Australian Government

Department of the Environment, Water, Heritage and the Arts

Geoscience Australia

Assessing the Need to Revise the Guidelines for Groundwater Protection in Australia

A Review Report

PREPARED BY GEOSCIENCE AUSTRALIA
FOR
THE AUSTRALIAN GOVERNMENT DEPARTMENT OF THE ENVIRONMENT, WATER, HERITAGE AND THE ARTS

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by

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Executive Summary

Background
The National Water Quality Management Strategy (NWQMS) provides national policies, guidelines, information and tools to help government and communities manage water resources to meet current and future needs. The Guidelines for Groundwater Protection in Australia were published in 1995 by Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and Australia and New Zealand Environment and Conservation Council (ANZECC). The primary purpose of the Groundwater Guidelines was to provide a national framework for protecting groundwater from contamination in Australia. Many jurisdictions have used the Groundwater Guidelines to develop groundwater policy and regulations designed to improve the management of groundwater resources. From time to time, components of the various NWQMS Guidelines are reviewed; however no systematic review of the Groundwater Guidelines has occurred since its development in 1995.

Purpose of the Project
The purpose of this project was to advise the Department of the Environment, Water, Heritage and the Arts (DEWHA) on whether there was a need to revise the NWQMS Guidelines for Groundwater Protection in Australia.

Project Methodology
The agreed process for this project included the following tasks:

- review of the relevant groundwater quality literature;
- review of the current regulatory and policy frameworks across all Australian jurisdictions for the management of groundwater quality;
- design of a survey / questionnaire (with DEWHA) based on the literature and regulatory review;
- email the survey / questionnaire to the selected end-user groups;
- conduct follow up telephone interviews with the selected end-user groups based on their initial response to the survey / questionnaire; and
- report on the findings to DEWHA (this report).

Key findings
Groundwater Quality Literature Review

- Salinity is the major groundwater quality issue in Australia, followed by acidity, trace elements, nutrients and pesticides. Wetlands and surrounding native vegetation and aquatic ecosystem health are at high risk due to saline groundwater discharge in a number of locations.
- Coastal groundwater salinity and acidity is also becoming an issue in a number of locations and many wetlands are acidified.
- In general, nutrients and pesticides have been detected in groundwater in the most intensively irrigated agricultural regions.
- Groundwater contamination by industrial organic and inorganic contaminants is largely associated with existing and former industrial sites, and occurs mainly in urbanised areas.
- In New Zealand, nitrates and trace elements (iron, manganese and arsenic) are the two major national groundwater quality issues. Nitrate contamination is a major issue in shallow groundwater due to anthropogenic sources.
- In some coastal aquifers, high salinity levels arise from seawater intrusion, which is a serious issue for groundwater resource management in some regions in both Australia and New Zealand.

- The connectivity between streams and aquifers can have significant implications for water quality. Increased groundwater extraction has decreased groundwater quality and impacted on groundwater-dependent ecosystems (GDEs) and woodlands in a number of locations.
- Climate change is likely to increase the stress on groundwater already under pressure from salinity, over-allocation and declining water quality.
- Increased groundwater extraction and sea level rise will result in increased salinisation of coastal fresh groundwater resources, resulting in reduced water quality, and possibly threatening associated GDEs.

Regulatory Review

- The regulatory review analysed almost 300 items of legislation, regulation and policy relevant to groundwater protection, categorised into three "Frameworks" that mirror the three "protection strategies" outlined in the Groundwater Guidelines. The three frameworks are the Groundwater Management Framework, the Environment Protection Framework and the Land-Use Planning Framework.
- The Review has found that the key elements of the Groundwater Guidelines are generally well implemented through the legislation, regulation and policy of the Australian jurisdictions, albeit often without explicitly referring to the Groundwater Guidelines.
- The jurisdictions all use the concept of beneficial uses or environmental values for groundwater, though they have applied these concepts to differing degrees. Encouragingly, some jurisdictions have strongly linked the use of beneficial uses for groundwater across Groundwater Management, Environment Protection and Land-Use Planning Frameworks.
- The jurisdictions generally implement the groundwater management, environment protection and land-use planning tools set out in the Guidelines, to varying degrees. The areas of diffuse pollution and market incentives, in particular, offer opportunities for further implementation.
- As might be expected, Australian legislation, regulation and policy in relation to groundwater protection have become significantly more sophisticated since the Groundwater Guidelines were published nearly 15 years ago.

End-user Survey

The end-user groups have found the Guidelines for Groundwater Protection in Australia to be a useful reference document for providing guidance on overall groundwater protection. However, a number of matters have also been raised for revision.

Recommendations

The key recommendations are:

- update groundwater use information which have become obsolete in relation to urban and community reliance on groundwater in Australia and overseas;
- ensure the Guidelines address current and emerging issues such as groundwater-surface water connectivity, acid sulfate soils, surface and sub-surface groundwater dependent ecosystems, managed aquifer recharge and climate change;
- include appropriate links to other NWQMS guidelines;
- include discussion on recent Australian Government water policy initiatives such as National Water Initiative (NWI), Water for the Future, Water Act 2007, National Groundwater Action Plan, and also directions undertaken at the State and Territory levels;
- update Tables in Appendices;
- update bibliography and include references since the Guidelines were published;
- develop as an interactive online document with links to other relevant websites so that users can easily access linked material such as ANZECC Drinking Water Quality Guidelines;

- expand the existing discussion in relation to the precautionary principle, the polluter pays principle and equitable considerations (in the form of intergenerational equity);
- expand the existing discussion in relation to intervention by "command" to include modern tools of best practice environmental management and waste minimisation;
- include modern examples of Australian best practice in relation to market incentives, controlling diffuse sources of pollution and waste minimisation;
- include discussion of the following "new" issues in groundwater protection law and policy: (a) water quality requirements of groundwater dependent ecosystems, including stygofauna; (b) the potential threat to groundwater quality posed by climate change; (c) "cultural and spiritual values" as a beneficial use; (d) regulation of geothermal energy and geological storage of greenhouse gases; (e) regulation of water use as well as abstraction; (f) managed aquifer recharge; (g) acid sulfate soils; and (h) strategic impact assessment; and
- include discussion of the significantly expanded role of the Commonwealth in the area of water management and water quality legislation, regulation and policy.

1. The NWQMS and the Groundwater Guidelines

1.1 THE NATIONAL WATER QUALITY MANAGEMENT STRATEGY

The National Water Quality Management Strategy (NWQMS) is Australia's overarching strategy for improving water quality. The NWQMS was developed co-operatively by the Commonwealth and the States through two Ministerial Councils – the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) and the Australia and New Zealand Environment and Conservation Council (ANZECC). The Natural Resources Management Ministerial Council, which assumed the functions of ARMCANZ, and the Environment Protection and Heritage Council, which assumed the functions of ANZECC and the National Environment Protection Council (NEPC), are now responsible for the NWQMS, including the Groundwater Guidelines.

The NWQMS aims to achieve a nationally consistent approach to managing water quality, while allowing different jurisdictions the flexibility to respond to differing circumstances at regional and local levels. The NWQMS comprises two types of documents:

- higher level documents describing policies and processes, which deal with water quality at a strategic level; and
- lower level guidelines, which deal with water quality in the particular context of end uses and particular water sources.

At the higher level, the NWQMS includes three documents produced by ARMCANZ and ANZECC: Water Quality Management – An Outline of the Policies (1994), Policies and Principles – A Reference Document (1994) (Policies and Principles Document), and Implementation Guidelines (1998) (Implementation Guidelines). These documents provide the framework within which the Groundwater Guidelines operate, and set out the broader context for analysing how the jurisdictions implement the Guidelines. At the lower level, several guideline documents deal with benchmarks for water quality and monitoring, groundwater protection, different types of diffuse and point sources, and recycled water. Figure 1, below, sets out how the documents relate to each other, and their relevance to groundwater protection.

1.2 THE GROUNDWATER GUIDELINES

Published in 1995, the Groundwater Guidelines are the only element of the NWQMS that specifically seeks to protect groundwater from contamination. The Groundwater Guidelines apply the elements of the higher level NWQMS documents at a detailed level, in the groundwater context. The Groundwater Guidelines adopt a number of key concepts, and set a planning process for protecting groundwater quality, described below.

1.2.1 Key Concepts

Chapters 1 and 2 of the Groundwater Guidelines introduce the Guidelines' objective, scope, and context, and outline the need for groundwater protection. Chapters 3 to 5 set out the key elements of the Guidelines for the purposes of this Review, namely:

- the underlying principles of the Groundwater Guidelines, being the concepts of beneficial uses and values, the polluter pays principle and equitable considerations in relation to groundwater quality protection (Chapter 3 of the Guidelines), while the precautionary principle also features in the Guidelines (pp.11 and 40);

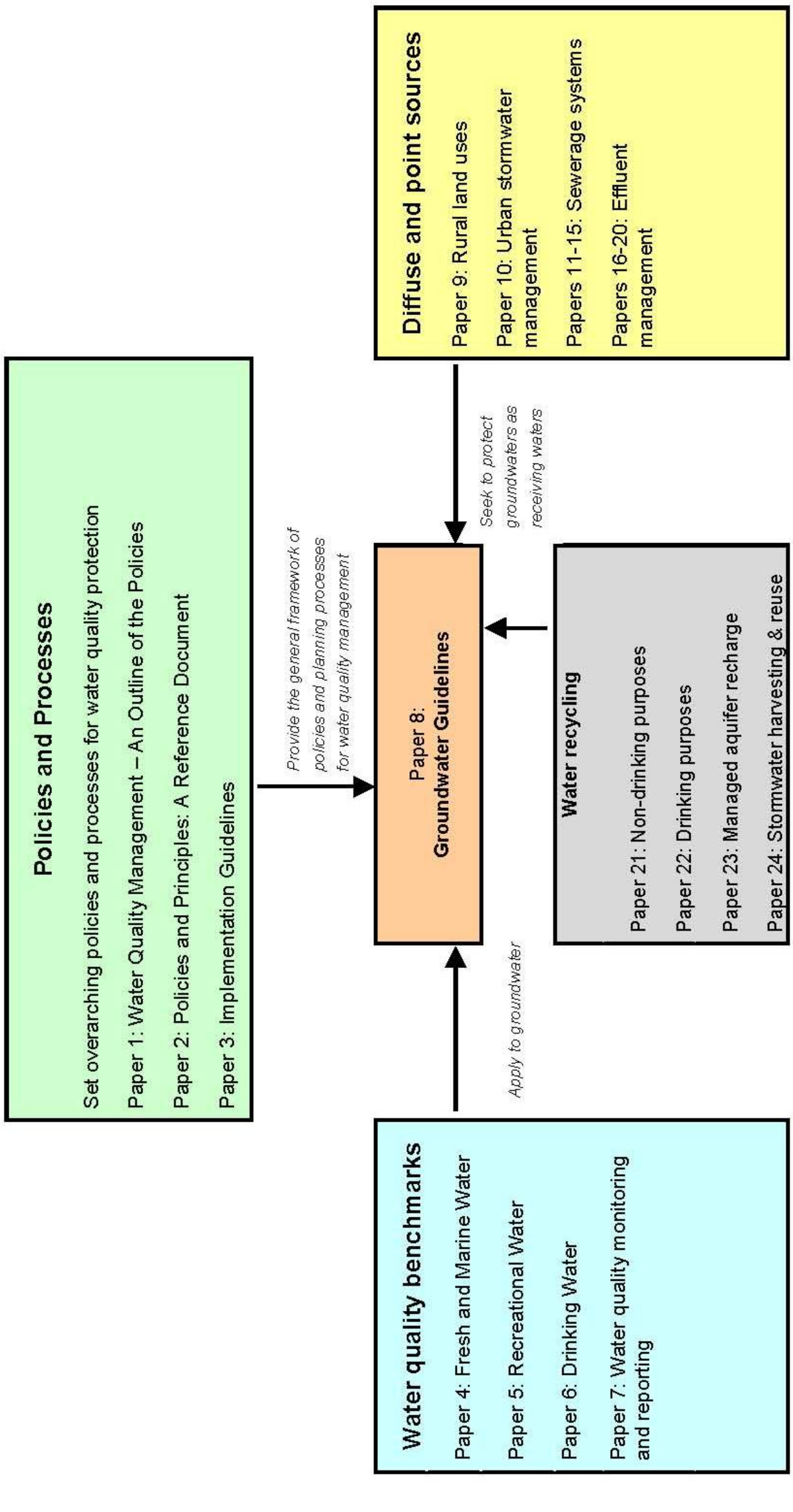


Figure 1: *The structure of the National Water Quality Management Strategy in overview*

- approaches to groundwater protection, namely:
  - three forms of "intervention": first, intervention by command—that is, by laws which directly control actions and activities; second, intervention through market mechanisms; and third, intervention through public participation and education (section 4.1 of the Guidelines); and
  - three types of "protection strategies" or types of legislative tools, within which particular protection measures are undertaken: first, groundwater management; second, land-use planning; and third, environment protection (sections 4.2 to 4.6 of the Guidelines); and
  - a general approach to groundwater protection planning, which involves assessing the resource, setting beneficial uses and accompanying criteria, developing protection measures, providing contingency measures and monitoring requirements, and implementing the plan (Chapter 5 of the Guidelines).

