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# Technical report series

## Groundwater


Leading policy and reform in sustainable water management

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The NSW Office of Water is a separate office within the Department of Environment, Climate Change and Water. The Office manages the policy and regulatory frameworks for the State's surface water and groundwater resources to provide a secure and sustainable water supply for all users. The Office also supports water utilities in the provision of water and sewerage services throughout New South Wales.

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- Native vegetation
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- Soil condition
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- Capacity of natural resource managers



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# Contents

1. Introduction ..... 1
1.1 Pressure, state and response model ..... 1
1.2 Origin of targets ..... 1
2. Background ..... 3
2.1 How is groundwater managed in NSW ..... 3
2.2 Groundwater dependent ecosystems ..... 4
2.3 Groundwater management areas ..... 4
2.3.1 Inland alluvial ..... 5
2.3.2 Fractured rock ..... 5
2.3.3 Porous rock ..... 5
2.3.4 Coastal sands ..... 5
2.3.5 Coastal alluvial ..... 5
2.4 Current groundwater monitoring ..... 6
2.5 State of the catchment reporting area ..... 6
3. Assessment framework ..... 7
3.1 Assessment indicators ..... 7
3.1.2 Selection of indicators ..... 8
3.2 Expert panel ..... 9
3.2.1 Expert panel ranking of condition and pressure ..... 11
3.3 Assessment of LTAAEL versus usage condition indicator and LTAAEL versus entitlement pressure indicator ..... 13
3.3.1 Long term annual average extraction limit ..... 13
3.3.2 Condition assessment of LTAAEL versus extraction ..... 14
3.3.3 Pressure assessment of LTAAEL versus entitlement ..... 15
3.4 Trend and data confidence ..... 16
4. Pressure and condition index ..... 17
5. Discussion ..... 20
6. Recommendations ..... 23
8. References ..... 24
Appendix A – Condition and pressure assessment matrix ..... 25

## Tables

Table 1: Condition and Pressure Indicator Categories ..... 8
Table 2: Expert Panel Condition and Pressure Indicator Categories..... 10
Table 3: Description of Condition Indicators..... 10
Table 4: Description of Pressure Indicators ..... 11
Table 5: Condition rating of percentage of the LTAEL Extracted allocated ..... 15
Table 6: Pressure rating of percentage of the LTAAEL to the level of entitlement ..... 16
Table 7: Condition and Pressure rankings for the indicators ..... 17
Table 8: Weighting of the condition and pressure indicators ..... 18
Table 9: Example of GWMA pressure and condition ranking ..... 19

## Figures

Figure 1 Condition Assessment Matrix..... 12
Figure 2 Pressure Assessment Matrix ..... 12

# 1. Introduction

State of the Catchment Reports have been completed to assess the condition and pressures on 13 environmental, social and economic natural resource targets established by the NSW Natural Resource Commission and adopted as part of the NSW State Plan (NSW Government 2006). There is a report for each target for the 13 NSW Catchment Management Authority (CMA) regions. The reports are aimed at establishing a baseline for each of the targets in the 13 NSW CMA regions.

The reports will assist the CMAs and the NSW Government to target future investment and monitoring in natural resource management. The reports also provide information at a catchment scale to the 2009 NSW State of the Environment report.

This report outlines the methodology used to identify the condition and pressures on groundwater systems for the 2009 NSW State of the Catchment Report based on the target of 'By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses'. The intent of the target as defined by the Natural Resources Commission (NRC) is to 'ensure that groundwater continues to support ecosystem functioning, human health and economic activity'.

The objective of the target is to identify gaps and limitations of current monitoring programs and the effectiveness of current management actions, and enables reporting to the NSW Government and public on the condition and pressures on groundwater systems. The focus of the target is to identify if:

- groundwater is available and of a suitable quality required for ecosystems that have a dependency
- groundwater quality and availability is maintained or improved for human consumption and economic activity.

The current drought has emphasised the significance and reliance of many ecosystems, regional communities and businesses on the availability and maintenance of groundwater quality.

## 1.1 Pressure, state and response model

The State of the Catchment Reports use a pressure, state and response approach to reporting. In the field of hydrogeology the term pressure is also a technical term which refers to groundwater pressure. This is not the meaning implied throughout this report.

In this report 'pressure' refers to the factors that are impacting on the groundwater system. The condition (state) assessment is a review of the current status of the groundwater system. The response enables the identification of actions and activities being undertaken to improve the groundwater system. The response is a combined response for the 13 targets for each State of the Catchment region.

## 1.2 Origin of targets

In November 2006, the NSW State Plan was released to guide the future direction for the State over the following 10 years. It identifies priorities for government action that will help achieve the goals identified (NSW Government 2006).

The NSW State Plan has five target areas, one being Environment for Living. A priority under this target is better outcomes for native vegetation, biodiversity, land, rivers, and coastal waterways. This is being assessed against 13 environmental, social and economic targets. These targets were identified by the NRC (NSW Government 2006).

The NRC has been specifically tasked with reporting on the 13 state-wide targets. The intent of the targets is to provide a common focus and guide to investment. They are intended to provide a clear, consistent focus for all natural resource managers and help to make the most of available resources (NSW Government 2006).

The groundwater target and the associated reporting of progress assist in the identification of gaps and limitations of current monitoring programs, the effectiveness of current management actions and enables reporting to the NSW Government and public on the condition and pressures on groundwater systems.

# 2. Background

This report outlines the methodology used to identify the condition and pressures on groundwater systems for the 2009 NSW State of the Catchment Report based on the target of 'By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses'.

The objective of the target is to identify gaps and limitations of current monitoring programs and the effectiveness of current management actions, and enables reporting to the NSW Government and public on the condition and pressures on groundwater systems. The focus of the target is identifying if:

- groundwater is available and of a suitable quality required for ecosystems that have a dependency
- groundwater quality and availability is maintained or improved for human consumption and economic activity.

The current drought has emphasised the significance and reliance of many ecosystems, regional communities and businesses on the availability and maintenance of groundwater quality.

## 2.1 How is groundwater managed in NSW

The management of groundwater in NSW is legislated under the *Water Act 1912* and the Water *Management Act 2000*. The protection of groundwater from contamination is handled by legislation such as the *Contaminated Land Management Act 1997* and *Protection of Environment Operations Act 1997*.

The use and management of groundwater resources in the State are also governed by a number of State Policies including:

- NSW State Groundwater Policy Framework Document (DLWC 1997)
- NSW State Groundwater Dependent Ecosystem Policy (DLWC 2002)
- NSW Groundwater Quality Protection Policy (DLWC 1998)

There is currently a transitional phase between the implementation of the *Water Management Act 2000* from the *Water Act 1912*. The *Water Management Act 2000* requires the implementation of a groundwater sharing plan for a groundwater management area. *The Water Management Act 2000* should be fully implemented inland by 2011 and shortly after for the coastal water sources

A groundwater sharing plan establishes the rules for the sustainable sharing of the resource between the environment and users, in that order. Groundwater sharing plans have been implemented for a number of groundwater management areas (GWMA) where they were identified as being over-allocated or of high environmental significance. The classification of GWMAs is outlined in section 2.3.

Implementation of these plans commenced in 2003. By 2011 all GWMAs within the Murray-Darling Basin will have a groundwater sharing plan. Water sharing plans (WSPs) for the coastal areas will be completed post 2011.

The implementation of the WSPs ensures the sustainable management of groundwater use in NSW and assists in achieving objectives of the Intergovernmental Agreement on a National Water Initiative (2004) and the Murray-Darling Basin Plan as defined in the *Commonwealth Water Act 2007*, which is currently being prepared.

## 2.2 Groundwater dependent ecosystems

A groundwater dependent ecosystem (GDE) is an ecosystem that has a dependency on groundwater. A GDE could be a wetland, vegetation, mound spring, river base flow, cave ecosystems, playa lakes, saline discharge, springs, mangroves, river pools, billabongs or hanging swamps. There are six categories of GDEs (Hatton and Evans 1998):

- Terrestrial vegetation
- Wetlands
- River base flow
- Aquifer
- Cave ecosystems
- Estuarine and near shore marine systems

The dependency of an ecosystem will range from complete reliance to partial reliance during periods of the year or during drought periods.

The attributes that a dependent ecosystem may be reliant upon, could be flow rate, availability or water quality. The response of an ecosystem to changes to these attributes will be variable and dependent on the ecosystem. There may be minimum water quality or groundwater level requirements, such as for stream base flow. An ecosystem may be able to adapt to changes in these attributes if there is a gradual change, such as the ability for vegetation to develop deeper root systems to source groundwater, when the groundwater level has declined either by drought or groundwater use. However, many will be unable to adapt due to very narrow habitat requirements.

In NSW, the protection of GDEs is guided by the NSW State Groundwater Dependent Ecosystem Policy (DLWC 2002). GDEs are also protected under the *Water Act 1912* by ensuring that appropriate licence conditions on developments prevent adverse impacts on any know GDEs. Under the *Water Management Act 2000*, high priority GDEs are identified in the water sharing plans, and various rules in the plans ensure their protection from groundwater extraction.

## 2.3 Groundwater management areas

Groundwater resources in NSW are managed by GWMAs. The GWMAs can be classified into five broad geological provinces:

- Inland alluvial
- Fractured rock
- Porous rock
- Coastal sands
- Coastal alluvial

At the time the NSW State of the Catchment Reports were being developed there were 94 GWMAs. The identification of individual GWMAs within each geological province is based on physical characteristics which separate the various aquifer systems, such as topography, hydraulic conductivity, connectivity and water quality. They are also based on social features, such as level of entitlement or development. The following section broadly describes the characteristics of the five geological provinces on which all of the GWMAs are based.

### 2.3.1 Inland alluvial

The inland alluvial aquifer province comprises large areas of unconsolidated sands, gravels, cobbles and clay. In the catchments of the Murray, Murrumbidgee and Lachlan Rivers, the main aquifers are located in Murray Basin – a geological unit. They consist of three main aquifers, being the Shepparton Formation, Calivil Formation and Renmark Group. The shallowest is the Holocene aged Shepparton Formation and consists mainly of clay with palaeo-channel fills of sands and gravels. The Pliocene aged Calivil Formation and Renmark Group consist mainly of unconsolidated sands, gravels and cobbles.

