water action and usually comprises finely divided particles of quartz, carbonate dust, carbon and iron pyrite minerals. Silt transmits and absorbs water but does not become sticky and is therefore considered to be non-plastic.

Siltstone - Siltstone is the result of grains of silt having been deposited layer upon layer, compacted by the weight of overlying material and cemented together over millions of years to form a hard rock.

Slate – uniformly fine-grained metamorphic rock which splits easily into smooth, lustrous plates.

Specific storage (Ss) - the amount of water absorbed or expelled from storage in a unit volume (i.e. 1 x 1 x 1) of aquifer under a unit change in hydraulic head (i.e. $\delta h = \pm 1$).

Specific yield (Sy) - the quantity of groundwater that will drain under gravity from a unit volume (i.e. 1 x 1 x 1) of an unconfined aquifer. A unit decline in hydraulic head under unconfined conditions results in both a reduction in pressure and in the saturated thickness of the aquifer. Because of this, the storativity of an unconfined aquifer is related to the specific yield (Sy), the thickness of the saturated zone (h) and the specific storage (Ss) according to the equation: $S = Sy + h\ Ss$. The product of specific storage and saturated thickness (i.e. h Ss) is generally considerably less than the value of the specific yield. Hence, for almost all unconfined aquifers, the storativity is considered to be equivalent to the specific yield (see Storage Coefficient, Specific Storage).

Standing Water Level (Static Water Level, SWL) – the depth to groundwater measured at any given time when pumping or recovery is not occurring.

Storage coefficient (Storativity; S) - the volume of groundwater that is expelled from or absorbed into storage under a unit change (i.e. $\delta h = \pm 1$) in hydraulic head over a unit area (i.e. 1 x 1) of the aquifer. The storativity of a confined aquifer is related to the specific storage (Ss) and saturated thickness (b), by the equation: $S = b\ Ss$ (see Specific Storage).

Sustainable Yield – the volume of groundwater that may be abstracted from an aquifer without detrimentally affecting existing supplies or flows to dependent environments.

Tailwater - the groundwater resulting from dewatering pumping or during development of a bore that is not intended for a water supply purpose.

Tertiary – a period of geologic time between approximately 65 and 2 million years ago (see Period).

Total Dissolved Solids (TDS) – an expression of the total soluble mineral content of water determined by either measuring the residue on evaporation or the sum of analysed chemical constituents. Usually quoted in milligrams per litre (mg/L) or the equivalent parts per million (ppm), TDS may also be approximated from electrical conductivity (EC) measurements using the conversion: EC (µS/cm) x 0.68 = TDS (mg/L) (see Electrical Conductivity).

Transmissivity (T) - the rate of horizontal groundwater flow through the full saturated thickness (b) of an aquifer across a unit width (i.e. an area of b x 1) under a unit hydraulic gradient ($\delta h / \delta l = 1$). Transmissivity may be quoted as m^3/day/m [L^3/T/L], but is more commonly expressed as m^2/day [L^2/T]. Transmissivity is related to the hydraulic conductivity of the aquifer by the equation: $T=Kb$.

Triassic – a period of geologic time extending from 230 to 180 million years ago (see Period).

Tuff – a rock formed from compacted and consolidated volcanic fragments and ash.

Unconfined Aquifer (Water Table Aquifer) – an aquifer in which the surface of the saturated zone is at atmospheric pressure.

Unsaturated Zone – the part of a body of soil or rock separating the land surface and the water table.

Watertable – the surface of a body of groundwater within an unconfined aquifer at which the pressure is atmospheric.

Well – a shallow work that is larger in diameter than a bore, but usually no greater than 1.5 m wide. Commonly, wells are less than 20 m deep and may be partially lined with concrete cylinders.

11.0 ADDITIONAL INTERNET RESOURCES

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