1.2.2 Developing a Protection Plan

The Groundwater Guidelines use the term "plan" broadly:

> Groundwater protection plans and their component measures may take many forms. They may vary from policy statements outlining broad management objectives to prescriptive regulatory programs, including statutory controls and specific regulations on contaminating activities: p.33.

They suggest the following steps for preparing a "plan", in this broad sense (Figure 3, Groundwater Guidelines):

(a) Define broad objectives for groundwater protection planning (para 5.4).

(b) Assess the resource: understand the quantity, quality and extent of the resource (para 5.3).

(c) Identify beneficial uses and values: identify the objectives of protection in terms of specific beneficial uses and values for the resource, recognising that these can differ for different parts of a large aquifer (paras 5.4 and 5.5). This will also require an assessment of the resource, existing and planned developments, environmental features and allocation policies.

The Groundwater Guidelines adopt the five broad categories of beneficial uses and values of groundwater that were outlined in the 1992 version of the ANZECC Australian Water Quality Guidelines for Fresh and Marine Waters (para 3.2):

(i) ecosystem protection;
(ii) recreation and aesthetics;
(iii) raw water for drinking water supply;
(iv) agricultural water; and
(v) industrial water.

A beneficial use is the expression of a desired long-term outcome for a particular groundwater resource (para 4.2). Beneficial uses are now termed "environmental values" and are described in the current ANZECC Guidelines as:

(i) aquatic ecosystem protection;
(ii) primary industries (irrigation and general water uses, stock drinking water;
(iii) aquaculture and human consumption of aquatic foods);
(iv) recreation and aesthetics;
(v) drinking water;
(vi) industrial water; and
(vii) cultural and spiritual values.

If there is no identified beneficial use or value (for example, in the case of a deep, extremely poor quality confined aquifer), "developments which affect the water quality in the aquifer would have to be carefully evaluated and justified in a way that meets the precautionary principle" (para 3.2).

(d) Set water quality criteria for the beneficial uses to be protected. Criteria may be narrative and therefore flexible, or prescriptive (para 5.6). Criteria may be applied at the boundary of a zone of discharge, at the boundary of a property on which discharge occurs, or at the point of discharge of effluent (para 5.7).

(e) Select appropriate protection strategies. There are three major types of protection strategies (para 4.2):

- (i) groundwater management tools, including vulnerability maps, aquifer classification systems, wellhead protection plans and measures related to the allocation and utilisation of the resource (para 4.2 and 4.3);
- (ii) land-use planning tools to prevent groundwater contamination at inappropriate locations (paras 4.2 and 4.4); and
- (iii) environment protection tools to control point source and diffuse pollution, minimise the production of waste, and protect groundwater at specific sites (paras 4.2 and 4.5).

(f) Engage in monitoring and review. A monitoring and review program should assess the effectiveness of a groundwater strategy (para 5.10), both:

- (i) in a broad sense, including an assessment of the extent to which the plan has been implemented, the success of the plan in meeting its goals, and difficulties in implementation and compliance; and also
- (ii) in a technical sense, through groundwater monitoring, including monitoring by a person whose activities pose a contamination risk, monitoring consistent with standards chosen, and reporting to the regulating agency.

(g) Include contingency measures: approval for a contaminating activity should include contingency measures that will apply in the event of contamination, for example, no action, ceasing the activity, containment, and clean-up (para 5.11).

(h) Select and implement preferred options: select a broad approach for State-wide application, and develop local measures at a more detailed level.

2. Project Background

2.1 OVERVIEW

The Guidelines for Groundwater Protection in Australia (NWQMS Guidelines #8) were published in 1995 by ARMCANZ and ANZECC. The primary purpose of the Groundwater Guidelines was to provide a national framework for protecting groundwater from contamination in Australia. Many jurisdictions have used the Groundwater Guidelines to develop groundwater policy and regulations designed to improve the management of groundwater resources.

Scientific knowledge of groundwater systems in Australia has grown significantly since the guidelines were first developed in 1995. Science has provided new insights into connectivity between aquifers and links between groundwater and surface water systems. In addition, recent drought-related reductions in surface water availability have resulted in greater use of groundwater resources. Previously unknown fauna and groundwater dependent ecosystems have also been described. From time to time, components of the various NWQMS Guidelines are reviewed; however no systematic review of the Groundwater Guidelines has occurred since its development in 1995.

In January 2009, the Australian Government commissioned a consultant, and drew on the expertise of the NWQMS Contact Group, to provide a preliminary review of the NWQMS Guidelines (1-22). The preliminary review suggested a major revision of the 1995 Groundwater Quality Guidelines. Aside from the views presented by the consultant, the extent to which the current guidelines specifically meet jurisdictional needs is unclear. In response to this Geoscience Australia was contracted to evaluate the need and extent for any revision of the guidelines.

The purpose of this review is to assess the existing published information relating to groundwater quality in Australia and New Zealand. Firstly, the review considered the range of relevant groundwater quality issues including: salinity, nutrients, pesticides, industrial contaminants and acidity; groundwater dependent ecosystems; and groundwater-surface water interactions. Secondly, the review considered the management implications and relevance of the Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 1995) to these issues. The information on various groundwater quality issues provided in this review report has been solicited mainly through publicly available web sources. While the collation of publicly available information from different sources is valuable, it needs to be noted that reports on groundwater quality are often unpublished and not publicly available.

2.2 SCOPE OF THE PROJECT

The Department of Environment, Water, Heritage and the Arts (DEWHA) has contracted GA to ascertain the need to revise the NWQMS Guidelines for Groundwater Protection in Australia (#8, 1995). If a review is required, GA must provide recommendations and advice on the scope of any review.

In summary, this project aims to:

- review scientific literature as it relates to management of groundwater quality;
- review current regulatory and policy frameworks across all jurisdictions for the management of groundwater quality;

- identify key stakeholders and end-users of groundwater quality guidelines and seek to understand the extent to which the guidelines are adequate for supporting end-user needs; and
- prepare a final report.

3. Project Methodology

The aim of the project is to advise on the need to revise the NWQMS Guidelines for Groundwater Protection in Australia (NWQMS Guidelines #8). The agreed process for this project is:

- review of the relevant groundwater quality literature (literature review);
- review of the relevant legislation, regulations and policies across all jurisdictions for the management of groundwater quality (regulatory review);
- design a survey / questionnaire (with DEWHA) based on the literature and regulatory review;
- email the survey / questionnaire to the selected end-user groups;
- follow up telephone interviews with the selected end-user groups based on their response to the survey / questionnaire; and
- report on the findings to DEWHA.

3.1 LITERATURE REVIEW

Firstly, the review considered the range of relevant groundwater quality issues including: salinity, nutrients, pesticides, industrial contaminants and acidity; groundwater dependent ecosystems; and groundwater-surface water interactions. Secondly, the review considered the management implications and the relevance of the Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 1995). The information on various groundwater quality issues provided in this review report has been solicited mainly through publicly available web sources in an effort to get a national picture.

3.2 REGULATORY REVIEW

The Regulatory Review analyses the extent to which, and precisely how, each Australian jurisdiction has implemented the elements of the Groundwater Guidelines through its legislation, regulation and policy. The methodology for the regulatory review involved:

Step 1: developing three standard "Framework Tables", which categorise and set out important components of the Guidelines for the three broad types of legislation, regulation and policy, corresponding to the three major types of "protection strategies" described in the Groundwater Guidelines (groundwater management, environment protection and land-use planning frameworks.

Step 2: identifying relevant items of legislation, regulation and policy by reviewing each jurisdiction's Administrative Arrangements Orders (which set out the legislation administered by each minister or department of the Government) and agency websites;

Step 3: analysing each item identified to assess how it implements components of the Groundwater Guidelines, and annotating the relevant Framework Table with the relevant symbol and explanation of implementation. Note that this analysis is correct to the state of the legislation, regulation and policy as of July 2009.

Step 4: for ease of use:

(i) summarising key points in relation to each jurisdiction's implementation of the Groundwater Guidelines (key strengths, opportunities for further implementations, and innovative approaches); and

(ii) representing the extent of each jurisdiction's implementation of the Groundwater Guidelines using a diagram for each Framework Table.

3.3 END-USER SURVEY

To assess the need to revise the Guidelines for Groundwater Protection in Australia, it is necessary to understand the target audience ("end-users") and their needs. A methodology has been developed to assess end-user needs and the steps involved are as follows:

- establish a network of key jurisdictional personnel, researchers and natural resources and catchment management authorities involved with use of the groundwater quality protection guidelines;
- design a survey questionnaire (with DEWHA) based on the literature and regulatory review;
- email the survey questionnaire to the selected end-users;
- follow up telephone interviews with the selected end-users based on their response to the survey questionnaire; and
- end-user analysis and report on the findings to DEWHA.

4. Current Knowledge of Groundwater Quality Issues - a literature review

4.1 UNDERSTANDING GROUNDWATER

4.1.1 What is Groundwater?

Groundwater is the water stored underground in rock fractures and pores that lay beneath the surface of the earth (AWA, 2007). Groundwater is a vast and slow moving resource that greatly exceeds the volume of other available freshwater sources (although much groundwater is saline rather than fresh). Geological formations composed of permeable materials and capable of storing and yielding large quantities of water are called aquifers. Aquifers typically consist of gravel, sand, sandstone or fractured rocks.

There are two types of major aquifers – unconfined and confined (Figure 2). An unconfined aquifer has no confining layers between the saturated zone and the land surface. Groundwater is in direct contact with the atmosphere through the open pore spaces of the overlying soil or rock. The water table forms the upper boundary of the unconfined aquifer. In an unconfined aquifer, the water level in a well rests at the water table. A confined aquifer is an aquifer that is overlain by a relatively impermeable layer of rock or substrate such as an aquitard. Confined aquifers are usually under pressure because they occur at depth from the surface and are compressed by the overlying confining rock and substrate. Groundwater that is under sufficient pressure to allow it to flow to the surface is referred to as artesian water.

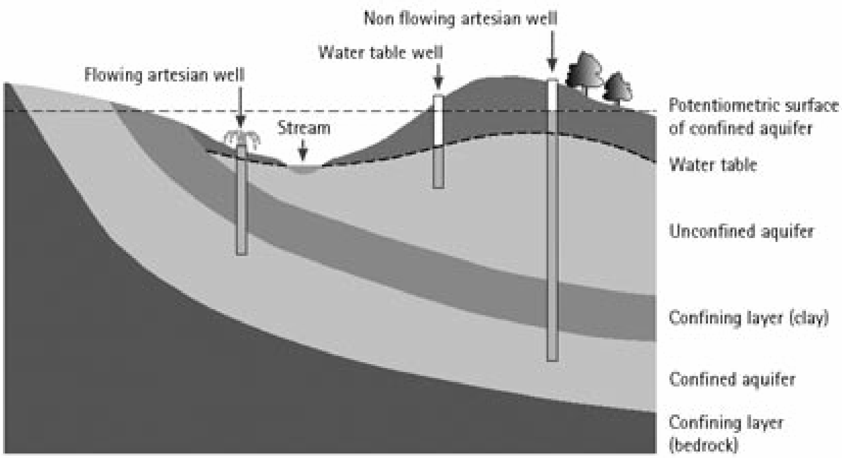


Figure2: *Types of aquifers (adapted from Plazinska, 2007)*

4.1.2 Groundwater in Australia - availability

Groundwater is found in many different types of aquifers in Australia. The geology of Australia is diverse, so there are different types of aquifers. Groundwater can be found beneath most land in Australia, however the resources are unevenly distributed and vary in quality and aquifer yield (Lau et al. 1987; Figure 3). In some regions groundwater provides the majority of water needs, while other regions have no access to viable groundwater resources. Many of the potentially high-yielding aquifers represent a limited resource as they are located in arid and semi-arid areas of the continent and receive relatively low rates of natural recharge compared with the volume of water they store. Poor groundwater quality (high salt content) can be a major impediment to development of the resource in other areas. Estimates of the total volume of drinking quality groundwater that can be sustainably extracted is about 25 000 GL/year (NLWRA, 2001).