The smaller mid-valley alluvial aquifer systems in the Murray, Murrumbidgee, and Lachlan River valleys, and the alluvial aquifer systems in the Macquarie, Namoi and Gwydir River valleys consist of alluvial deposits of sands, gravels, cobbles and clay of Holocene and Pliocene age.

By volume, the largest extraction of groundwater in the State occurs from the inland alluvial GWMAs. The high extraction from these GWMAs is associated with the large storage capacity of these systems and their permeability, which ensures a ready delivery of groundwater for extraction. The long term use of these alluvial aquifer provinces is restricted by the annual average recharge to these groundwater systems, rather than the volume that can be extracted.

The pressures on these systems are mining, urban development, local and major utility usage, and groundwater use either throughout the GWMA or in localised areas. These pressures are impacting on the availability of water for users and GDEs to be found within or associated with the systems.

### 2.3.2 Fractured rock

The fractured rock provinces consist of hard rock geological units. Water from these systems is mainly derived from the fractures, joints and bedding planes within the rock matrix. The associated rock types are generally Palaeozoic in age and of a considerable range of compositions, except for the areas where there are Tertiary aged basalts.

Water extracted from these aquifers is generally suitable for stock and domestic purposes, mining, industry and occasionally small sized irrigation developments that require low daily irrigation volumes, e.g. various types of horticulture and viticulture.

### 2.3.3 Porous rock

The porous rock provinces consist of sandstone, siltstone and shale geological units. Water in these geological provinces is derived from the pores, fractures, joints and bedding planes within the rock matrix.

### 2.3.4 Coastal sands

The coastal sands province consists of the unconsolidated coastal sands and dunes. These systems exist along the coast, forming the boundary between the ocean and consolidated rock groundwater systems. They are also closely related to tidally-influenced estuaries and lakes. Groundwater from these systems is sourced from the primary porosity between the unconsolidated sand grains.

### 2.3.5 Coastal alluvial

The coastal alluvial aquifers consist of the unconsolidated sands, gravels, cobbles and clay associated with the alluvial valleys of the major coastal river systems, such as the Hunter, Richmond, Clarence and Manning Rivers, and others. Essentially these systems are associated with the estuarine reach of major river systems.

## 2.4 Current groundwater monitoring

The monitoring of groundwater resources in the State consists of:

- state groundwater level monitoring network of about 3600 bores
- groundwater use monitoring.

The groundwater level monitoring network is concentrated in areas of groundwater use mainly in the inland alluvial aquifer province and in areas of known GDEs. The monitoring network is currently being expanded in the coastal areas to monitor groundwater use and water levels in the vicinity of known GDEs.

Groundwater use monitoring occurs mainly in the inland alluvial aquifer province within the Murray-Darling Basin. Presently, metering of use on the coast is mainly of the local and major water utilities.

The NSW Office of Water with support from the National Water Commission and the Bureau of Meteorology is undertaking a number of projects to improve the level of groundwater level monitoring and knowledge of groundwater systems. The Bureau of Meteorology is providing support in the following areas:

- installaing telemetred time series groundwater level loggers
- surveying the existing monitoring network
- maintaining the existing monitoring network
- collating various data set into the Groundwater Database System (GDS). The State groundwater bore and groundwater level database.
- The auditing of existing data within the GDS.

The National Water Commission is providing support to improve knowledge in the following areas:

- the relationship between surface water and groundwater systems
- methods for monitoring groundwater quality change caused by mixing of water from different aquifers from groundwater used in the inland alluvial aquifer provinces.

## 2.5 State of the catchment reporting area

The State of the Catchment Reports are based on the 13 CMA regions. The assessment of the groundwater target is based on the GWMAs in each CMA region. The GWMAs are the smallest management unit by which groundwater is assessed in NSW. At the time the State of the Catchment Reports were being developed there were 94 GWMA. The GWMAs within each State of the Catchment Report region can be found in Appendix 1.

# 3. Assessment framework

Groundwater resources in NSW are managed by GWMAs as identified in section 2.3. The assessment of the target for each State of the Catchment region therefore was based on the GWMAs.

The data required for establishing a baseline and for measuring a change in the condition and pressure in relation to the target is broader than the current groundwater data collected for groundwater level and use monitoring. Current groundwater data collection is focussed on groundwater levels from about 3600 sites and metering of groundwater extraction which is concentrated in the inland alluvial aquifer provinces to monitor the influence of groundwater use on water table levels, potentiometric heads and groundwater/surface water interaction. There is limited monitoring of groundwater levels in the vicinity of GDEs and no ongoing monitoring of the condition of GDEs.

An analysis of the groundwater levels at a GWMA scale would identify the areas of influence of groundwater extraction where there is sufficient groundwater monitoring network coverage. The State monitoring network has a suitable coverage of the inland alluvial aquifer provinces to identify the influence of groundwater extraction. However, the monitoring network in the fractured rock, porous rock, coastal sands and coastal alluvial aquifer provinces is insufficient to be able to effectively monitor these areas. In the fractured rock and porous rock aquifer provinces the heterogeneous characteristics of the aquifer systems and the general dispersed distribution of the licensed groundwater extraction also influences the ability to effective monitor groundwater level variations.

The difficulty with the analysis of groundwater levels is that different impacts occur on a temporal as well as a spatial scale. The analysis of groundwater levels in isolation from factors such as landscape, groundwater extraction, aquifer characteristics and connectivity with river systems would influence the assessment. Assessments of groundwater are ‘snapshots in time’ and groundwater systems typically respond slowly, but unquestionably, to imposed changes including land use variation, intensification and native vegetation clearing, change of crop type or pattern, grazing, urbanisation, and climate effects

A key aspect of the target is the ability of groundwater systems to support GDEs. A number of GDEs have been identified across the State using a desk top based methodology outlined in Dependent Ecosystems Assessment, Registration and Scheduling of High Priority Manual 2006

The current identified GDEs have been shown in the State of the Catchment Reports and they are also included in the individual water sharing plans were they have been identified as existing at the time of implementation of the plan. There has been no field verification of the identified GDEs, assessment of monitoring of their condition. This limits the ability to measure if there has been a change in the condition of the GDEs for reporting against the target.

## 3.1 Assessment indicators

The target is ‘By 2015 there is an improvement in the ability of groundwater systems to support groundwater dependent ecosystems and designated beneficial uses’.

The objective of the target is to identify gaps and limitations of current monitoring programs and the effectiveness of current management actions, and enables reporting to the NSW Government and public on the condition and pressures on groundwater systems. The focus of the target is identifying if:

- groundwater is available and of a suitable quality required for ecosystems that have a dependency
- groundwater quality and availability is maintained or improved for human consumption and economic activity.

The current drought has emphasised the significance and reliance of many ecosystems, regional communities and businesses on the availability and maintenance of groundwater quality.

The ability to measure the target condition requires indicators that addressed the objectives of the target. It was considered that the main factors that indicators for the target should address are:

- the need to identify the current condition and pressures on GDEs
- the availability and quality of water for human consumption and economic activity
- the influence of land use change on recharge to groundwater systems
- the hydrological condition of aquifer systems.

To be able to identify the current condition and pressures for the target in each State of the Catchment region a combination of an expert panel methodology and available information was used. Seven condition and seven pressure indicator categories were selected (Table 1), based on the main factors that needed to address for the target.

**Table 1: Condition and rressure indicator categories**

| Condition indicator categories | Pressure indicator categories |
|---|---|
| • GDE condition | • GDE groundwater availability |
| • Landscape condition | • Land use pressures |
| • Regional groundwater levels | • Regional impacts |
| • Local groundwater levels | • Localised impacts |
| • Groundwater quality | • Groundwater quality impacts |
| • Aquifer integrity | • Aquifer structure pressures |
| • Long term annual average extraction limit (LTAAEL) versus use | • Long term annual average extraction limit (LTAAEL) versus entitlement |

### 3.1.2 Selection of indicators

The indicator categories for condition and pressure were selected to identify the impacts and condition of groundwater system to be able to support groundwater dependent ecosystems and designated beneficial uses. The following outlines the limitations and the selection of the indicators.

There is limited information available on the location, dependency and condition of GDEs. An additional level of complication for GDEs is determining the level of groundwater dependence and if the change in condition is associated with groundwater availability, quality or other factors. The objective of the indicator is to identify if the known or suspected dependent ecosystems were under pressure and if it was believed that this pressure was causing a change in the condition of the dependent ecosystem.

Land use has the ability to alter the volume of water that is recharging an aquifer system, which in some circumstances can impact on the landscape when groundwater levels either significantly increase or decline. The general long lag time of response of groundwater systems to land use change meant that this question was framed as being pre-European settlement.

The potential land use factors that may influence groundwater recharge are:

- clearing native vegetation and replacing it with a land use that increases recharge, such as irrigation, or decreases or increases it such as urbanisation and change of cropping
- changing the land use to agro-forestry which has the potential to reduce runoff and groundwater recharge
- using a natural groundwater discharge area as a water storage, potentially causing an alteration to the regional groundwater flow direction and groundwater protection levels in the vicinity of the activity.

There has been significant change in the landscape since European settlement. However, the impact on groundwater systems generally is not significant except where there has been significant development of the groundwater resource. The intent of this indicator was to identify GWMAs where land use change may be placing pressure on groundwater systems and the associated landscape and the condition of the groundwater system and landscape from those pressures.

Groundwater extraction can cause impacts on groundwater systems at a regional and localised scale. The intent of these indicators is to identify where there may be regional or localised groundwater level impacts caused by groundwater extraction and the significance of the impact.

Groundwater quality can be influenced by a number of sources including

- Contamination from dispersed or discrete sources.
- Groundwater use by inducing the migration of water of a lower quality and induce mixing in the aquifer being used, or by water and rock interactions in some aquifer systems.
- Groundwater use can cause a decline in groundwater levels and expose acid sulphate and cause the acidification of groundwater.
- The excessive extraction of groundwater from a coastal sands aquifer may cause a change in the seawater and groundwater interface. The over extraction of groundwater may cause the up-welling of underlying saline water, reducing the productivity of the fresh groundwater aquifer.

The objective of the groundwater quality indicators was to identify where there may be potential impacts on groundwater quality.

Dewatering of confined alluvial aquifers also has the potential to cause aquifer compaction. Depressurisation of the aquifer system may cause movement of the aquifer particles and a reduction in the pore space, which may result in compaction of the aquifer system and subsidence on the surface. The objective of the aquifer integrity indicators is to identify if there is any impact on groundwater system from aquifer integrity and the condition of the structure of groundwater systems.

One of the most direct sources of stress and effect on the condition of aquifer systems is groundwater extraction. The sustainable management of groundwater extraction requires knowing the sustainable level of extraction. This is based on the amount of recharge to aquifer systems, with a portion assigned for use by the environment with the remaining made available for groundwater users. In NSW the sustainable level of extraction is known as the long term annual average extraction limit (LTAAEL). The objective of the indicators relating use and entitlement to LTAAEL is to identify the level of development and potential impact from groundwater extraction in the GWMAs.

## 3.2 Expert panel

An expert panel methodology was applied to assess six of the condition and six of the pressure indicator categories (Table 2)

**Table 2: Expert panel condition and pressure indicator categories**

| Condition indicator categories | Pressure indicator categories |
|---|---|
| • GDE condition | • GDE groundwater availability |
| • Landscape condition | • Land use pressures |
| • Regional groundwater levels | • Regional impacts |
| • Local groundwater levels | • Localised impacts |
| • Groundwater quality | • Groundwater quality impacts |
| • Aquifer integrity | • Aquifer structure pressures |

This approach was taken because the data required for establishing a baseline and for measuring a change in the condition and pressure in relation to the target is broader than the current groundwater data collected, as identified in section 3.0. The condition and pressure indicator categories are described respectively in Table 3 and Table 4. Each indicator category had a number of indicators to enable the assessment of the category (Appendix A).

**Table 3: Description of condition indicators**

| Indicator category | Description |
|---|---|
| **GDE condition** | The condition of GDEs in the region, in terms of their access to the amount and quality of groundwater they require. |
| **Landscape condition** | The condition of the wider landscape in terms of potential changes caused by land use to groundwater quality and the volume of water available for recharging the aquifer. Increased recharge causes groundwater levels to rise, which can impact the productivity of agriculture and the condition of urban infrastructure. Taken together, these measures can be used to make an assessment of landscape condition. |
| **Regional groundwater levels** | Changes in regional groundwater levels from the influence of extraction. Where groundwater levels are not monitored, changes in the duration of pumping time that groundwater is available for basic landholder access and for other licensed uses can be used as a surrogate. |
| **Local groundwater levels** | Change in local groundwater levels from the influence of extraction. |
| **Groundwater quality** | Groundwater quality, as measured by the following:<br>• groundwater acidity<br>• groundwater salinity<br>• nutrient concentrations<br>• contamination from heavy metals and hydrocarbons<br>• changes in beneficial use category (resulting from groundwater quality changes)<br>• freshwater/salt water interface (indicated by electrical conductivity). |
| **Aquifer integrity** | The integrity of the aquifer matrix, which can be affected by dewatering and compaction with consequent ground subsidence or upsidence or by various land use activities. |

**Table 4: Description of pressure indicators**

| Indicator category | Description |
|---|---|
| **GDE groundwater availability** | The pressure on GDEs from long term and seasonal changes in groundwater levels, including the influence of changes in groundwater levels in highly connected systems. |
| **Land use pressures** | The pressure of land use on aquifer systems. The indicator also identifies the pressure that shallow groundwater levels place on productive land or urban areas (e.g. the creation of salinity issues), and combines both these measures into a single indicator. |
| **Regional impacts** | The extent to which current groundwater extraction could potentially affect regional groundwater levels. |
| **Localised impacts** | The extent to which current groundwater extraction could potentially affect localised groundwater levels. |
| **Groundwater quality impacts** | Potential contamination of groundwater from:<br>• various discrete or disperse courses<br>• migration of water of a lower quality<br>• acidification from exposure of acid sulphate soils through the lowering of groundwater levels<br>• changes to seawater and groundwater interfaces from extraction in coastal sand aquifers. |
| **Aquifer structure pressures** | The effect on groundwater flow systems from compaction, or changes to aquifer material through groundwater extraction and from the removal of aquifers in mining or quarrying activities. |

The expert panel assessments were conducted across the State, with the panels consisting of hydrogeologists from the NSW Office of Water. These hydrogeologists are located throughout the State and have local knowledge of the various GWMAs in their regions.

### 3.2.1 Expert panel ranking of condition and pressure

The State of the Catchment Report scores the condition and pressure of indicators on a five tier scale for each GWMA in the region covered by the report card. Condition is scored from very good to very poor, while pressure is from very low to very high.

The assessment of condition and pressure for each of the indicator categories was based on a number of indicators (Appendix A), except for the condition indicator of LTAAEL versus use and pressure indicator LTAAEL versus entitlement which are based on available information. The assessment of these indicators are discussed in Section 3.3.

The condition assessment is a ranking of the ‘modification of state’ on the y-axis to the ‘level of resilience’ on the x-axis to establish the condition for each indicator (Figure 1). The ‘modification of state’ refers to how altered the indicator field is from its natural state, while the ‘level of resilience’ is the ability to buffer the modification of state. For example, in relation to the category of access to groundwater at a regional scale the level of extraction may be high and the resilience to that level of extraction is also high. This will plot as having a fair condition. A GWMA with a low level of use may have a very poor resilience, and will plot as being in very poor condition.

The pressure assessment is a ranking of the 'amount of pressure on the y-axis to the 'level of consequence' on the x-axis (Figure 2). The 'amount of pressure' refers to the amount of pressure in respect to the indicator, while the 'level of consequence' is the influence of the pressure on the indicator.

For example, in relation the category of regional impacts, the impact of groundwater may be high but the consequence of that extraction is small. This will plot as having a modest pressure. A GWMA with a low impact from groundwater use may have a very large consequence and will plot as having a high pressure score.

Each condition and pressure indicator category has a number of indicators. As a precautionary approach, the highest ranking condition and pressure scores for an indicator category is taken as the score for the indicator. The limitation of this approach is that it may exaggerate the level of pressure or the quality of the condition of the indicator category. However, it identifies areas that are likely to require further investigation and may require management actions.

In assessing some of the indicators the expert panels were unable to provide an assessment for the condition and pressure, because of there being insufficient information about the indicator. In these circumstances the response was recorded as unknown.

**Figure 1 Condition assessment matrix**

| Modification to state | | | | | | |
|---|---|---|---|---|---|---|
| | **High** | Good | Fair | Poor | Very poor | Very poor |
| | **Moderate** | Very good | Good | Fair | Poor | Very poor |
| | **Low** | Very good | Very good | Good | Fair | Poor |
| | | Very high | High | Average | Low | Very low |
| | | Level of resilience | | | | |

**Figure 2 Pressure Assessment Matrix**

| Amount of pressure | | | | | | |
|---|---|---|---|---|---|---|
| | **High** | Low | Moderate | High | Very high | Very high |
| | **Moderate** | Very low | Low | Moderate | High | Very high |
| | **Low** | Very low | Very low | Low | Moderate | High |
| | | Very small | Small | Modest | Large | Very large |
| | | Level of consequence | | | | |

## 3.3 Assessment of LTAAEL versus usage condition indicator and LTAAEL versus entitlement pressure indicator

One of the most direct sources of stress and effect on the condition of aquifer systems is groundwater extraction. The sustainable management of groundwater extraction requires knowing the sustainable level of extraction. The sustainable level of extraction is based on the amount of recharge to aquifer systems, with a portion assigned for use by the environment with the remaining made available fpr groundwater users. In NSW the sustainable level of extraction is known as the long term annual average extraction limit (LTAAEL), explained in section 3.3.1.

The LTAAEL versus usage condition indicator and LTAAEL versus entitlement pressure indicator were included as part of the assessment enabling the identification of the current level of groundwater extraction relative to the LTAAEL, and to identify the potential impact of GWMAs based on the current level of licensed entitlement. These indicators were based on information available from the NSW Office of Water.

The assessment of extraction and entitlement to the sustainable long term average annual rate of extraction assumes that groundwater extraction is evenly distributed across the GWMA. This is generally not the situation and there will always be areas where there will be a need to protect environmental assets from extraction. The use of the sustainable long term average annual rate of extraction provides a GWMA scale indication of the condition and pressures on the aquifer system.

The LTAAEL is explained in section 3.3.1. In brief, the LTAAEL is the long term volume of water that can be extracted annually from an aquifer system in an effort to represent sustainable practices in an historic timeframe. It assumes that although recharge will not be constant over time there is sufficient storage in the aquifer systems to maintain them during periods of below average recharge.

### 3.3.1 Long term annual average extraction limit

To enable assessment of the condition indicator of LTAAEL versus extraction and the pressure indicator of LTAAEL versus entitlement requires determining the LTAAEL for each GWMA.

The LTAAEL is the proportion of the long term average recharge available for extraction. In NSW, the consideration of recharge to aquifer systems is based on the long term annual average rates of recharge due to the lag time between when water moves from the unsaturated zone through the aquifer.

In small aquifer systems with a high permeability, aquifer systems respond to seasonal variations in rainfall. However, larger aquifer systems with low rates of permeability will have a longer lag time response to rainfall recharge and the response will represent a longer term trend of average rainfall.

The effect of climate change on long term annual average rainfall recharge is that there may be a reduction in the proportion of rainfall that recharges aquifer systems or possibly an increase in some topographic domains. The reduction in recharge would be associated with an increase in the available rainfall being retained in the soil profile and evaporated prior to it percolating from the unsaturated to the saturated profile; an increase is likely to be associated with mounding. Where recharge is due to or assisted by infiltration from streams, the effect of climate change may extend to a lessening (or possibly an increase) of the supply and/or a lowering (or rising) in the driving stream's head.

The LTAAEL was determined for areas where a WSP does not exist, from the percentage of annual average rainfall contributing to groundwater recharge. In inland alluvial WSP areas of the Lower Murray, Lower Murrumbidgee, Lower Lachlan, Lower Macquarie, Upper and Lower Namoi and Lower Gwydir Rivers, the groundwater recharge has been determined by numeric groundwater models. In the other WSP areas the LTAAEL is based on the annual average rainfall recharge and was

determined in consultation with the community, due to numeric models not being available and the limited data available to develop the models for these areas.