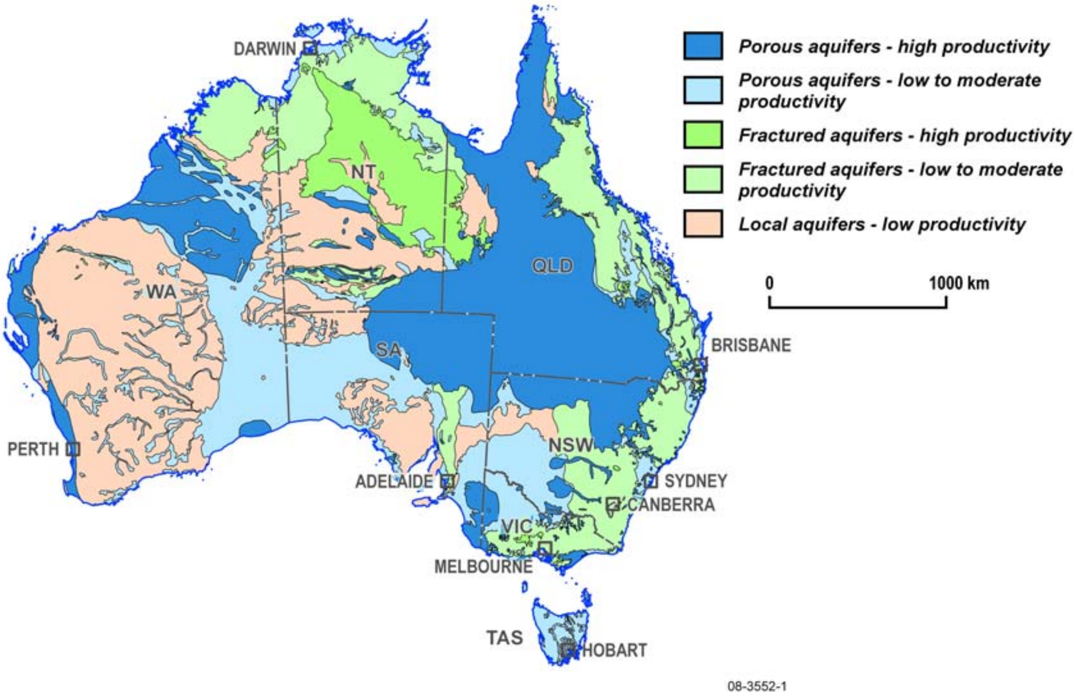


Figure3: *Groundwater basins in Australia*

About 20% of all bores in Australia are in alluvial systems and they account for 60% of Australia's groundwater extraction. Alluvial aquifers are a major source of irrigation, town, stock and domestic users. Due to their shallow and unconfined nature, alluvial aquifers are susceptible to contamination and pollution. Approximately 33% of all bores in Australia are in fractured systems, representing 10% of total groundwater extraction. The quality of groundwater is highly variable in fractured systems.

The Great Artesian Basin is one of the largest groundwater basins in the world. Eight of the ten provinces with the highest groundwater use are in eastern Australia. The Great Artesian Basin underlies arid and semi-arid regions across 1.7 million km^2 or one-fifth of Australia and stores over 60 000 000 GL of water (Habermehl, 2007). It covers 22% of the Australian continent and contains water that is up to two million years old. Artesian groundwater quality is good and suitable for domestic, town water supply and stock use.

4.1.3 Groundwater Management Units

Australia has 61 major groundwater provinces – areas of broad uniformity of hydrogeological and geological conditions with reasonably uniform water-bearing characteristics (predominantly sediment or fractured rock).

For the purposes of better and more efficient groundwater management, smaller groundwater management units (GMU) have been used. There are 422 GMUs in Australia. Groundwater management units are defined by state and territory governments and are based on areas where groundwater has a low salinity and high use or where groundwater is used in environmentally sensitive areas. Groundwater management units include one or more hydraulically connected aquifers; and one unit may lie below or above many other units. Since the states and territories undertake groundwater management, groundwater management units do not cross state or groundwater province boundaries. Areas outside of groundwater management units are called 'unincorporated areas'.

4.1.4 Groundwater in New Zealand

All of the major aquifers in New Zealand are sedimentary (Thorpe, 1992). The aquifers in Canterbury, Hawke's Bay, Wellington, and Gisborne are composed of gravels and sands, mostly derived from greywacke boulders eroded into valleys by rivers and alluvial fans. In the Tasman District, many of the sedimentary aquifers have been derived from granitic material. Other important aquifers are composed of fractured basalts (Waikato, Auckland, Northland), pumice (Bay of Plenty), and limestones (Tasman), although these aquifers are minor in comparison to the alluvial gravel aquifers.

Many of the aquifers are unconfined and shallow (42%) or semi- confined (18%), but 40% are confined and deep. The average thickness of the aquifers is 19 m, and the average depth to the top of the aquifers is 38 m. However, 38% of the bores have water levels <10 m below the surface.
The areal extent of most aquifers in New Zealand is relatively small on a world scale, but they are relatively complex due to the active tectonic regime in New Zealand (Thorpe, 1992). The Canterbury Plains gravel aquifer system is the largest in the country, and covers about 8000 km^2 and may be up to 500 m thick.

4.1.5 Groundwater Use in Australia

Groundwater makes up approximately 17% of Australia's accessible water resources and accounts for over 30% of our total water consumption (NWC, 2008). Groundwater use across Australia's States and Territories increased by 58% from 2600 GL in 1983/84 to 4200 GL in 1996/97 (NLWRA, 2001). Total groundwater use across Australia's States and the Territories in 2004/05 is estimated at 3500 GL/year (AWR 2005; Table 1). Groundwater use represents a greater fraction of total water use during dry periods. With the imposition of caps on surface water use and recent drought, current groundwater use is estimated to be around 6000 - 8000 GL/year. The increased groundwater use has greater impacts on groundwater quality.

In the Murray-Darling Basin (MDB) the introduction of a surface water Cap in 1995 has caused many communities to switch to using groundwater for irrigation (MDBC, 2003). Over large areas of the MDB, groundwater levels have declined during the last decade due to the combined effects of on-going drought and excessive groundwater pumping (MDBC, 2004). Current (2004/05) estimated groundwater use for the MDB is 1832 GL/year and future groundwater extraction could double (according to current groundwater management plans) and reach 3956 GL/year by 2030 (CSIRO, 2008). Available data suggest that there are now large areas of the MDB where groundwater is being used above a sustainable rate; groundwater levels are declining as a consequence of over-use and drought.

Table 1: Mean annual groundwater use (GL) in 1983-84, 1996-97 and 2004-05

STATE/ TERRITORY	TOTAL GROUNDWATER USE (GL) 1983-84[1]	TOTAL GROUNDWTAER USE (GL) 1996/97[1]	TOTAL GROUNDWATER USE (GL) 2004-05[2]
New South Wales	318	1008	800
Victoria	206	622	401
Queensland	1121	831	222[3]
Western Australia	373	1138	1501
South Australia	542	419	518
Tasmania	9	20	21
Northern territory	65	128	65
ACT	n/a	5	0.7
Total	2634	4171	3528.7

[1]Source: NLWRA (2001)
[2]Source: AWR (2005)
[3]only metered bores in Queensland GMUs

4.1.6 Groundwater as a Resource

Groundwater resources support many urban, rural and remote communities around Australia. Groundwater has provided great benefits for many communities in recent decades through its direct use as a drinking water source, for irrigated agriculture, industrial development and, indirectly, through ecosystem and stream flow maintenance. About 32% of groundwater is extracted for urban-industrial use, 51% for irrigation and 17% for stock watering and rural use; but this varies by state (Ball et al. 2001). Considerable variation exists in groundwater usage between the states and territories (Table 1). For example, South Australia, New South Wales and Victoria use more than 60% of extracted groundwater for irrigation, whereas Western Australia uses 72% for urban and industrial purposes. Queensland uses a third of groundwater for rural stock and domestic uses.

Many Australian capital cities and some major urban centres also benefit from groundwater (Figure 4). In recent years, groundwater use in major urban centres and cities increased significantly due to reduced surface water availability. Figure 4 shows the amount of surface water and groundwater used for some of Australia's capital cities (AWR, 2005). Groundwater is particularly important for the Perth urban centre where it accounts for about 80% of all the water used. Other capital cities such as Sydney, Darwin and Adelaide also use groundwater, accounting for 25, 32 and 20% respectively, of the total water used.

Most remote communities of Australia are in the arid and semi-arid regions and are heavily reliant on groundwater resources for their survival. However, limited information is available on the groundwater quality, recharge, or on the total volumes being extracted by the dependant communities and other users. Groundwater supply security in some remote communities has been compromised by increases in salinity due to drought. In Australia, up to 4 million people are depending totally or partially on groundwater for domestic water supplies (AWA, 2007). The Northern Territory and Western Australia have the highest proportions of distributed water originating from groundwater resources, making up approximately 70% of their total water use (AWA, 2007).

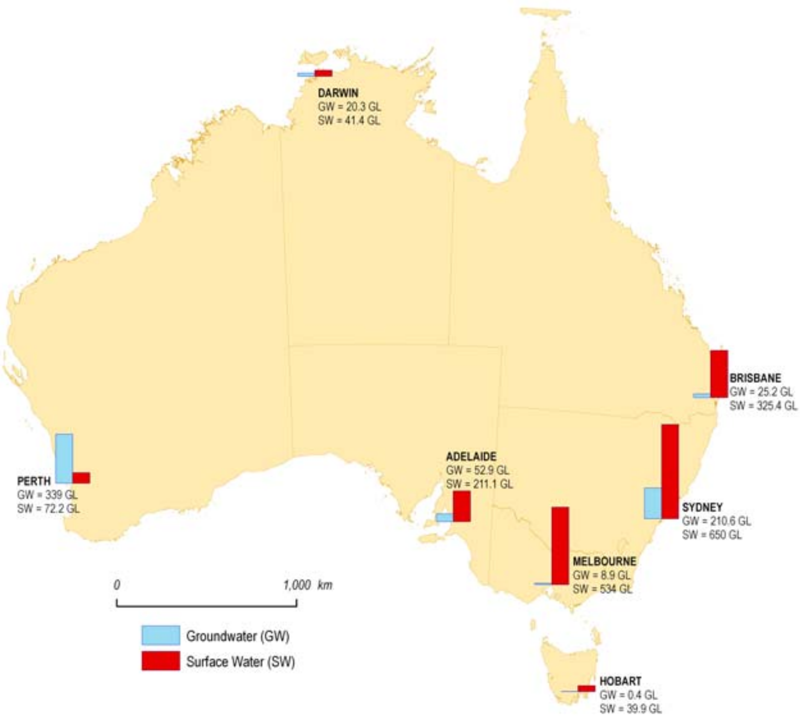


Figure 4: *Groundwater and surface water use in some major capital cities of Australia*

4.1.7 Groundwater Extraction on Water Availability and Quality

Groundwater is increasingly being seen as an alternative source to surface water supplies in recent years in Australia and New Zealand. However, when groundwater extraction exceeds the average long-term recharge rates from rainfall, groundwater levels will steadily decline and impact on aquifer yields and quality. For example:

- Lower yields mean less water is available for domestic water supply, stock drinking water, irrigation and other uses.
- Springs, wetlands, streams and rivers that are fed by groundwater may partially or completely dry up, causing adverse ecological effects.
- Low flows of rivers may not be sufficient for proper dilution of discharged wastewater, resulting in greater surface water pollution.
- An increased threat of saltwater intrusion into fresh groundwater supplies in coastal regions.
- Deterioration of groundwater quality.

To avoid irreversible damage to groundwater systems, the extraction amount for any aquifer should be established based on the long-term sustainable yield assessment, i.e. the volume of groundwater that can be extracted annually from a groundwater basin without causing adverse effects.

4.1.8 Connectivity – Groundwater and Surface water

Groundwater and surface water are interconnected and interchangeable resources in many regions of Australia (Brodie et al. 2007). In many cases it is actually the same water: groundwater becomes surface water, and surface water becomes groundwater. Nearly all surface water features (streams, lakes, wetlands and estuaries) interact with groundwater. As a result, withdrawal of water from streams can deplete groundwater or conversely, extraction of groundwater can deplete water in streams, lakes or wetlands. Contamination of surface water may cause degradation of groundwater quality; and, conversely, contamination of groundwater can degrade surface water (Figure 5).

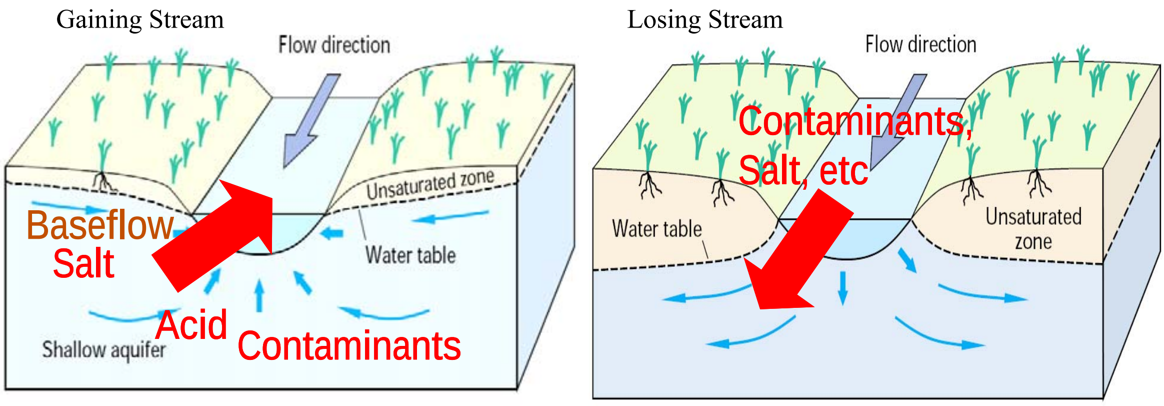


Figure 5: *Groundwater-surface water interaction and water quality (source: Winter et al.1998)*

4.1.9 Groundwater Contamination

Contamination of groundwater may be associated with specific point sources or may occur over a wide area (non-point source). The sources of groundwater contamination are numerous and diverse, including: improper disposal, use and storage of chemicals; poor installation and maintenance of septic tanks; landfills; leaking or poorly located storage lagoons used by industries, farms, mining operations, oil and gas producers; over- and improper application of fertilisers and pesticides; land application of sludges and wastewater or urban runoff. Contaminants can be extremely hard to remediate, with pollution often resulting in permanent damage to the aquifer. It is better to prevent groundwater contamination than risk contamination and subsequently spend significant resources to clean it up.

Point source contamination of groundwater is generally controlled by Environmental Protection Agencies (EPA) in the states and territories in Australia. Great improvements in groundwater pollution prevention have occurred in the last few decades, but diffuse source contamination (for example, pesticides, fertilisers, and septic tanks) remains poorly controlled in some jurisdictions (Harris, 2006). In New Zealand, regional councils, through the Resource Management Act, are responsible for the management of groundwater resources.

4.2 GROUNDWATER QUALITY ISSUES – LITRETURE REVIEW

Major threats to groundwater quality include: increased levels of salinity, nutrients, acidity, trace elements, pesticides and other industrial contaminants. These can occur either from direct contamination or through changes in groundwater behaviour as a result of over-extraction or reduced groundwater recharge. Knowledge of the present status of groundwater quality and its improvement or degradation with time is fundamental to improving water quality management. There is, however, a paucity of information available on the quality of Australia’s groundwater resources. The available information is summarised and presented below.

4.2.1 Salinity

4.2.1.1 Salinity in Australian groundwater

Salinity is a major groundwater quality issue in Australia. Salts are a natural component of the Australian landscape and are derived from different sources. Salinisation of groundwater mainly occurs by dryland salinity, irrigation salinity or seawater intrusion. Review of the salinity status of groundwater undertaken for the National Land and Water Resources Audit (NLWRA) in 2001 revealed that approximately 72% of Australia’s readily accessible groundwater supply is suitable for drinking water (NLWRA, 2001; Table 2). The limited availability of data and the intensity of monitoring coverage limit the comprehensiveness of this groundwater salinity assessment. There has been no comprehensive assessment of the status of national groundwater salinity since this report.

Table 2: Groundwater sustainable yield (GL) by salinity status (mg/L)
(adapted from NLWRA, 2001)

STATES	<500	500-1000	1000-1500	1500-3000	3000-5000	5000-14000	>14000	TOTAL
NSW	554	4237	129	790	480	-	-	6189
VIC	302	422	244	367	207	1377	797	3717
QLD	1422	1030	113	160	35	23	-	2784
WA	514	1162	1150	1500	766	841	371	6304
SA	-	290	709	102	21	25	-	1146
TAS	1585	767	-	178	-	-	-	2531
NT	5785	186	324	141	5	-	-	6441
ACT	103	-	-	-	-	-	-	103

Shallow groundwater salinity is highly variable in Western Australia (WA) and most is naturally brackish to saline (Figure 6). Pockets of shallow fresh groundwater are found along the Swan Coastal Plain, the South West corner of the State and parts of the Pilbara and Kimberley. Groundwater salinity levels have tend to be more stable in recent years, except where catchment hydrology has been altered or high rates of water extraction occur in WA (EPA WA, 2007). Irrigation salinity is also a problem in some irrigated areas of the southern Swan Coastal Plain, from Gingin to Dunsborough and also in the Ord River irrigation area (Smith et al. 2007).

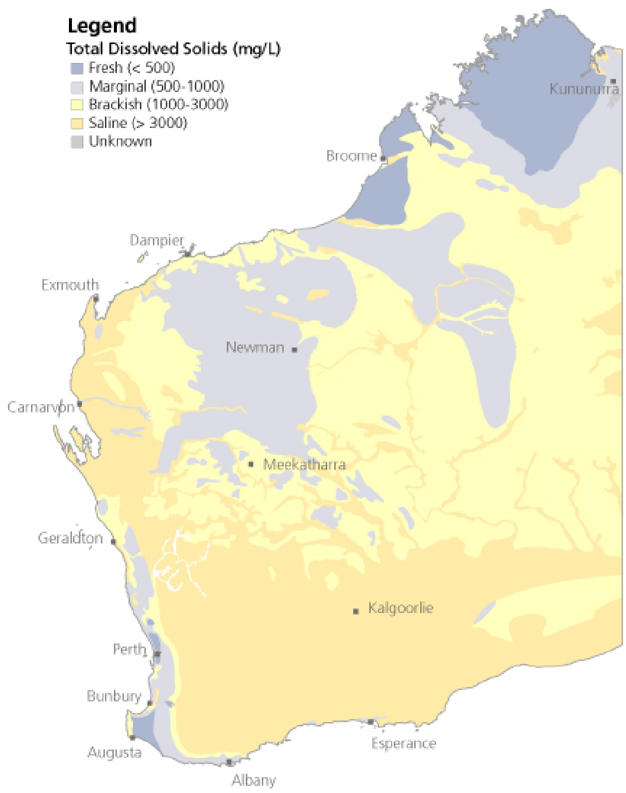


Figure 6: *Groundwater salinity of shallow aquifers across Western Australia (adapted from EPA WA, 2007)*

In New South Wales (NSW), the salinity of groundwater is highly variable and there are many areas where groundwater is not suitable for consumption or irrigation (DEC NSW, 2006). Activities such as over-pumping can result in the salinisation of good quality groundwater resources. Many areas of south-western NSW are underlain by sediments of marine origin which yield regionally saline groundwater (DEC NSW, 2006).

Groundwater salinity in Queensland (QLD) may be increasing in some areas, but decreasing in others. For example, coastal areas of the Burdekin, as well as parts of the other larger catchments such as the Fitzroy, Burnett, Condamine and Lockyer, groundwater salinity is rated poor to moderate for general use, although moderate to good for irrigation (EPA QLD, 2007). Groundwater salinity is increasing in coastal catchments due to salt water intrusion. Groundwater in the Moonie, Border Rivers (west of Goondiwindi) and Lower Balonne has significant, though variable salinity (Biggs et al. 2005). Salinity induced by irrigation (horticulture) and leaky dams occurs at many sites in the Granite Belt of southern Queensland (Biggs et al. 2005).

Groundwater in the South East of South Australia, Northern Adelaide Plains, Adelaide Plains, Barossa Valley, Willunga Basin and Eyre Peninsula are rated poor for salinity (EPA SA, 2008). Groundwater salinity has increased in some regions due to continued pressure from heavy extractions and poor irrigation practices in SA. A broad assessment of groundwater monitoring across SA during the period 2002-07 indicated that 44% of samples exceeded the drinking water quality criteria.

Groundwater salinity is a major issue in Victoria and approximately 240,000 ha of land are known to be affected by discharge of saline groundwater (Vic SoE, 2008). Salinisation of surface water is also an important consequence of rising saline groundwater. Saline groundwater may discharge into sensitive areas of remnant native vegetation, arable land, near towns or directly into rivers and streams. Wetlands and surrounding native vegetation is particularly at risk because their low elevation coincides with saline groundwater discharge areas. Victoria has 11 Ramsar wetland sites (DSE, 2008) and five of these (45%) may be at risk of damage from salinity and shallow saline groundwater by 2020 (Table 3).

Table 3: Victorian assets at risk of damage from salinity and shallow saline groundwater (Adapted from NLWRA, 2001)

	YEAR	
ASSET AT RISK	**2000**	**2020**
Agricultural land (ha)	555,000	1,170,000
Perennial vegetation (ha)	6,200	11,830
Length of stream or perimeter of wetlands (km)	10,121	18,146
Ramsar wetlands (number)	4	5
Towns (number)	10	21
Roads (km)	3,896	8,054
Railway (km)	131	303

Wetlands in the Goulburn Broken and Corangamite catchments are considered to be most at risk from salinity. Many rare or threatened species occur in areas that have or are predicted to develop shallow groundwater tables in Victoria and these species will come under further pressure as a result of loss or change of habitat due to salinity (Vic SoE, 2008).

4.2.1.2 Salinity in New Zealand groundwater

Salinity is not a major issue in New Zealand aquifers. The relevant aesthetic guideline values are exceeded at only 2−4% of all sites tested for groundwater during 2006 (Ministry for the Environment, 2007). High-salinity groundwater are found in certain regions, notably Gisborne but also in northern Hawke’s Bay, central Manawatu, south Wairarapa, Auckland (especially deep aquifers), and south Canterbury around Oamaru (Figure 7). In some coastal aquifers high salinity arising from seawater intrusion is a serious issue in regions such as Northland, Bay of Plenty and Horowhenua (Ministry for the Environment, 2007).

Significant increasing and decreasing trends in salinity are detectable at approximately equal proportions of monitoring sites (16.5% and 14.2%, respectively) during 1995-2006. Sites with increasing trends in salinity are found in most areas of New Zealand, especially Waikato, Southland and Wellington (Ministry for the Environment, 2007).

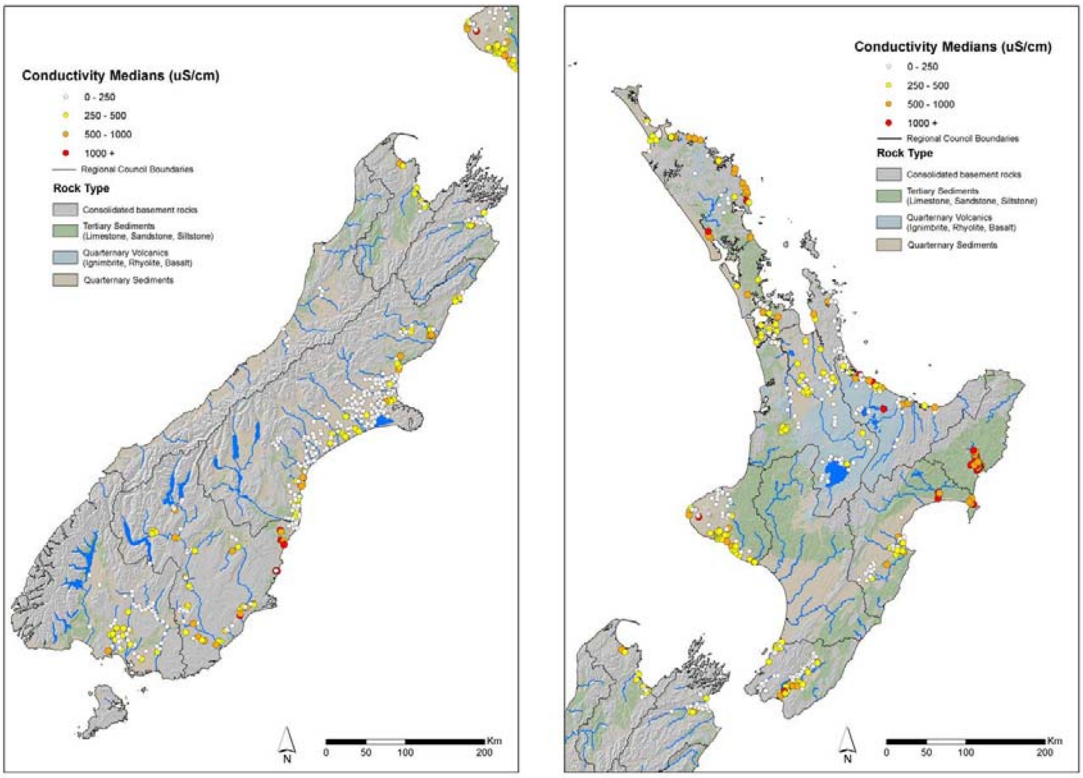


Figure 7: *Median salinity in New Zealand groundwater (adapted from Ministry for the Environment, 2007)*

4.2.2 Nutrients

4.2.2.1 Nitrogen in Australian groundwater

Among the nutrients nitrate is perhaps the most widespread contaminant in Australian and New Zealand groundwater. Nitrate is highly soluble and very mobile, which facilitates plant uptake, but also makes it highly susceptible to leaching to groundwater. There are many sources of nitrate, both natural and anthropogenic, that can contribute to groundwater contamination. Anthropogenic sources includes intensive agriculture (nitrogen-containing fertilisers), dairy and sewage effluent.