In areas where a WSP has not been implemented the annual average recharge and LTAAEL is based on the method in Bish and Williams *et al* 2006. The LTAAEL for each GWMA was determined by an interagency expert panel approach to assess the environmental, social and economic aspects to determine the proportion of recharge to be set as the LTAAEL.

The long term average groundwater recharge was determined on a proportion of the long term average rainfall. The proportion of rainfall that contributed to recharge was generally based on the soil/rock permeability of the geological province and expert opinion of the NSW Officer of Water hydrogeologists.

This was a precautionary approach as it did not take into consideration leakage from surface water features (rivers, creeks, lakes) for GWMAs where there is leakage from these sources. These were excluded due to the low confidence in the level of knowledge on the relationship between the systems on a State scale and the temporal and spatial variations that exists.

A NSW government position on the determination of the LTAAEL for WSP is that rainfall recharge for each GWMA excludes recharge to the National Parks area, except in the coastal sands aquifers where 5 per cent of the annual average rainfall recharge in the National Park area is included as through flow to the adjoining area of the GWMA.

The distribution of the annual average rainfall for each GWMA is based on the monthly average rainfall from Hutchinson and Kesteven (1998). They used a rainfall data set that comprises 12,983 stations located on the Australian mainland with data of acceptable quality within the period January 1921 to December 1995. The rainfall distribution was discretised on 200 x 200 metre grid squares.

The annual average rainfall for each GWMA was determined with ArcMap spatial analysis zonal statistics as a table tool, with the raster cell size set at 159.36.

### 3.3.2 Condition assessment of LTAAEL versus extraction

This indicator could not be applied across the State as groundwater extraction is not metered throughout NSW. The majority of metering is in the high extraction areas in the inland alluvial aquifer systems.

The data was obtained from the Water Management Act Water Accounting System. The usage information for the Tomago Tomaree Stockton GWMA, which has a WSP, was supplied by Hunter Water Corporation. The groundwater use for each GWMA was based on the 12 month period from July 2007 to June 2008.

Generally there is little usage data for GWMAs that do not yet have a water sharing plan. There are, however, a small number of GWMAs where, under a service level agreement with State Water Corporation, these data are collected. This information was extracted by a spatial data extraction from the DWE Water Ordering and Usage Database, using a spatial layer of GWMAs and the DWE ArcMap NavWater Tool application.

The condition indicator was based on the percentage of LTAAEL extracted as outlined in Table 5. The condition categories in Table 5 extend greater than 100 per cent because it is possible to use more than 100 per cent of the LTAAEL in any year. This is because of the ability for licence holders to carry over allocation from the previous year. The State of the Catchment Report only considers use from July 2007 to June 2008. If extraction exceeds the LTAAEL it is likely to be near or below the LTAAEL in the following year depending on the total allocation that a licence can retain as carryover. There are some GWMAs where the total allocation of carryover that a licence holder can retain is greater than 100 per cent and that the maximum that they can extract in any one year is less than the allocation

that they have accumulated. There are also GWMAs where the level of extraction exceeds the LTAAEL. Water sharing plans are now being implemented in these areas, with a key aspect of the plans being the reduction of entitlements over the operational period of the plan to 100 per cent of the LTAAEL.

In GWMAs where there is no known metered groundwater extraction it was not possible to assess the indicator, in these circumstances the response was recorded as unknown.

**Table 5: Condition rating of percentage of the LTAEL extracted allocated**

| Condition | Percentage LTAAEL extracted % |
|---|---|
| **Very good** | 0-33 |
| **Good** | 33.01-66 |
| **Fair** | 66.01-100 |
| **Poor** | 100.01-125 |
| **Very poor** | >125.01 |

### 3.3.3 Pressure assessment of LTAAEL versus entitlement

All groundwater licences in NSW are issued with an entitlement except for stock, domestic and farming purposes. The entitlement is the volume of water that the licence holder is permitted to extract from the groundwater system. Entitlements are not issued for stock, domestic and farming purposes, as these are generally used to extract small volumes of water.

The entitlement for each GWMA was determined by a spatial data extraction process from the NSW Office of Water's Licence Administration System, using a spatial layer of GWMAs and the NSW Office of Water's ArcMap NavWater Tool application.

To capture all licence holders within a GWMA an assumed entitlement of 2 megalitres (ML) for domestic, 3 ML for stock and 5 ML for farming was applied for each property within a coastal catchment GWMA. For GWMAs in inland catchments each property was ascribed an estimated entitlement 3 ML for domestic, 4 ML for stock and 6 ML for farming purposes. This estimated entitlement is required to enable the identification of the total level of entitlement or maximum potential use for each GWMA to determine the potential impact on each GWMA.

The proportion of the LTAAEL allocated was then ranked into one of the five categories as outlined in Table 6. The condition categories in Table 6 extend greater than 100 per cent because there are GWMAs that have a total entitlement greater than the LTAAEL. An entitlement greater than 100 per cent of the LTAAEL is not classified as being very high pressure because entitlement for stock, domestic and farming licensed purposes is an estimate and there is a level of uncertainty as there is insufficient information to measure and monitor the annual average rate of recharge accurately in each GWMA.

**Table 6: Pressure rating of percentage of the LTAAEL to the level of entitlement**

| Pressure | Percentage LTAEL allocated % |
|---|---|
| **Very low** | 0-33 |
| **Low** | 33.01-66 |
| **Moderate** | 66.01-100 |
| **High** | 100.01-125 |
| **Very high** | >125.01 |

## 3.4 Trend and data confidence

The ability to understand if the current pressure or condition of an indicator is changing is documented by the assessment of the trend. The purpose of showing the trend is to indicate:

- if the condition of the indicator is improving, declining, no change or unknown
- if the pressure on the indicator is increasing, decreasing, no change or unknown.

This information assists in determining if the current pressures are influencing the condition of the indicators. For example, if there is an increasing pressure trend and the condition trend is showing no change, it is likely, assuming there is a minimal time lag between cause and effect, that the pressure is not causing a significant influence on the indicator condition.

The data confidence was documented to indicate the level of information and knowledge that was used to assess each indicator category. The confidence was scored from low to high.

# 4. Pressure and condition index

Indexes have the potential to under and over represent the significance of indicators depending on their weighting. The benefit of an index is that is provides a single colour or score to enable the comparison of one area to another. However, it disguises the underlying level of data and analysis used to establish the index. When an index is used to compare one area to another it can be mistakenly assumed that the same level of data and analysis has been applied to establishing the index for each area.

The individual condition and pressure indicator categories for each GWMA with each State of the Catchment regions have been developed to provide a single condition and pressure index. The overall pressure and condition index for each GWMA is based on a weighting of each of the indicator categories. The condition and pressure index rankings are given a score from 1 to 5, as detailed in Table 7.

**Table 7: Condition and pressure rankings for the indicators**

| Condition | Score |
|---|---|
| **Very good** | 1 |
| **Good** | 2 |
| **Fair** | 3 |
| **Poor** | 4 |
| **Very poor** | 5 |

| Pressure | Score |
|---|---|
| **Very low** | 1 |
| **Low** | 2 |
| **Moderate** | 3 |
| **High** | 4 |
| **Very high** | 5 |

To determine the condition and pressure index for each GWMA, the seven conditions and seven pressure indicator categories (Section 3.0) were weighted (Table 8). The only indicators that were based on data were the condition indicator category of LTAAEL versus use and the pressure indicator category of LTAAEL versus entitlement. The other condition and pressure indicator categories where based on available information and expert opinion.

The condition indicator categories were weighted based upon the indicator being a direct indicator of an impact such as groundwater extraction or land use change. The highest weighting was applied to the LTAAEL versus use indicator as it is likely the earliest sign of change in the condition in the GWMA. The regional groundwater levels, local groundwater levels and groundwater quality category indicators are likely to be the first indicators to respond to any change in groundwater use. The lowest weighting was given to the GDE indicator and aquifer integrity indicator categories. The low priority of the GDE indicators was because of the current limited information available for these indicator categories. The aquifer integrity indicator categories were given the lowest rating as it is likely that the other indicators will show a change prior to any change being noticed in these indicators.

An increased availability of information for the GDE indicators would require that these ratings are reassessed. An improved understanding on the dependency of GDEs on the availability and quality of groundwater may make them an important indicator of initial signs of change in the condition in a GWMA.

The pressure indicator categories were weighted based upon the indicator being a direct indicator of an impact such as groundwater extraction or land use change. The highest weighting was applied to the LTAAEL versus entitlement indicator as it is likely the earliest sign that there is likely to be a change in the condition in the GWMA. The regional impacts, localised impacts and groundwater quality impact category indicators are likely to be the first indicators to respond to any change in groundwater use. The lowest weighting was given to the GDE groundwater availability and aquifer

structure pressure indicator categories. These were given the lowest rating as it is likely that the other indicators will show signs of pressure changes prior to any change in pressure being noticed in these indicators. They were also given the lowest weighting because of the current limited information available for these indicator categories.

**Table 8: Weighting of the condition and pressure indicators**

| Condition Indicator Category | Weighting |
|---|---|
| **GDE condition** | 0.1 |
| **Land condition** | 0.15 |
| **Regional groundwater levels** | 0.15 |
| **Local groundwater levels** | 0.15 |
| **Groundwater quality** | 0.15 |
| **Aquifer integrity** | 0.1 |
| **Long term average extraction limit (LTAEL) versus use** | 0.2 |

| Pressure Indicator Category | Weighting |
|---|---|
| **GDE groundwater availability** | 0.1 |
| **Land use pressures** | 0.15 |
| **Regional impacts** | 0.15 |
| **Localised impacts** | 0.15 |
| **Groundwater quality impacts** | 0.15 |
| **Aquifer structure pressures** | 0.1 |
| **Long term average extraction aimit (LTAEL) versus entitlement** | 0.2 |

To determine the overall condition and pressure score for each GWMA, the score of the individual indicators categories was multiplied by the indicator weighting (Table 9). The value for each indicator was summed to give a total condition or pressure rank for each GWMA. A limitation of this method is that where there is no information available it will have possibly produced an index for the GWMA that indicates it is in better state than is actually occurring. This is especially the situation where multiple indicator categories for a GWMA were assessed as not having sufficient information to make a ranking.