Data on nitrogen levels in Australian groundwater are very limited. A key source of nitrate concentration data is the one-off analysis of groundwater samples obtained from newly constructed bores. Although not providing an indication of any temporal variability, this information continues to provide data on the spatial distribution of nitrate contamination. This is particularly the case for broad scale diffuse source monitoring. In contrast, smaller scale point source or multiple point source plumes can be more readily identified by targeted observation bore networks.

Available data on nitrate-N concentrations are shown in Figure 8. The results indicate that there is a limited monitoring of nitrate in groundwater in some areas of Australia. The major sources of data in Figure 8 are generally related to specific research and investigation projects from 1995-2008 (eg. Watkins et al. 1998; Baskaran et al. 2001; Rasiah et al. 2005; Smith et al. 2007).Typically these data sets are restricted to the length and scope of the project. There is no consistent program of nitrate monitoring of groundwater in most parts of Australia.

Nitrate-N concentrations typically range from 0.001 to 29 mg/L. Although median nitrate-N concentration was low, groundwater from some locations has significantly elevated concentrations. In general, groundwater with elevated nitrate-N concentrations occurs in areas of intensive agriculture where repeated use of nitrogenous fertiliser application has resulted in high concentrations of nitrate-N.

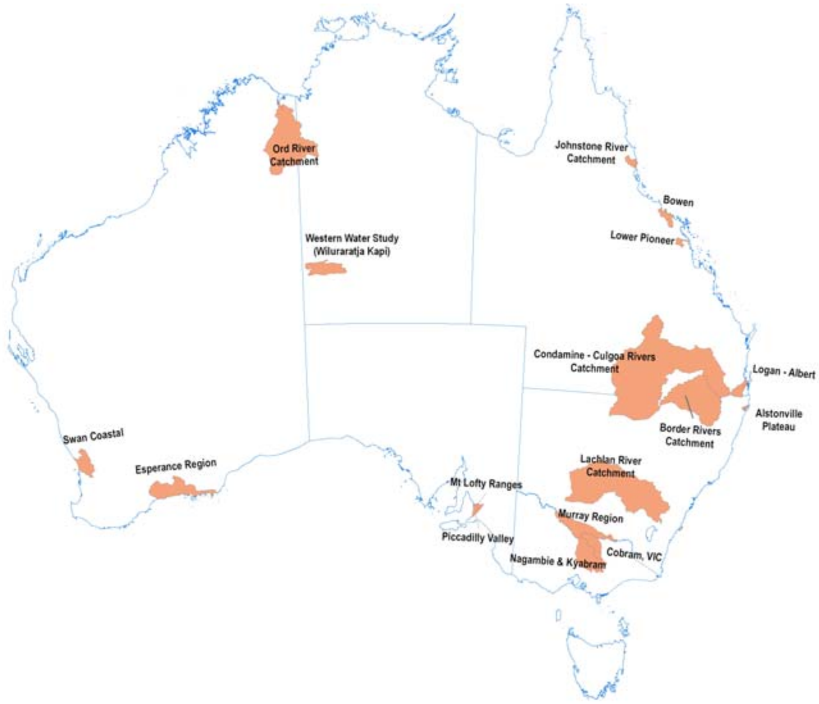


Figure 8: *Areas of Australia where Nitrate-N have been detected in groundwater*

Nitrate-N concentrations in groundwater exceeded the Drinking Water Health Guideline Value of 11.3 mg/L-N (NHMRC/NRMMC, 2004) in some areas. Some groundwater also exceeded the long term trigger value (5 mg/L) for nitrate in irrigation water (ANZECC/ARMCANZ, 2000). However, these are the results of one limited sampling program at a single point in time in terms of weather conditions, growing season and fertiliser application. Vulnerability of groundwater to nitrate contamination depends on a combination of factors such as geology, soil, land use, land and water management practices and hydrology. It is not appropriate to assume that groundwater in the study area is not vulnerable to nutrient contamination, given suitable conditions. Studies have shown that nutrient concentrations vary seasonally, largely in response to changes in precipitation and stream flow and in differences in time since fertiliser application.

A broad assessment of groundwater monitoring across SA state during the period 2002-07 shows that in most cases, groundwater was rated as poor for nitrate in the South East, Northern Adelaide Plains, Adelaide Plains, Barossa Valley, Willunga Basin and Eyre Peninsula (EPA SA, 2008). Nitrogen levels sometimes exceeded ecosystem protection guidelines in the irrigated catchments such as the Burdekin, Fitzroy, Burnett, Condamine and Lockyer in QLD, but did not exceed health guidelines (EPA QLD, 2007).

In some states there is routine monitoring of town water supply bores for health purposes for nitrate and a range of other parameters. The length of record varies considerably although these data sets are not publicly available.

Time series data are usually inadequate to establish seasonal and other variability in groundwater nitrate contamination. This is particularly the case for rural areas outside key groundwater supply areas. There is no systematic approach to data collection of nitrate across Australia. The absence of regularly collected long-term data makes it difficult to determine long-term patterns in nitrate contamination and does not allow adequate interpretation of the rate of any increase or decrease in nitrate concentrations.

4.2.2.2 Nitrogen in New Zealand groundwater

Nitrate contamination is widespread in shallow unconfined aquifers in New Zealand. Sites with elevated nitrate-N concentrations are found in many regions of New Zealand, especially Waikato, southern Manawatu−Wanganui (Horowhenua), Canterbury and Southland (Figure 9). The calculated national median for nitrate-N in groundwater during 2006 is 1.3 mg/L (Ministry for the Environment, 2007). Previous studies have provided estimates of 0.3−1.0 mg/L for median nitrate-N concentration in unaffected groundwater in New Zealand (Burden, 1982; Morgenstern et al. 2004; Daughney and Reeves, 2005). Of the 956 sites at which a site-specific median could be calculated, 4.9% exceeded the Maximum Acceptable Value (MAV) based on the Drinking Water Standards for New Zealand (DWSNZ) (11.3 mg/L), 10.3% exceeded the trigger value (TV) for ecosystem protection based on the ANZECC guidelines (7.2 mg/L), and none exceeded the ANZECC TV for stock drinking-water (400 mg/L).

Elevated nitrate-N concentrations in groundwater are likely to be due to anthropogenic sources. A previous study defined a threshold value of > 1.6 mg/L (about twice the estimated background, or around quarter of the TV) as a probable indicator of human influence (Daughney and Reeves, 2005). The same study defined a threshold of > 3.5 mg/L (about four times the estimated background, or around half the TV) as an almost certain indicator of human influence.

Significant increasing trends in nitrate-N concentration were detected at around 13% of monitoring sites considered for the national study during 1995-2006 (Ministry for the Environment, 2007). Significant decreasing trends in nitrate-N concentration were detected at approximately same number of monitoring sites. In agreement with the trend-based categorisation, sites with detectable trends in nitrate-N are found in all regions of the country, especially in Waikato and Southland, but also along the West Coast, where water quality is generally good, and Gisborne, where many groundwater systems are oxygen-poor and would not be expected to contain significant concentrations of nitrate-N (Ministry for the Environment, 2007).

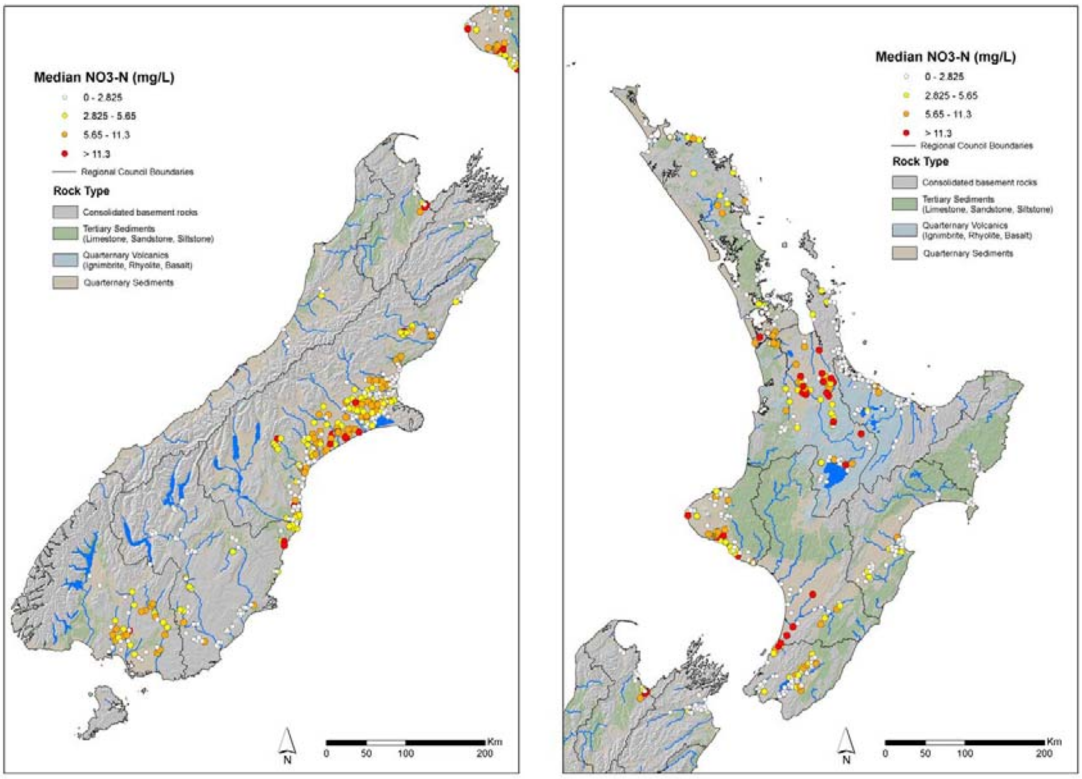


Figure 9: *Median nitrate-N concentrations in New Zealand groundwater (adapted from Ministry for the Environment, 2007)*

4.2.3 Pesticides

4.2.3.1 Pesticides in Australian groundwater

Data on pesticides in Australian groundwater are very limited. However, results from various studies conducted across Australia during 1996-2007 showed detections for 9 herbicides and 1 degradation product, and 2 insecticides (Figure 10) (Watkins and Bauld, 1999; Please et al. 2000; CBWC, 2002 and Smith et al. 2007). In 2009, the Department of Primary Industries, Parks, Water and Environment (DPIPWE) in Tasmania conducted Ground Water Monitoring across Tasmania. This involved one-off sampling of 58 bores and testing of 19 pesticides. The results showed detections for 4 herbicides (2,4-D, atrazine, MCPA and hexazinone) in four locations (http://www.dpiw.tas.gov.au/inter.nsf/webpages/cart-69stwk?open#dd). Most compounds detected in groundwater were herbicides that are most frequently used to control weeds either in crops or irrigation channels (Tomlin, 1997). Atrazine, desethyl atrazine, ametryn, bromacil, fluometuron, diuron, hexazinone, metolachlor, prometry and simazine herbicides were detected along with 2 insecticides (chlordane and chlorpyrifos) in one or more groundwaters at low concentrations. Among the pesticides, atrazine has been detected in the majority of studies. Although pesticide concentrations versus depth to water table showed no statistical relationship, 50% of pesticide samples were found in relatively shallow groundwater.