When a score for the condition and pressure indexes was not a whole number the ranking was rounded to the nearest whole number. As the assessment of the indicator categories was based mainly on expert opinion and available information a precautionary approach was used in ranking the indexes. If an index score was 0.5 or greater it was assigned to the lower index rank. For example a condition index score of 1.5 would be ranked as good condition rather than very good condition. An example of this is shown in Table 9.

**Table 9: Example of GWMA pressure and condition ranking**

| Indicator | Condition score | Weighting | Indicator value | Pressure score | Weighting | Indicator value |
|---|---|---|---|---|---|---|
| **GDE groundwater availability** | 0 | 0.10 | 0 | 2 | 0.10 | 0.20 |
| **Land use** | 3 | 0.15 | 0.45 | 2 | 0.15 | 0.30 |
| **Access at regional scale** | 1 | 0.15 | 0.15 | 1 | 0.15 | 0.15 |
| **Localised impacts** | 1 | 0.15 | 0.15 | 5 | 0.15 | 0.75 |
| **Water quality** | 3 | 0.15 | 0.45 | 2 | 0.15 | 0.30 |
| **Aquifer integrity** | 1 | 0.10 | 0.10 | 2 | 0.10 | 0.20 |
| **Long term average extraction limit (LTAEL) versus use** | 1 | 0.20 | 0.20 | | | |
| **Long term average extraction limit (LTAEL) versus entitlement** | | | | 3 | 0.2 | 0.60 |
| **GWMA ranking** | | | 1.5 (good) | | | 2.5 (high) |

# 5. Discussion

The development of State of the Catchment Reports for the groundwater target has identified significant issues that include an inability to monitor the target appropriately, and the need to focus monitoring in areas of high ecological value and groundwater extraction. The major impacts on groundwater systems are groundwater use and changes in the landscape that alter the rates of groundwater recharge. The monitoring of changes in the landscape requires monitoring that meets all of the 13 targets in E4 of the NSW State Plan and identification of the key linkages between the targets.

The reporting on the condition and pressure for each State of the Catchment region at the GWMA scale identifies the GWMA areas where management action may be required. However, the GWMAs have a diverse spatial distribution and it is impossible, from the State of the Catchment Reports for some of the larger GWMAs, to identify which State of the Catchment region there are actually issues. Where the GWMAs are within the State of the Catchment region it is not possible to spatially identify the location that management actions are required. Future State of the Catchment Reports for the target should concentrate on the areas of high ecological value that are dependent on groundwater as well as the areas of groundwater extraction. This would enable monitoring to be prioritised on these areas and changes to be measureable.

The State of the Catchment Reports were developed using existing information and no new information was collected as part of the assessment process. The monitoring of groundwater resources in the State consists of:

- State groundwater level monitoring network of about 3600 bores
- groundwater use monitoring.

The State groundwater level monitoring network provides the most information on aquifer systems in the State. The network coverage is concentrated mainly in areas of high groundwater extraction and does not provide a State-wide coverage of aquifer systems. The monitoring bores are either equipped with automated time series groundwater level monitoring equipment or are monitored by manual measurements at a frequency from monthly to annually.

Groundwater levels provide information on the influence of climatic variation, land use and groundwater use on aquifer systems. The individual pressures that cause these influences may not be clearly distinguishable, because of variations within the aquifer systems between developed and non-developed areas, especially in fractured rock and porous rock provinces.

The level of pressure on an aquifer system and its condition cannot be directly related to a percentage or actual metres of groundwater level decline or increase. This is due to the variations within and between GWMAs in their aquifer matrix, storage, hydraulic conductivity and size, as well as all the factors related to land use and aquifer hydrochemistry.

To be able to assess the pressures and the condition on aquifer systems requires data from multiple sources including groundwater extraction, groundwater quality and detailed knowledge of the physical characteristics of the various GWMAs and their variability. Numerical groundwater models provide a good understanding of the long term annual average rate of recharge relative to the level of extraction. These models exist for a limited number of alluvial GWMAs. Numerical models are not as reliable in fractured and porous rock provinces due to the heterogeneity of those systems. It is difficult to develop a numerical model for these areas without detailed geological structural and aquifer information. This level of information is generally only available for case study or site specific investigations. However, a model has been developed for the Great Artesian Basin (a very large porous rock and fractured rock aquifer complex).

The identification of a LTAAEL is largely a socially and economically acceptable level of development that is identified as having a minimal impact on the environment. It is derived through the planning process where any trade-offs occur.

The impacts on GWMAs are generally not at a management area scale. They occur as localised or regional scale impacts within the area such as from excessive groundwater extraction. The indicators and the indicator questions had the objective of identifying the stresses and the variation in condition that occurs within GWMAs.

The assessment of condition and pressure for the State of the Catchment Reports was based mainly on expert hydrogeological opinion, with the respondent's level of confidence recorded. Expert opinion is subjective and biased by the respondent's knowledge, beliefs and experience. However, the documentation of their level of confidence assists in providing an indication of the potential for there to be significant variation from actual conditions.

There is limited information available on the location, dependency and condition of GDEs. An additional level of complication for GDEs is determining the level of groundwater dependence and if the change is condition is associated with groundwater availability, quality or other factors. For a significant number of the GWMAs it was not possible to assess the condition or pressure on GDEs. It is an area that requires additional information to be collected prior to an assessment can being conducted on the ability of groundwater systems to support GDEs.

Land use has the ability to alter the volume of water that is recharging an aquifer system, which in some circumstances can impact on the landscape when groundwater levels either significantly increase or decline. The general long lag time of response of groundwater systems to land use change meant that this question was framed as being pre European settlement.

The potential land use factors that may influence groundwater recharge are:

- clearing of native vegetation and replacing it with a land use that increases recharge, such as irrigation, or decreases or increases it e.g. urbanisation and change of cropping
- changing the land use to agro-forestry which has the potential to reduce runoff and groundwater recharge
- using a natural groundwater discharge area as a water storage, potentially causing an alteration to the regional groundwater flow direction and groundwater protection levels in the vicinity of the activity.

There has been significant change in the landscape since European settlement and this was indicated in many of the pressure indicator ranks for the GWMAs. However, the impact on the condition of the groundwater systems was found generally not to be significant, except in areas where development of the groundwater resource has occurred. Groundwater quality monitoring is not undertaken in NSW on a regular basis and has historically been project-based on specific areas, which provides limited information for the assessment of the pressures and condition of groundwater aquifers systems at a catchment scale. This was highlighted in the assessment with limited to no information available on the condition – groundwater quality.

Contamination of an aquifer system can occur from dispersed or discrete sources. The regulation of the rehabilitation of contaminated sites in NSW is the responsibility of the Department of Environment, Climate Change and Water. Generally at a GWMA scale groundwater quality is not significantly impacted by contamination, the exception being the Botany sand beds where a large area has been contaminated by various industries in the area over the past 100 years. The groundwater quality indicator was designed to identify the condition and pressure at a GWMA scale.

Groundwater extraction can impact on groundwater quality by inducing the migration of water of a lower quality and induce mixing in the aquifer being used or by water and rock interactions in some aquifer systems. An example of simple water mixing is in the Cryon area in northern NSW. The groundwater quality in the fresh water aquifer is being influenced by the induced leakage of saline groundwater from an overlying aquifer; see Barrett and Williams (2006) for further information. The assessment identified this as an issue in some of the inland alluvial GWMAs. This issue is currently being investigated as part of a National Water Commission project on the influence of groundwater extraction on the mixing of groundwater from different aquifers.

Consideration of the proportion of the LTAAEL allocated identified that there are a number of aquifer systems that are over-allocated. The large inland alluvial GWMAs where WSPs have been implemented are reducing the level of entitlement to the LTAAEL over the 10 years of the plan. A number of other GWMAs have been identified as being over-allocated. These systems may, in fact, not be over-allocated since the initial assessment was based solely on rainfall recharge with no consideration of the frequency of flood inundation and river leakage. To determine the actual number of GWMAs over-allocated requires an assessment of the input and outputs to an aquifer system and assigning a level of long term average extraction that does not adversely impact on the aquifer system and its dependent ecosystems.

Further work is required to target groundwater quality monitoring in areas under pressure such as in areas of high groundwater extraction or in the coastal sands where there is the potential for an impact from seawater intrusion. There is a need for the identification of all GDEs and the verification of identified potential GDEs. In addition, there is a need for the assessment of their condition and identification of the pressures on these ecosystems. The collection of groundwater extraction information from a higher proportion of licence holders will also assist in the review of groundwater level data in the identification of areas under pressure and to review if current LTAAEL are appropriate.

# 6. Recommendations

It is recommended that any future groundwater State of the Catchment reporting is targeted at areas of high ecological value with a dependence on groundwater and area of groundwater use. This would be of greater benefit to State agencies and CMAs to be able to focus management actions and monitoring in these areas. It will also enable any changes in the condition of the groundwater systems in these areas to be measured.

To ensure that potential high priority GDEs are identified requires the use of analysis of satellite imagery and a desk top assessment, to identify sites and to evaluate their significance. To ensure that all of the areas of groundwater extraction are identified that may be influencing GDEs an expert panel assessment is suggested. It is through both of these approaches that it is likely that the majority of known stressed and high priority GDE areas would be identified. The assessment could then target these areas.

A broad-scale State-wide monitoring program of groundwater levels, collection of usage information and groundwater quality is still required to be able to capture emerging and unidentified pressures.

In addition to the current groundwater level and usage monitoring, there is a need to undertake the following activities to improve the monitoring of the groundwater theme:

- the identification of GDEs, site verification and evaluation together with the field characterisation of their inputs and relationship to groundwater systems
- identification of stressed and potentially stressed areas, and the identification and verification of priority GDEs
- groundwater quality monitoring in stressed aquifer systems
- maintenance and extensive enhancement of the existing groundwater level monitoring network to enable regional scale monitoring of groundwater levels for water management and other designated beneficial uses.