The concentrations of pesticides and number of detections in groundwater varied with locations. In general, herbicide use is likely to be moderate to high in irrigated agriculture areas; furthermore, soil and geologic conditions would tend to favour rapid movement of herbicides to groundwater. Most herbicides detected in groundwater are highly mobile, allowing them to move rapidly to the water table, and have moderate to long environmental half-lives, enabling them to persist for some time in the subsurface environment (USGS, 1999; CBWC, 2002). The pesticides detected in Australian groundwater were below the Australian Drinking Water Health Guidelines (NHMRC/NRMMC, 2004).

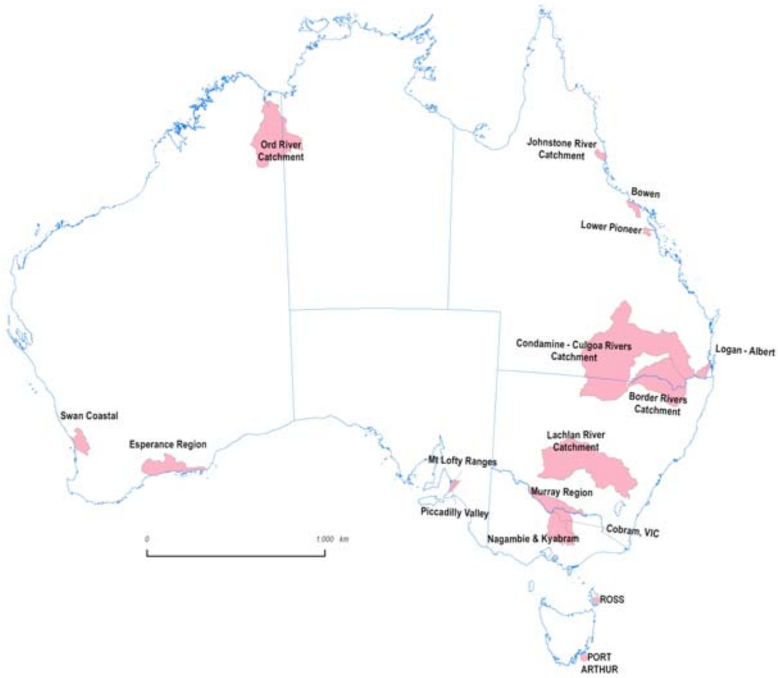


Figure 10: *Areas of Australia where pesticides have been detected in groundwater*

Much of the groundwater pesticide detections presented in Figure 10 have been obtained from either one-year studies or *ad hoc* monitoring, therefore it is difficult to ascertain clear trends on contamination potential. There are, however, temporal and spatial variations of contaminants in aquifers, and in some cases, poor agricultural land and water management practices are creating groundwater contamination risks. Therefore, it is important to continue monitoring Australian groundwater for pesticides.

4.2.3.2 Pesticides in New Zealand groundwater

National surveys of pesticides in New Zealand groundwater have been carried out at 4-yearly intervals since 1990 (Close and Flintoft, 2004). Previous national and regional groundwater surveys in New Zealand have shown low levels of pesticides in some groundwater systems, particularly those shallow unconfined systems that are vulnerable to pollution. The results of the national survey showed that pesticides were detected in 28 groundwater sites (21%), with 13 groundwater sites (10%) having two or more pesticides (Close and Flintoft, 2004). One or more wells with detectable pesticides levels occurred in nine of the 15 regions. No pesticides were detected in wells from the Northland, Hawke's Bay, Manawatu-Wanganui, Taranaki, Wellington, and West Coast regions.

None of the groundwater in the 2002 survey had pesticides at levels above the maximum acceptable value (MAV) for drinking water (Close and Flintoft, 2004). Twenty-one different pesticides were detected, including two triazine metabolites, usually at very low concentrations. Thirty-nine out of the 58 pesticide detections (67%) belonged to the triazine group. Lower groundwater temperatures and higher nitrate levels were associated with the increased detection of pesticides in those surveys. A comparison with earlier surveys indicates that pesticide detections have been relatively stable over the past 12 years. The overall frequency of pesticide detections in the 4-yearly surveys were: 1990 (7%), 1994 (13.6%), 1998 (11%), and 2002 (9%).

4.2.4 Trace Elements

4.2.4.1 Trace elements in Australian groundwater

Data on trace elements in Australian groundwater are very limited and the extent of groundwater contamination due to trace elements is unknown at this stage. Fifteen trace elements have been detected (at very low concentrations) in one or more locations. Figure 11 displays locations where trace elements have been detected during 1996-2008 and the source of data produced are from specific research and investigations (eg. Hostetler et al. 1998; Watkins et al. 1998; Baskaran et al. 2001). Among the trace elements, arsenic, boron, barium, iron, manganese, lead, iron, selenium and uranium and fluoride are most common. In some locations the trace element concentrations exceeded the NHMRC health guidelines and in others it exceeded the ANZECC guidelines for ecosystem protection.

Recent monitoring in the City of Stirling and some parts of the Gnangara Mound in WA showed some bores are contaminated with arsenic, aluminium and other heavy metals (Appleyard et al. 2004). Sampling of deep drains in the agricultural wheatbelt also showed high levels of heavy metals including iron, aluminium, cobalt, copper, zinc, lead and uranium have leached under acidic conditions (Rogers and George, 2005). Similarly, trace elements have been found in some inland waters following acid mine drainage, and in areas of acid sulfate soils.

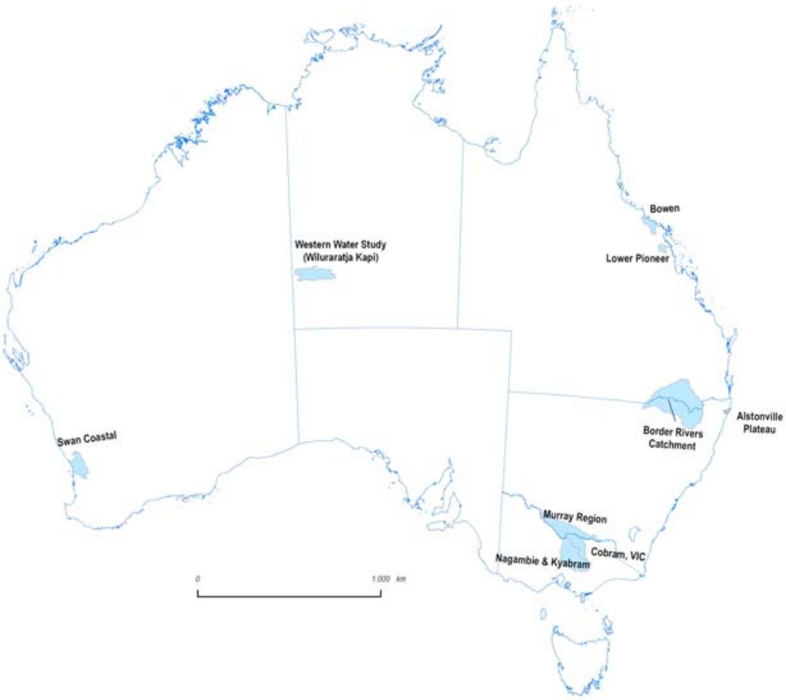


Figure 11: *Areas of Australia where trace elements have been detected in groundwater*

Arsenic in groundwater systems is a problem in many parts of the world owing to ever-increasing extraction of groundwater resources to meet the needs of growing populations. However, water quality monitoring in Australian sandy aquifers is usually limited to a small suite of major elements and salinity measurements to determine the quality of groundwater and to identify any potential problems from seawater intrusion as a result of over-extraction. Minor and trace elements, particularly toxic elements, have largely been ignored in regular monitoring programs.

Trace elements in groundwater come from natural as well as anthropogenic sources. Elements that are naturally introduced come primarily from rock weathering and other geochemical processes involving leaching of continental rocks and sediments. Anthropogenic inputs, particularly due to the application of fertilisers and pesticides to agricultural land, also lead to significant leaching to groundwater. Some elements are essential, in low concentrations, for proper metabolism in all living organisms, yet are toxic at higher concentrations; other elements currently thought of as non-essential are toxic even at relatively low concentrations. Table 4 lists some elements according to their toxicity to human and ecosystem health.

Table 4: Classification of naturally occurring elements according to their toxicity and availability in the hydrologic environment (adopted from Wood, 1974)

NON-TOXIC	LOW TOXICITY	MODERATE TO HIGH TOXICITY
Aluminium	Barium	Arsenic
Calcium	Tin	Boron
Iron		Cadmium
Magnesium		Chromium
Manganese		Cobalt
Molybdenum		Lead
Potassium		Mercury
		Nickel
		Selenium
		Uranium

Major sources of toxic elements arising from human activities are domestic and industrial wastewaters, together with their associated solid wastes, and the application of synthetic fertilisers and pesticides to agricultural lands. In recent years solid waste or sewage sludge has been commonly disposed in agricultural fields or sold as fertiliser. Trace elements can also be released through leaching of sewage sludge in agricultural fields. In addition, natural processes such as erosion, weathering or dissolution of mineral salts also add metals and trace elements to groundwater.

The data presented for trace elements in Figure 10 are restricted to the length and scope of the project. There is no consistent program of trace element monitoring of groundwater throughout most parts of Australia.

4.2.4.2 Trace elements in New Zealand groundwater

Trace metals in New Zealand groundwater are generally present at low concentrations and thus do not pose a risk to human health (Ministry for the Environment, 2007). Among the trace elements, iron and manganese were detected in many locations during 2006. The calculated national medians during 2006 for iron and manganese are 0.03 and 0.01 mg/L, respectively, which is in good agreement with previously reported values (Rosen, 2001; Daughney, 2003; Daughney and Reeves, 2005). Elevated concentrations of dissolved iron and/or manganese can impart an unpleasant taste to drinking water and can lead to staining and clogging of pipes, and so the DWSNZ includes aesthetic GVs of 0.2 and 0.04 mg/L for iron and manganese, respectively. Due to risks to human health and freshwater ecosystems, manganese has a MAV of 0.4 mg/L and a TV of 1.9 mg/L (there is no MAV or TV for iron).

Of the monitoring sites at which median concentrations could be determined, 27% exceeded the GVs for iron and 33% for manganese, 15% exceeded the MAV for manganese, and 2% exceeded the TV for manganese (Ministry of the Environment, 2007). Elevated concentrations of dissolved iron and/or manganese generally arise from natural microbial respiration in oxygen-poor aquifers which are found in many regions of New Zealand. Groundwater with high concentrations of iron and/or manganese are found in many regions of New Zealand, especially Gisborne, Auckland and Manawatu−Wanganui, but also in western Northland, coastal Bay of Plenty, northern Hawke's Bay, south Wairarapa, and some parts of Otago and Southland (Ministry of the Environment, 2007).

From the results it is difficult to determine whether or not trace metal concentrations in groundwater pose a serious threat to ecosystem health. This is because, for many heavy metals, the ANZECC TV is near or below the detection limit of many analytical methods.

Arsenic has been detected in some groundwater in New Zealand, although arsenic concentrations are typically less than the health-related MAV (0.01 mg/L). However, of all sites at which median arsenic concentrations could be determined (n = 157), 10% exceeded the MAV.

4.2.5 Other contaminants

Organic and inorganic contaminants are sometimes inadvertently released to the groundwater by many activities, such as manufacturing, transport, storage and waste disposal. The extent of information about groundwater contamination by industrial chemicals is limited. Some of the available information is presented below.

In WA, leaking underground storage tanks at petrol stations are a widespread threat to groundwater, due to their large number and distribution (EPA WA, 2007). Leaks may go undetected for long periods and, on reaching groundwater, contaminants may affect drinking water supplies, residential or production bores, and eventually wetlands and waterways. Of about 6500 licensed premises in WA with dangerous goods, an estimated 57% have underground storage tanks. Nearly half of these are located in the Perth metropolitan area. Just over 3% (or 217) of premises have leaking tanks and many of the sites involved are being investigated and undergoing remediation.

In NSW, groundwater contamination is largely associated with long-standing existing and former industrial areas, and occurs at about 90 of the currently regulated sites (DEC NSW, 2006). These tend to be in urbanised areas and concentrated in Sydney, Newcastle and Wollongong. The sources of contamination are distributed between purpose-built hydrocarbon storage sites such as service stations and depots (30%), industrial sites (38%), and landfills, gasworks and other land uses (32%). The main contaminants at 46% of sites are hydrocarbons – including total petroleum hydrocarbons; benzene, toluene, ethyl benzene and xylenes; and polycyclic aromatic hydrocarbons. Twenty-five per cent are affected by heavy metals, 9% by chlorinated solvents and 7% by nutrients. Several sites are affected by more than one contaminant.