# 8. References

Ali A, Merrick N P, Williams R M, Mampitiya D, d 'Hautefeuille F and Sinclair P (2004) Land Settlement Due to Groundwater Pumping in the Lower Namoi Valley of NSW. Murray-Darling Basin Groundwater Workshop

Barrett C, Williams R M (2006) Groundwater chemistry changes due to mixing –Lower Namoi Valley, New South Wales. Murray-Darling Basin Groundwater Workshop, Canberra

Bish S, Williams RM, Gates G & Gill J (2006) Assessment of Sustainable Limits for Groundwater Sources in New South Wales. Murray-Darling Basin Groundwater Worksop

Commonwealth Government (2004) Intergovernmental Agreement on a National Water Initiative http://www.nwc.gov.au/resources/documents/Intergovernmental-Agreement-on-a-national-water-initiative.pdf. accessed 2 February 2010.

DLWC (1997) NSW State Groundwater Policy Framework Document, Department of Land and Water Conservation, Sydney

DLWC (1998) NSW Groundwater Quality Protection Policy. Department of Land and Water Conservation, Sydney

DLWC (2002) NSW State Groundwater Dependent Ecosystem Policy. Department of Land and Water Conservation, Sydney

DWE (2008) Draft Process to Identify Potential and Known High Priority Groundwater Dependent Ecosystems. DWE, Armidale, Unpublished

Hatton T, Evans R, 1998. Dependence of ecosystems on groundwater and its significance to Australia LWRRDC Occasional Paper No 12/98.

Hutchinson M F and Kesteven J L (1998) – *Monthly Mean Climate Surfaces for Australia*. Cres ANU (unpubl.)

NSW Government (2006) NSW State Plan, http://www.nsw.gov.au/stateplan/index.aspx?id=3fa4b747-8a40-4795-b789-2067946487f5, accessed 4 June 2009. Premier's Department. Sydney

# Appendix A – Condition and pressure assessment matrix

**Condition – modification to state indicator questions**

| | | Modification to state | | | | | |
|---|---|---|---|---|---|---|---|
| **Question** | **GDE condition** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **1** | Where there are known GDEs what has been the long term change in groundwater levels or pressure by land use or groundwater use? | There is a decline or increase in water tables or piezometric pressure levels that are likely to cause stress or alter the condition of the GDEs. | There is a moderate decline or increase in water tables or piezometric pressure levels that are likely not significantly alter the availability of water to GDEs. | No change or small change in piezometric levels or groundwater levels. | | | |
| **2** | Where there are known GDEs what has been the seasonal change in groundwater levels fluctuations caused by land use or groundwater use? | Reduction or increase in groundwater level(s) or piezometric pressure beyond established trigger levels or which are likely to cause stress or alter the condition of the GDEs. | Reduction or increase in groundwater level(s) or piezometric pressure nearing established trigger levels or seasonal variation that is likely to cause stress to an existing GDEs. | No change or small in piezometric levels or watertable levels not impacting on GDES. | | | |
| **3** | Where there are known GDEs what has been the level of decline in groundwater levels in connected systems caused by groundwater use or land use? | Permanent reversal of base flow conditions or disconnection from surface water systems over an extended area. Or permanent accession of saline groundwater to a river system. | Temporary reversal of base flow conditions exceeding seasonal variation over an extended area. Permanent reversal of base flow conditions in small localised areas. Or temporary/seasonal accessions of saline groundwater to a river system. | Temporary reversal of base flow conditions in small localised areas or no/limited alternation in base flow conditions. | | | |
| | **Landscape condition** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **4** | What is the influence of land use on regional groundwater levels? | There has been a permanent change in the groundwater flow and recharge characteristics of the aquifer system. | There is a measured reduction or increase in watertable levels or piezometric pressures beyond anticipated natural conditions. | Unchanged or minimal alteration. | | | |
| **5** | What is influence of shallow water levels impacting on arable land or urban areas? | Saline groundwater water levels are known to be less than 2 metres below natural surface in greater than 10% of the area. | Saline groundwater water levels are know to be between 2 and 5 metres of natural surface in greater than 10% of the area. | Saline groundwater water levels are known to be greater than 5 metres. | | | |
| | **Regional groundwater levels** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **6** | What is the impact of groundwater use on the recovery of groundwater pressures? | Recovery levels have a declining trend. | Recovery levels have established a new equilibrium or are declining and likely to establish a new sustainable equilibrium. | Unchanged or minimal alteration. | | | |
| **7** | What is the impact of groundwater use on the recovery of watertable levels? | Recovery levels have a declining trend associated with groundwater use | Recovery levels have established a new equilibrium or are declining and likely to establish a new sustainable equilibrium. | Unchanged or minimal alteration. | | | |
| **8** | What is the influence on groundwater level fluctuations by groundwater use? | Groundwater use is greater than 60% of LTAEL. | Groundwater use is less than 60% of LTAEL. | There is minimal groundwater use in the area. | | | |
| | **Local groundwater levels** | **High** | **Moderate** | **Low** | | **No information** | **Data confidence Low/medium/high** |
| **9** | What is the influence of localised impact areas on groundwater levels? | There are currently identified localised areas of long term groundwater level declines cause by groundwater use. | There are currently areas experiencing localised fluctuations with full or close to full recovery of groundwater levels. During periods of non-pumping. | No Impact. | | | |
| **10** | What is the influence of groundwater use on surface water? | There is a long term impact on surface water flows that can be measured and is impacting on the level of access for surface water users or riverine health. | There is an impact on surface water flows that can be measured but is not reducing the level of access for surface water users or riverine health. | No Impact. | | | |

**Condition – modification to state indicator questions (cont'd)**

| | Groundwater quality | High | Moderate | Low | | No information | Data confidence Low/medium/high |
|---|---|---|---|---|---|---|---|
| **11** | What is the influence of groundwater use on the beneficial use category? | The area of groundwater quality change is broadly across the area. | The area of groundwater quality change is localised. | Negligible change (<5%). | | | |
| **12** | Has there been a change in the acidity? | A broad area of the aquifer is affected. | There are localised areas affected. | Negligible change (<5%). | | | |
| **13** | Has there been a change in nutrient concentrations? | A broad area of the aquifer is affected. | There are localised areas affected. | Negligible change (<5%). | | | |
| **14** | What is the influence of land use/water use on the freshwater/salt water interface? | The area of influence is broad. | The area of influence is localised. | No detectable change or N/A. | | | |
| **15** | Has there been a change in groundwater salinity? | The area influenced by higher salinities due to land use or water use is a broad area of the aquifer system. | The area influenced by higher salinities due to land use or water use is localised. | Minimal change. | | | |
| **16** | What is the influence of heavy metal contamination? | Known occurrence of heavy metals in numerous areas. | Known occurrence of localised area impacted by heavy metals. | No detectable change from natural seasonal variation. | | | |
| **17** | What is the influence of hydrocarbon contamination? | Known occurrence of hydrocarbon contamination in numerous areas or a large area of the GWMA is impacted. | Known occurrence of localised areas impacted by hydrocarbon contamination. | Limited/isolated instances of hydrocarbon contamination. | | | |
| | **Aquifer integrity** | **High** | **Moderate** | **Low** | | **No information** | **Data confidence Low/medium/high** |
| **18** | Is there evidence of substrate compaction/subsidence? | Permanent change of an area of an aquifer system from being confined to unconfined or a watertable aquifer is dewatered over a broad area of the aquifer. | A reduction in the permeability and/or porosity of the aquifer system. | No change/not applicable. | | | |

**Condition – Level of resilience indicator questions**

| | | Level of resilience | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Very Good** | **Good** | **Fair** | **Poor** | **Very poor** | | | |
| **Question** | **CDE condition** | **1** | **2** | **3** | **4** | **5** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **1** | Where there are known GDEs what has been the influence of long term change in groundwater levels or pressure buy land use or groundwater use? | No change to ecosystems. | Potentially temporary stressed ecosystems. | Identified temporary stress defined ecosystems. | Potentially permanent loss of defined GDE ecosystems or change in ecosystems. | Identified permanent loss of defined GDE habitat type or change in habitat type. | | | |
| **2** | Where there are known GDEs what has been the influence of seasonal change in groundwater levels fluctuations caused by land use or groundwater use? | No change to habitat type. | Potentially temporary stressed habitat type. | Identified temporary stress defined habitat type. | Potentially permanent loss of defined GDE habitat type or change in habitat type. | Identified permanent loss of defined habitat type or change in type associated with groundwater levels. | | | |
| **3** | Where there are known GDEs what has been the influence of the decline in groundwater levels in connected systems caused by groundwater use or land use? | No change to habitat type. | Potential temporary impact on aquatic ecosystems. | Identified temporary impact on aquatic ecosystems. | Potential permanent impact on aquatic ecosystems. | Identified permanent impact on aquatic ecosystems. | | | |
| | **Landscape condition** | **Very Good** | **Good** | **Fair** | **Poor** | **Very poor** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **4** | What is the influence of land use on regional watertable levels? | No impact on water tables levels, land use or the quality of the aquifer system. | There is minimal impact on watertable levels or the quality of the aquifer system. | There is an impact on watertable levels or the quality of the aquifer system in a significant part of the area. | Reduced the potential use of groundwater or the quality of groundwater. | Preventing the use of groundwater or the quality of groundwater. | | | |
| **5** | What is influence of shallow water levels impacting on arable land? | Minimal or no impact. | There is a decline in productivity less than 2% of the area. There is limited evidence of urban salinity. | There is a decline in productivity in less than 5% of the area. Urban infrastructure is impacted by salinity but not adversely impacted. | There is a decline in productivity in less than 7.5% of the area. The level of impact on urban infrastructure by salinity has not been identified as significant for the area. | There is a decline in productivity in less than 10% of the area. Significant amount of urban infrastructure has been damaged by salinity in the area. | | | |
| | **Regional groundwater levels** | **Very good** | **Good** | **Fair** | **Poor** | **Very poor** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **6** | What is the impact of groundwater use on the recovery of groundwater pressures? | No influence. | The recovery levels are causing minimal change to the potentiometric surface and no impact on BLR or other licence holders. | A broad area of the region is showing a change in the potentiometric levels associated with the recovery levels. There is limited impact on BLR and other licence holders. Some shallow BLR bores may be dry. | The declines in the recovery levels may not be sustainable. There are BLR holders with limited or no access. Licence holders are lowering pumps to increase yields. | Recovery levels are showing a non-sustainable level of groundwater use. There are reduced yields from bores and pumps being lowered. | | | |

**Condition – Level of resilience indicator questions (cont'd)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **7** | What is the impact of groundwater use on the recovery of watertable levels? | No influence. | The recovery levels are causing minimal change to the potentiometric surface and no impact on BLR or other licence holders. | A broad area of the region is showing a change in the potentiometric levels associated with the recovery levels. There is limited impact on BLR and other licence holders. Some shallow BLR bores may be dry. | The declines in the recovery levels may not be sustainable. There are BLR holders with limited or no access. Licence holders are lowering pumps to increase yields. | Recovery levels are showing a non-sustainable level of groundwater use. There are reduced yields from bores and pumps being lowered | | | |
| **8** | What is the influence on water level fluctuations caused by groundwater use on a regional scale? | No influence. | There are no broad scale fluctuations in groundwater levels. | The fluctuations in groundwater levels are around the seasonal trend with limit or no impact on BLR or other licence holders. | There are large seasonal variations that are likely to impact on BLR access and licence holder access. | The level of fluctuation is causing temporary dewatering of a watertable aquifer or a confined aquifer to become unconfined in more than a localised area. | | | |
| | **Local groundwater levels** | **Very good** | **Good** | **Fair** | **Poor** | **Very poor** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **9** | What is the influence of localised impact areas on groundwater levels? | No Impact | Groundwater levels are not fully recovering compared to natural trends. However, there is no clear indication from groundwater level monitoring that there is a localised decline in groundwater levels. | Groundwater levels are not fully recovering compared to natural trends. There is a clear area of influence caused by groundwater use but it is not causing any localised impact on access to water where users are required to lower pump intakes or have lost. | Groundwater levels are not fully recovering compared to natural trends. There is a clear area of influence caused by groundwater use that is approaching management trigger levels or lost of access for shallow stock and domestic bores. | Groundwater levels are not fully recovering compared to natural trends. There is a clear area of influence caused by groundwater use that has required management intervention and or the lowering of pump intakes from production bores. | | | |
| **10** | What is the influence of groundwater use on surface water? | Disconnected system or not applicable. | Level of impact is minimal. | A gaining stream or losing stream has had an increase in the level of loss from the surface water system in isolated areas. | A gaining stream or losing stream has had an increase in the level of loss from the surface water system over an extended localised areas | A previously connected system is disconnected due to groundwater use | | | |
| | **Groundwater quality** | **Very Good** | **Good** | **Fair** | **Poor** | **Very poor** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **11** | What is the influence of groundwater use on the beneficial use category? | Negligible change (<5%). | There are potential temporary changes in beneficial use category. | There are known temporary changes in beneficial use category. | There is potentially a permanent change in beneficial use category. | There is a known permanent change in beneficial use category. | | | |
| **12** | Has there been a change in the acidity? | No detectable change or at background levels. | The pH is less than 6.5 and there has been a decline in water pH of less than 1 caused by land use change or groundwater use. | The pH is less than 6.5 and there has been a decline in water pH of 1 caused by land use change or groundwater use. | The pH is less than 6.5 and there has been a decline in water pH of more than 1 to 2 caused by land use change or groundwater use. | The pH is less than 6.5 and there has been a decline in water pH of more than 2 caused by land use change or groundwater use. | | | |
| **13** | Has there been a change in nutrient concentrations? | Concentration of nutrients below ANZECC guideline standards or at background levels. | Concentration of nutrients increasing towards ANZECC guideline standards and above background levels. | Concentration of nutrients close to ANZECC guideline standards and above background levels. | Concentration temporarily above ANZECC guideline standards and above background levels. | Concentration greater than ANZECC guideline standards and are above background levels. | | | |
| **14** | What is the influence of land use/water use on the freshwater/salt water interface? | No change or not applicable. | There is a measured change but is not causing any impact on human access or GDEs. | There is temporary or there likely to be a change in the location or gradient of salt/freshwater interface beyond natural variation. | There is potentially a permanent change in the location or gradient of salt/freshwater interface beyond natural variation. | There is a permanent change in the location or gradient of salt/freshwater interface beyond natural variation. | | | |

**Condition – Level of resilience indicator questions (cont'd)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **15** | Has there been a change in groundwater salinity? | No change in potential uses for human consumption or impact on GDEs. | A change in salinity has been identified with no impacts on potential uses and GDEs. | The change in salinity may cause impacts on potential uses and GDEs. | There has been a temporary change in the groundwater salinity that could alter potential uses or impacted on GDEs. Management intervention would improve the groundwater salinity. | A permanent change in salinity has altered the potential uses or impacted on GDEs. | | | |
| **16** | What is the influence of heavy metal contamination? | Concentration below ANZECC guideline standards or at background levels. | Concentration increasing towards ANZECC guideline standards and above background levels. | Concentration close to ANZECC guideline standards and above background levels. | Concentration temporarily above ANZECC guideline standards, or remediation is occurring and are above background levels. | Concentration greater than ANZECC guideline standards and are above background levels. | | | |
| **17** | What is the influence of hydrocarbon contamination? | No known or all known hydrocarbon contamination sites have been rehabilitated. | Known sites of hydrocarbon contamination causing no or minimal impact on human access or GDEs. | Known sites of hydrocarbon contamination are being rehabilitated with no impact on human access or impact on GDES. | Known sites of hydrocarbon contamination are being rehabilitated with management actions in place to ensure that protection of human access or GDEs. | hydrocarbon contamination preventing human access or impacting on GDEs. | | | |
| | **Aquifer integrity** | **Very good** | **Good** | **Fair** | **Poor** | **Very poor** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **18** | Is there evidence of substrate compaction? | No change. | There is potentially localised change in the aquifer matrix. | There is localised change in the aquifer matrix. | There is potentially a greater than 5% of the aquifer has experienced a change in the aquifer matrix. | Greater than 5% of the aquifer has experienced a change in the aquifer matrix. | | | |

**Pressure – Amount of pressure indicator questions**

| | | Amount of Pressure | | | | | |
|---|---|---|---|---|---|---|---|
| **Question** | **GDE groundwater availability** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **1** | Where there are known GDEs is there long term watertable levels or groundwater pressures by land use or groundwater use? | The types of GDEs are known or documented to be sensitive to changes in the availability of groundwater. | GDEs are documented as experiencing stress or the influence of reduced availability of groundwater. | No or minimal impact. | | | |
| **2** | Where there are known GDEs what has been the consequence of seasonal change in groundwater levels fluctuations caused by land use or groundwater use? | There has been a documented permanent change in the ecosystem or the GDE is no longer present. | The GDE is documented as experiencing stress or the influence of reduced availability of groundwater. | No or minimal impact. | | | |
| **3** | Where there are known GDEs what has been the consequence of changes in groundwater levels in connected systems caused by groundwater use or land use? | There has been a documented permanent change in the ecosystem or the GDE is no longer present. | The GDE is documented as experiencing stress or the influence of reduced availability of groundwater. | No or minimal impact. | | | |
| | **Land use pressures** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **4** | What is the impact of land use on groundwater levels? | Prevents the availability of groundwater for GDEs, the availability for human consumption or causes water logging. | Reduces the availability of groundwater for GDEs or for human consumption or causes temporary water logging. | No or minimal impact. | | | |
| **5** | What is the impact of saline shallow water levels on the urban environment or arable land? | Permanent loss of arable in more than 10% of the area or salinity is known to be impacting on infrastructure in urban centres. | Temporary or permanent loss of arable in less than 10% of the area or there is signs of urban salinity one or more centres. | Minimal or no impact. | | | |
| | **Regional impacts** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **6** | What is the impact of groundwater use on the recovery of watertable levels? | There has been a loss of access of water for BLR or user access impacted by groundwater use. | There has been a decline in groundwater levels for BLR or user access caused by groundwater use. | No or minimal impact on BLR or user access. | | | |
| **7** | What is the impact of groundwater use on the recovery of groundwater pressures? | There has been a loss of access of water for BLR, GDEs or user access caused by groundwater use where the works were not close to being dry prior to groundwater use. | There has been a decline in groundwater levels for BLR, GDEs or user access caused by groundwater use. | No or minimal impact on BLR, GDEs or user access. | | | |
| **8** | What is the consequence of water level fluctuations being influenced by groundwater use? | Prevents access for stock and domestic users and other licence holders. | Limits access for stock and domestic users and other licence holders. | No or minimal impact. | | | |
| | **Localised impacts** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **9** | What is the impact of groundwater use in localised areas? | The localised impact has required management actions or reductions in access to ensure the availability of water for BLR, GDEs. | The localised impact is causing some impact on BLR, GDEs. | Negligible change. No impact on BLR, GDEs and aquifer integrity. | | | |
| **10** | What is the impact of groundwater use on surface water? | Induced river leakage is over a broad area of the river systems or has resulted in an extended period of disconnection. | Induced river leakage occurs in isolated areas. | Natural conditions or induced river leakage is event based and has negligible impact on surface water flows or no impact. | | | |

**Pressure – Amount of pressure indicator questions (cont'd)**

| | Groundwater quality impacts | High | Moderate | Low | Trend | No information | Data confidence Low/medium/high |
|---|---|---|---|---|---|---|---|
| **11** | What is the consequence of a change in the acidity? | There are a number of activities that influence groundwater levels. | There are a small number of activities that influence groundwater levels. | No change or not applicable. | | | |
| **12** | What is impact of nutrients on the aquifer system? | There is a high use of nutrients in the landscape. | There is a level of use of nutrients in the area that is likely to cause an impact. | There is no or minimal use of nutrients. | | | |
| **13** | What is impact of agricultural chemicals on the aquifer system? | There is a high use of agricultural chemicals in the landscape. | There is a level of use of agricultural chemicals in the area that is likely to cause an impact. | There is no or minimal use of agricultural chemicals. | | | |
| **14** | What is the consequence of land use/water use influencing the freshwater/salt water interface? | There has been a documented or known extended period of upwelling of saline groundwater. | There are periods of extraction that are likely to cause upwelling of saline water. | Minimal declines in groundwater levels. | | | |
| **15** | What is the likelihood of a change in groundwater salinity? | The storage in the fresh aquifer is unlikely to significantly buffer inflows from an adjacent or overlying saline aquifer. | There is sufficient storage in the fresh aquifer to buffer inflows from an adjacent or overlying saline aquifer. | Minimal or no impact. | | | |
| **16** | What is the likelihood heavy metal contamination? | There is a level of use of heavy metals that could cause an impact. | There is a level of use of heavy metals that may cause an impact. | There is no use of heavy metals in the area. | | | |
| **17** | What is the likelihood of hydrocarbon contamination? | There is a high concentration of potential sources or known points of hydrocarbon contamination in a large area of the region. | There is concentration of potential sources or known points of hydrocarbon contamination in a large area of the region. | There is no or minimal storage, potential sources of hydrocarbon contamination or minimal known cases of hydrocarbon contamination. | | | |
| | **Aquifer structure pressures** | **High** | **Moderate** | **Low** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **18** | What is the consequence of substrate compaction or subsidence? | There is likely to be a change in the aquifer matrix caused by aquifer dewatering or subsidence. | There is a known change in the aquifer matrix caused by aquifer dewatering or subsidence. | No change. | | | |