4.2.6 Acidity

Acidification of groundwater is an important and emerging environment issue in Australia. Acidification of groundwater may be caused by natural processes in the soil profile or by external factors imposed on the soil water system. The information on groundwater acidity in Australia is limited.

Groundwater in some parts of the WA wheatbelt is saline and very acidic with pH commonly between 3 and 4. The acidic groundwater contains high concentrations of dissolved aluminium, iron and trace metals like lead, nickel, copper and zinc (Shand and Degens 2008). More than 50 per cent of groundwater observation sites in the Avon basin and about 46 per cent in the Esperance coastal basin are acidic. The groundwater acidity hazards include the transport and accumulation of trace elements such as lead, cadmium, uranium, arsenic and selenium in surface environments. This carries longer-term risks of accumulation in lakes and waterways, producing toxic effects on aquatic life and possible longer-term bioaccumulation through aquatic food chains.

Coastal groundwater acidity became a prominent issue in Perth in 2002 with the discovery that water from some household bores in the suburb of Stirling was killing garden plants (EPA WA, 2007). The groundwater was found to be acidic (with a pH as low as 1.9 in some places) and had become contaminated with aluminium and arsenic released from the soil (Appleyard et al. 2004). Nearby urban wetlands (e.g., Spoonbill Lakes) had also acidified. Heavy use of garden bores and dewatering of a nearby wetland for a housing development caused the acidification.

Investigations have also shown that extensive acidification of shallow groundwater occurs on the crests of the Gnangara and Jandakot mounds, with pH levels as low as 2.4 and high levels of dissolved aluminium and arsenic (Appleyard, 2004 and 2005). High aluminium levels can kill plants and wetland aquatic fauna. High arsenic levels pose a risk to human health if the groundwater is used for drinking water, and represents a long-term toxicological problem for ecosystems.

Several wetlands on the Gnangara Mound are now permanently acidified. For example, Lake Gnangara has been acidified to a pH of less than 4 since the late 1970s, and Mariginiup and Jandabup lakes have both had temporary acidification events (McHugh, 2004). In other wetlands and waterways the source of acidity is likely to be disturbed acid sulfate soils, which have been detected in wetlands and waterways adjacent to the Swan-Canning, Peel-Harvey, Leschenault and Vasse-Wonnerup estuaries, the Scott Coastal plain and low lying coastal areas on the south coast near Albany (Department of Environment, 2004).

In Queensland, groundwater in Moonie and Border Rivers west of Goondiwindi (at shallow depths) and Lower Balonne (at variable depths) has significant, though variable, acidity (Biggs et al. 2005).

4.3 CURRENT AND EMERGING GROUNDWATER QUALITY ISSUES

4.3.1 Groundwater – Surface water interaction and Implications for Water Quality

Groundwater-surface water interaction impacts on water availability and water quality. In areas where groundwater quality is good, it can have beneficial impacts on streams and on aquatic ecosystem health. Conversely, contamination of groundwater can have detrimental impacts on stream water quality, the ecology of wetlands and their surrounding areas. Movement of water between aquifers and surface water features such as rivers, lakes and estuaries can also involve transport of salt, acid, nutrients or contaminants. Hence, an understanding of surface water-groundwater interactions is important in the management of river salinity, acid sulfate soils and algal blooms.

This section provides some examples of groundwater-surface water interaction and effects on water quality.

4.3.1.1 Salinity

The role of groundwater processes in both dryland and irrigation–induced salinity has been recognised in Australia in recent years. Across significant areas of Australia, land clearing and cropping have increased groundwater recharge rates, raised the watertable and driven increased discharge of saline groundwater into nearby streams. The NLWRA estimated that about 25,000 km^2 of salt-affected lands could potentially increase to 170,000 km^2 by 2050. The current annual cost in terms of lost agricultural production and infrastructure damage has been estimated at $250M with degradation of ecological assets undefined (NLWRA, 2001). Of concern are increasing trends in stream salinity in the Murray-Darling Basin and the south-west of Western Australia. About a third of divertible surface water in streams in south-west WA is classified as brackish and saline, with only half of streams classified as potable in terms of salinity (WA Government, 2000).

4.3.1.2 Shallow acid groundwater discharge, Tuckean Swamp, North Coast NSW

The Tuckean Swamp is a large estuarine back swamp on the north coast of New South Wales that has been highly modified with construction of drains and a tidal barrage to manage frequent flooding. The drainage network efficiently reduces the incidence of flooding and waterlogging, but also tends to lower the shallow watertable. The swamp contains significant acid sulfate soils and the watertable decline has caused the oxidation of pyrite within the previously waterlogged shallow estuarine sediments. This chemical reaction generates sulfuric acid. Following major rainfall events, the store of acid migrates into the drains and is exported to the estuary. The consequences of increased acidity are fish kills, poor water quality, land degradation, reduced agricultural productivity, loss of estuarine fisheries habitat, and degraded vegetation and wildlife values (Hagley, 1996).

Figure 12 provides an overview of drain pH in the Tuckean Swamp (Brodie, 2007). The results highlight the north-eastern quadrant as a priority area in terms of discharge of shallow acidic groundwater. For Meerschaum Drain in the northeast, the pH gradually decreases from near-neutral (pH 6.9) in its upper reaches to about 4.1, before quickly dropping to 3.1 with acid conditions maintained down-drain. In contrast, the Tucki and Marom Drains in the western half of the swamp contain good quality water.

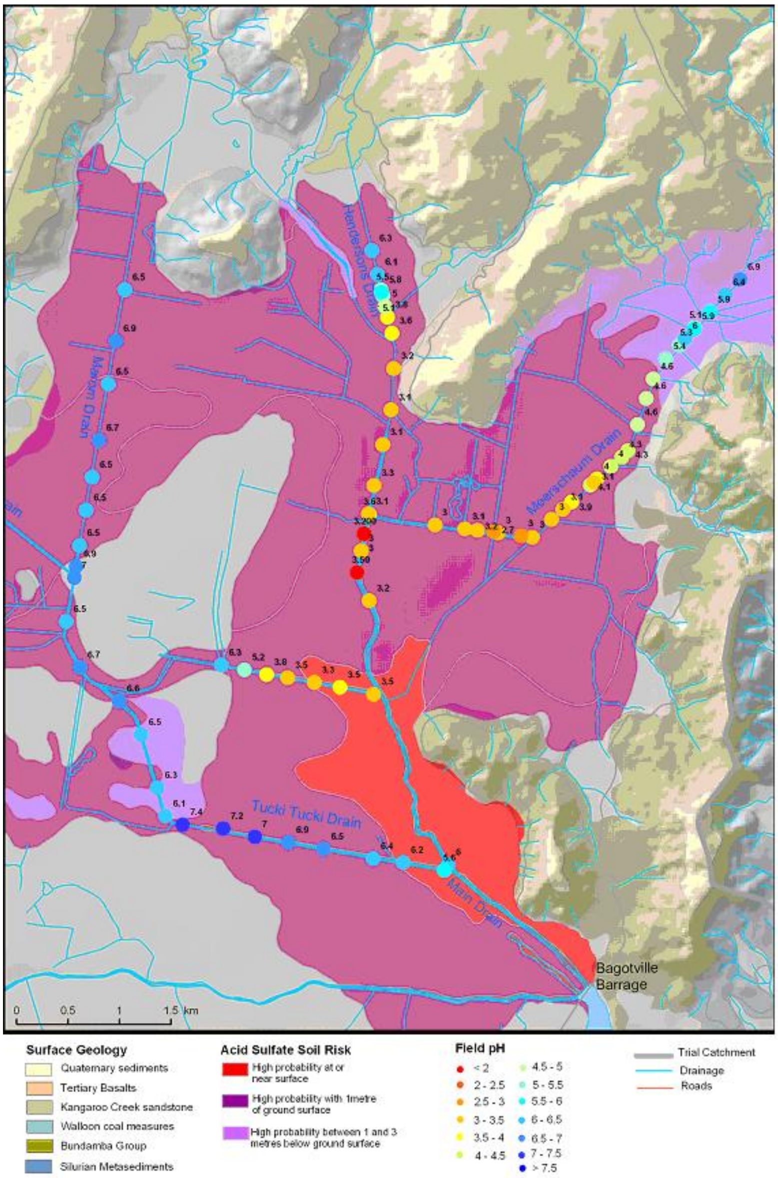


Figure 12: *Field pH of Tuckean Swamp drains, September 2004. Meerschaum Drain and Hendersons Drain are a priority in terms of discharge of shallow acid groundwater(adapted from Brodie, 2007).*

4.3.1.3 Groundwater nitrate-N on aquatic ecosystem health

The impact of fertilised cropping on nitrate-N in groundwater has been assessed in the wet tropical Johnstone River catchment in northeast Queensland (Rasiah et al. 2005). The Johnstone River estuary discharges into the Great Barrier Reef lagoon. The results of the study indicated that in 90% of the bores 80% of the nitrate-N values exceeded the maximum trigger value provided in the ANZECC guidelines for sustainable health of aquatic ecosystems. Nitrate-N increased with increasing rainfall at the beginning of the wet season, with a rapid decrease after the rains ceased. The results suggested that there is a potential for nitrate-N in groundwater to be discharged as a lateral flow into streams which can impact on down-stream aquatic ecosystems (Rasiah et al. 2005).

4.3.2 Groundwater Dependent Ecosystems

4.3.2.1 Surface Groundwater Dependent Systems

Groundwater plays a vital role in sustaining both surface and subsurface ecosystems. Groundwater dependent ecosystems (GDEs) are a diverse and important component of biological diversity. The ecosystems may rely on specific groundwater flows, or on specific ranges of fluctuations in level or pressure, or on specific groundwater quality parameters such as temperature or mineral content. Clifton and Evans (2001) identified six major types of surface GDEs in Australia:

- terrestrial vegetation
- wetlands
- river baseflow systems
- aquifer and cave ecosystems
- terrestrial fauna
- estuarine and near shore marine ecosystems.

The dependency of ecosystems on groundwater is based on one or more of four basic groundwater attributes (SKM, 2001):

- flow or flux - the rate and volume of supply of groundwater;
- level - for unconfined aquifers, the depth below surface of the water table;
- pressure - for confined aquifers, the potentiometric head of the aquifer and its expression in groundwater discharge areas; and
- quality - the chemical quality of groundwater expressed in terms of pH, salinity and/or other potential constituents, including nutrients and contaminants.

4.3.2.2 Subsurface Groundwater Dependent Systems

Subsurface groundwater dependent ecosystems (SGDEs) are ecosystems occurring below the surface of the ground that would be significantly altered by a change in the chemistry, volume and/or temporal distribution of its groundwater supply (Parsons and Wentzel, 2007). A recent report (Tomlinson and Boulton, 2008) provides current knowledge of the biodiversity, ecological processes and ecosystem services of SGDEs in Australia.

The stygofauna are present across a variety of Australian subsurface environments and are generally characterised by high diversity and local scale endemicity (Tomlison and Boulton, 2008). Microbes are a key component of SGDEs, forming the basis of the food chain and mediating the metabolism of carbon and other nutrients. Microbial activity degrades contaminants and delivers energy and nutrients to aquifer food webs and to biota in connected systems. Microbially mediated bioremediation and metabolism are examples of ecosystem services provided by SGDEs.

Knowledge of SGDEs has improved in recent years in Australia, with many explanatory surveys being conducted, particularly in WA as part of the environmental impact assessment for mining activities. Existing surveys cover some coastal and inland alluvial, fractured rock and arid zone karstic and calcrete aquifers and caves in NT, NSW, QLD, Tasmania, WA and Christmas Island (Tomlison and Boulton, 2008). Much of Australia's stygofaunal biodiversity still remains unsurveyed and there is a lack of taxonomic capacity despite the efforts of the last decade (Humphreys, 2008).

4.3.3 Impacts of Groundwater Quality on Groundwater Dependent Ecosystems

The use of groundwater resources increased in Australia in the last decade, both as the result of surface water caps in the Murray-Darling Basin (MDB) and declining rainfall that may be associated with regional climate change. As a consequence of these factors, it is increasingly important to understand what level of groundwater use is sustainable in any given aquifer and the potential environmental impacts of excessive groundwater use on groundwater quality.