**Pressure – Level of consequence indicator questions**

| | | Level of consequence | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Very low** | **Low** | **Moderate** | **High** | **Very high** | | | |
| **Question** | **GDE groundwater availability** | **1** | **2** | **3** | **4** | **5** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **1** | Where there are known GDEs is there long term watertable levels or groundwater pressures by land use or groundwater use? | No or minimal change. | Potentially alteration in groundwater level(s) or piezometric pressure beyond long term trends. | Alteration in groundwater level(s) or piezometric pressure beyond long term trends. | Potential alteration in groundwater level(s) or piezometric pressure beyond established trigger levels causing the near dewatering of a watertable aquifer or localised unconfinement of confined aquifers | Alternation in groundwater level(s) or piezometric pressure beyond established trigger levels causing the near dewatering of a watertable aquifer or localised unconfinement of confined aquifers. | | | |
| **2** | Where there are known GDEs what is the likely impact of seasonal change in groundwater levels fluctuations caused by land use or groundwater use? | No or minimal change. | Potentially fluctuations in groundwater level(s) or piezometric pressure are beyond seasonal variation. | Fluctuation in groundwater level(s) or piezometric pressure beyond seasonal variation. | Potentially fluctuation in groundwater level(s) or piezometric pressure beyond established trigger levels. | Ffluctuation in groundwater level(s) or piezometric pressure beyond established trigger levels. | | | |
| **3** | Where there are known GDEs what has been the consequence of changes in groundwater levels in connected systems caused by groundwater use or land use? | No or minimal change. | Potentially temporary reversal of base flow conditions exceeding seasonal variation or saline groundwater inflows not impacting on surface water quality. | Temporary reversal of base flow conditions exceeding seasonal variation or saline groundwater inflows causing a minimal increase in surface water salinity. | Potentially permanent reversal of base flow conditions. Or temporary inflows of saline groundwater impacting on surface water quality. | Permanent reversal of base flow conditions. Or permanent inflows of saline groundwater impacting on water quality. | | | |
| | **Land use pressures** | **Very low** | **Low** | **Moderate** | **High** | **Very high** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **4** | What is the impact of land use on groundwater levels? | No influence. | Land use has had a minimal influence on groundwater levels. | A change in land use has temporary altered groundwater levels. | A change in land use is likely to permanently alter groundwater levels. | A change in land use is known to permanently influence groundwater levels. | | | |
| **5** | What is the impact of saline shallow water levels on the urban environment or arable land? | Saline groundwater levels are known to be greater than 5 metres in more than 95% of the area or not applicable. | Saline groundwater levels are known to be greater than 5 metres in more than 90% of the area or within urban areas. | Saline groundwater water levels are known to be between 2 metres and 5 metres of natural surface in 10% of the area or within urban areas. | Saline groundwater water levels are known to be less than 2 metres of natural surface in more than 5% of the area in isolated areas of urban areas. | Saline groundwater water levels are known to be less than 2 metres of natural surface in 10% in large part of urban areas. | | | |
| | **Regional impacts** | **Very low** | **Low** | **Moderate** | **High** | **Very high** | **Trend** | **No information** | **Data confidence Low/medium/high** |
| **6** | What is the impact of groundwater use on the recovery of groundwater pressures and watertable levels? | No influence. | There is minimal use of groundwater in the region. | Groundwater use is between 40% and 60% of the LTAEL. | Groundwater use is greater than 60% and less than 80% of the LTAEL. | Groundwater use is greater than 80% of LTAEL. | | | |
| **7** | What is the impact of groundwater use on the recovery of groundwater pressures and watertable levels? | No influence. | There is minimal use of groundwater in the region. | Groundwater use is between 40% and 60% of the LTAEL. | Groundwater use is greater than 60% and less than 80% of the LTAEL. | Groundwater use is greater than 80% of LTAEL. | | | |

**Pressure – Level of consequence indicator questions (cont'd)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **8** | What is the impact of groundwater use on groundwater level and watertable level fluctuations? | No influence. | There is minimal use of groundwater in the region. | Groundwater use is between 40% and 60% of the LTAEL. | Groundwater use is greater than 60% and less than 80% of the LTAEL. | Groundwater use is greater than 80% of LTAEL. | | | |
| | **Localised impacts** | **Very low** | **Low** | **Moderate** | **High** | **Very high** | | **No information** | **Data confidence Low/medium/high** |
| **9** | What is the impact of groundwater use in localised areas? | No Impact. | There are currently areas experiencing localised declines in groundwater levels associated with groundwater use. | There are currently areas experiencing long term localised declines in groundwater levels associated with groundwater use. | There are currently areas identified to be experiencing localised groundwater level declines. | There are currently identified areas of localised groundwater level impact. | | | |
| **10** | What is the impact of groundwater use on surface water? | Disconnected system or the level of impact is minimal. | Groundwater use impacts on surface water flows with a low level of connection. | Groundwater use impacts on surface water flows with a moderate level of connection. | Any groundwater use may impact on surface water flows. | Any groundwater use will impact on surface water flows. | | | |
| | **Groundwater quality impacts** | **Very low** | **Low** | **Moderate** | **High** | **Very high** | | **No information** | **Data confidence Low/medium/high** |
| **11** | Is acidity likely to occur within the aquifer? | Minimal or no influence. | The aquifer has a low susceptibility to acidification. | The aquifer has a moderate susceptibility to acidification. | The aquifer has a moderate to high susceptibility to acidification. | The aquifer is highly susceptible to acidification. | | | |
| **12** | What is impact of nutrients on the aquifer system? | The aquifer has a low permeability and/or watertable levels greater than 20 metres or limited or no use of fertilisers. | The aquifer has a low or moderate permeability and/or watertable levels between 16 metres and 19 metres below natural surface and there is a moderate to high use of fertilisers in the area. | The aquifer has a moderate permeability and/or watertable levels less than 15 metres and there is a moderate to high use of fertilisers in the area. | The aquifer has a moderate to high permeability and/or watertable levels between 6 metres to 10 metres and there is a moderate to high use of fertilisers in the area. | The aquifer has a high permeability and/or watertable levels less than 5 metres and there is a high use of fertilisers in the area. | | | |
| **13** | What is impact of agricultural chemicals on the aquifer system? | The aquifer has a low permeability and/or watertable levels greater than 20 metres or limited or no use of agricultural chemicals. | The aquifer has a low or moderate permeability and/or watertable levels between 16 metres and 19 metres below natural surface and there is a moderate to high use of agricultural chemicals. | The aquifer has a moderate permeability and/or watertable levels less than 15m and there is a moderate to high use of agricultural chemicals in the area. | The aquifer has a moderate to high permeability and/or watertable levels between 6 metres and 10 metres and there is a moderate to high use of agricultural chemicals in the area. | The aquifer has a high permeability and/or watertable levels less than 5 metres and there is a high use of agricultural chemicals in the area. | | | |
| **14** | What is the likelihood of groundwater use influencing the freshwater/salt water interface? | Not applicable. | There is minimal or no change in water quality indicated by monitoring or anticipated where there is no monitoring. | There are known or documented temporary changes in the location or gradient in the salt/freshwater interface beyond natural variation. | There is likely to be a change in the location or gradient in the salt/freshwater interface beyond natural variation. | There is a known change in the location or gradient of salt/freshwater interface beyond natural variation. | | | |
| **15** | What is the likelihood that there has been a change in groundwater salinity? | There is minimal impact or no groundwater use. | Groundwater use within a fresh aquifer is not causing any observed change in the aquifer salinity due to leakage from an adjacent or overlying saline aquifer. | The use of water from a low salinity aquifer that is overlain or adjacent to a saline aquifer is observed to seasonally alter the groundwater salinity in the fresh aquifer. | The use of water from a low salinity aquifer that is overlain or adjacent to a saline aquifer is observed to be causing localised permanent changes in groundwater salinity. | The use of groundwater from a low salinity aquifer that is overlain or adjacent to a saline aquifer is observed to be causing permanent changes in the groundwater salinity of the fresh aquifer. | | | |
| **16** | What is the likelihood of heavy metal contamination? | The aquifer has a low permeability. | The aquifer has a low or moderate permeability and there are potentially sources of heavy metal contamination. | The aquifer has a moderate permeability and there are potentially sources of heavy metal contamination. | The aquifer has a moderate to high permeability and there are potentially sources of heavy metal contamination. | The aquifer has a high permeability and there are potentially sources of heavy metal contamination. | | | |

**Pressure – Level of consequence indicator questions (cont'd)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **17** | What is the likelihood of hydrocarbon contamination? | The aquifer has a low permeability. | The aquifer has a low or moderate permeability and there are potentially sources of heavy metal contamination. | The aquifer has a moderate permeability and there are potentially sources of heavy metal contamination. | The aquifer has a moderate to high permeability and there are potentially sources of heavy metal contamination. | The aquifer has a high permeability and there are potentially sources of heavy metal contamination. | | | |
| | **Aquifer structure pressures** | **Very low** | **Low** | **Moderate** | **High** | **Very high** | | **No information** | **Data confidence Low/medium/high** |
| **18** | What is the consequence of substrate compaction or subsidence? | No or minimal development of the aquifers. | Low level of development in groundwater use and mining not likely to cause subsidence. | Moderate level of development in groundwater use. | Moderate to high level of development in groundwater use or mining activities causing subsidence. | High level of development in groundwater use or a number of mining activities causing subsidence. | | | |