Management of groundwater resources may become much less effective if declining rainfall and increasing groundwater extraction can cause large regional declines in groundwater levels. Under these conditions, some of the trace elements in the aquifer material can be oxidised by exposure to the atmosphere and can cause an increase in groundwater acidity. This will lead to environmental problems in groundwater-dependent wetlands and woodland. Both surface and subsurface GDEs are threatened by over-extraction and poor groundwater quality. Particular groundwater quality threats include increases in salinity, contaminants (eg. trace elements) in discharging groundwater, acidity and nitrates. In addition urban developments, intensive irrigation, clearing of vegetation and filling or draining of wetlands are also threats to GDEs. In some caves and peat bogs, scientific research into past environments relies upon the fossil record, however fluctuating water levels and changes in water quality can destroy this record.

Recently it has been shown that the groundwater has become acidic in areas of high drawdown in a sandy unconfined aquifer on the Gnangara Mound in WA (Appleyard and Cook, 2009). The combined effects of low rainfall, groundwater use in excess of 300 GL/year and reduced recharge in area covered by pine plantations has caused the water table on the Gnangara Mound to drop by 5 m. The result is that the groundwater has become acidic in areas of high drawdown with pH values typically less than 5.0 at the water table and elevated concentrations of trace elements such as aluminium, iron, zinc, copper, nickel and lead (Appleyard and Cook, 2009). Monitoring has indicated that at least eight groundwater-dependent wetlands in the Gnangara Mound area have become either permanently or episodically acidic in recent years, particularly in areas where there has been a large decline in the water table. Gnangara Lake was the first wetland in the area to have acidified in recent times (in the 1970s), but other lakes in the area are now showing a similar trend of declining pH and biodiversity (Sommer and Horwitz, 2001).

Input of saline groundwater is a substantial threat to the biodiversity of surface wetlands and rivers in south-west WA (Halse et al. 2003). Elevated salinities have already caused substantial changes to the biological communities of aquatic ecosystems. In addition to salinity, increased water volumes, longer periods of inundation and more widespread acidity are also likely to be detrimental to the biota in the south-west WA (Halse et al. 2003).

Coastal aquifers provide base flow to creeks and rivers during dry periods, thus supporting diverse ecosystems. Salinisation occurs in the Australian coastal aquifers due to seawater intrusion. The degree to which the productivity of the coastal irrigation is reliant on groundwater supplies is yet to be fully quantified. Fresh water contaminated by seawater at a level of only 5% renders it unsuitable for many important uses including drinking water supplies, irrigation of crops, parks and gardens and sustaining GDEs.

Elevated concentrations of nitrates leached from agricultural fertilisers, urban and industrial point sources have been detected in Australian groundwater. Increased nitrate levels in drinking water affects human health, and together with increases in phosphate levels in discharging groundwater, is likely to contribute to eutrophication in freshwater, estuarine and marine discharging zones (Linderfelt and Turner, 2001; Slomp and Van Cappellen, 2004; Rasiah et al. 2005).

4.3.4 Impacts of Climate Change on Groundwater Quality

Climate models suggest that drought could be as much as 20 percent more common by 2030 over much of Australia and up to 80 percent more common in south-western Australia by 2070 (Commonwealth of Australia, 2003). There is also a predicted increase in frequency in extreme weather events with associated increased incidence and severity of flooding and erosion. This is likely to have implications for groundwater processes such as recharge and discharge, and potentially detrimental effects on groundwater quality. Climate change may also increase the stress on groundwater already under pressure from salinity, over-allocation and declining water quality.

Highly transmissive, sandy coastal aquifers will be more sensitive to changes in recharge, temperatures and sea level rise than deep inland aquifers with low rates of recharge (Crosbie, 2007).

In general, reduction in groundwater recharge is the most direct impact of climate change. Groundwater storage volumes are expected to decrease due to reduction in recharge, with a parallel decrease in capillary rise in vegetation and a loss of discharge to springs and streams (Tomlinson and Boulton, 2008). Lowered groundwater input to streams could alter the hydraulic gradient between the stream and the connected aquifers. Higher water temperatures and reduced recharge and stream flows will tend to adversely affect groundwater quality. Drought attenuates the flushing of nitrates and dissolved organic carbon into groundwater, limiting microbial metabolism and reducing the supply of energy and nutrients to streams (Dahm et al. 2003).

Higher surface water temperatures can be expected to be particularly strong in summer in groundwater-fed streams, with increases in mean annual oxygen consumption, rates of mineralisation and higher bacterial biomass (Sand-Jensen et al. 2007). Higher groundwater temperatures will be associated with a decrease in viscosity and a resulting increase in hydraulic conductivity (Freeze and Cherry, 1979), with implications for enhanced transport of contaminants. In areas where rainfall and severity of storms is expected to increase, higher rates of recharge will result in increases in the rate of flow of water in aquifers and potentially elevate rates of nitrates and other contaminants leaching.

The impacts of climate change and sea level rise have the potential to affect both the yield and quality of important strategic water resources provided by coastal aquifer systems. Sea level rise will result in increased salinisation of coastal groundwater and surface water, resulting in reduced water quality, possibly threatening GDEs associated with coastal aquifers. Climate change and sea-level rise can potentially impact coastal groundwater resources in the following ways:

- Seawater intrusion and inland migration of the fresh-saline interface.
- Seawater inundation (surface flow into low-lying areas) and flooding of unconfined aquifers by seawater.
- Contamination of bores by storm surges and flooding of surface fittings.
- Changing recharge due to variable rainfall and evapotranspiration resulting in an altered distribution of freshwater in the aquifer.
- Changing discharge patterns that can generate waterlogged conditions and may impact on aquatic and wetland ecosystems.

High water table can also impact on infrastructure including leakage to septic tanks, sewer systems, and basements and causing instability of swimming pools, tanks and other subsurface structures that are not anchored.

4.4 MANAGEMENT RESPONSE TO GROUNDWATER QUALITY PROTECTION

The Guidelines for Groundwater Protection (NWQMS Guidelines #8; ARMCANZ and ANZECC, 1995) is the only national document specifically covering groundwater quality protection in Australia. The focus of the Guidelines is on the broad-scale protection of groundwater quality from contamination and also from land-based management of groundwater resources. Groundwater quality protection in Australia varies across states and territories and is generally inconsistent and uncoordinated. However, there are a variety of strategies that have been implemented to protect groundwater quality. Some of the strategies are discussed below.

4.4.1 Bore Construction Considerations

Water agencies in each of the states and territories have responsibility for the management of groundwater resources. The owner or legal occupier of the land on which a bore is to be constructed must obtain the appropriate licence or permit from the licensing authority in the relevant state or territory. After the bore has been constructed, the driller must provide the drilling logs, construction details of the bore and decommissioning report to the state and territory water agencies.

In Australia, all groundwater bores should be drilled, cased and equipped according to national construction standards defined in Minimum Construction Requirements for Water Bores in Australia (ARMCANZ, 2003). This document deals with a broad range of issues pertaining to water bores, including licensing, construction, development, decommissioning, water sampling, casing, recording and reporting of data.

4.4.2 Tools for Groundwater Quality Protection

Jurisdictions have developed a number of tools to protect groundwater quality. The tools include groundwater vulnerability maps, beneficial use maps, wellhead protection plans, groundwater management plans, education and community awareness programs. The tools are valuable resources that should be used by groundwater managers, planners, developers, and regulatory agencies to make better informed judgements on where to locate potentially polluting activities so as to minimise the risk to groundwater.

4.4.2.1 Groundwater Vulnerability Mapping

Groundwater vulnerability mapping is used as a guide in determining which areas are more susceptible to groundwater contamination. The preparation of groundwater vulnerability maps involves the simplification of complex geologic and hydrogeologic characteristics of a particular site using a rating index approach. The parameters in the development of a groundwater vulnerability map include: depth to watertable, recharge, aquifer media, soil media, topography, and the impact of the vadose zone. Three classes of vulnerability ranking are widely used to describe the probability of a groundwater resource to contamination: low, medium and high. These classes are shown as distinct colours on the final vulnerability map.

Many jurisdictions have developed groundwater vulnerability maps for particular catchments. An example of a vulnerability map developed for the Lachlan catchment is presented in Figure 13.

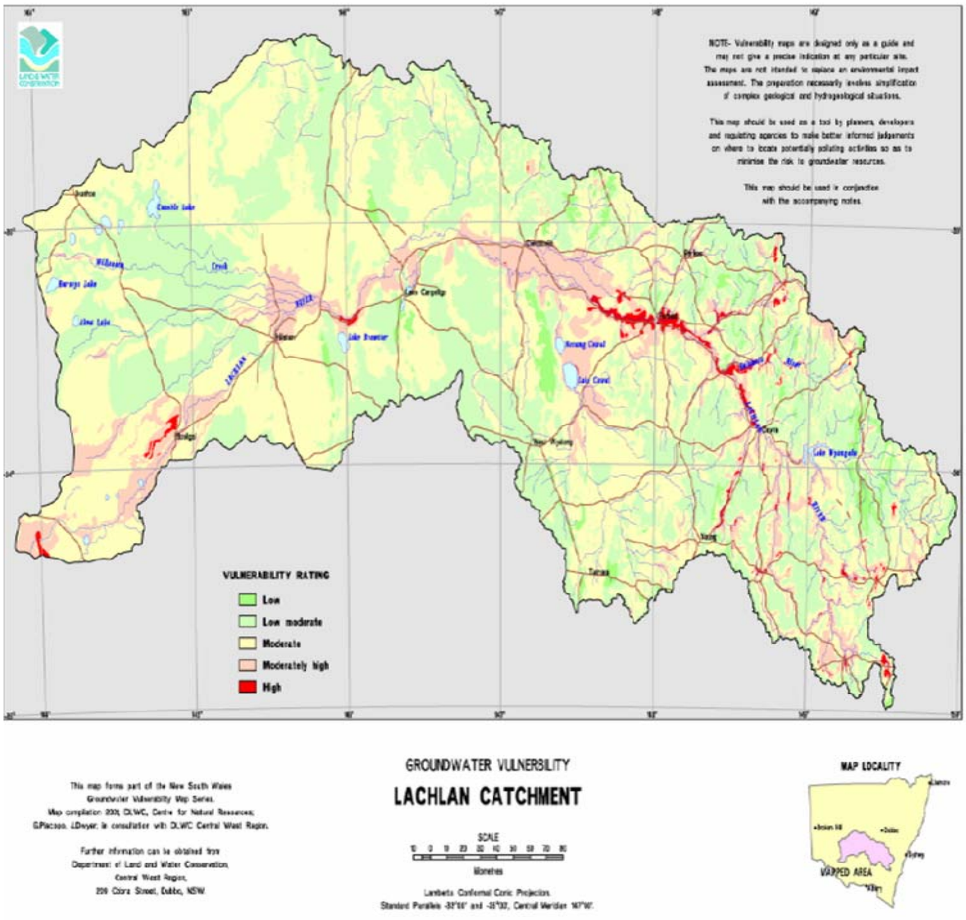


Figure 13: *Groundwater vulnerability map for Lachlan Catchment (source: NSW DLWC, 2001)*

4.4.3 Groundwater Quality Monitoring and Guidelines

Monitoring is the reality check for managers. Groundwater quality monitoring is a critical component of overall groundwater resource management programs. Groundwater quality monitoring is defined as an integrated activity for obtaining and evaluating information on the physical, chemical, and biological characteristics of groundwater in relation to human health, aquifer conditions, ecosystem health, and designated ground and surface water uses. Ideally, groundwater quality monitoring should be carried out on a regular basis where groundwater is being extracted for a variety of uses. It should be an integral aspect of groundwater management.

In Australia, state and territory agencies are responsible for groundwater quality monitoring. The Environmental Protection Agencies (EPA) commonly undertakes monitoring, but water departments or other agencies may also have this responsibility. Among the various water quality parameters, electrical conductivity (EC) is one of the most important and commonly measured parameters in groundwater. Other parameters such as nutrients, pesticides, trace elements and acidity are measured less frequently or usually not measured as part of the on-going monitoring program. The frequency of groundwater quality sample collection, the sampling methods, the number of sites sampled and the groundwater quality parameters measured, vary between the states and territories. There is no consistent national program of groundwater quality monitoring in Australia.

Groundwater quality is monitored in every region of New Zealand. Groundwater quality monitoring is routinely carried out in 15 regional councils and also by the National Groundwater Monitoring Programme (NGMP). The monitoring programmes conducted in different regions vary in terms of the number of sites sampled, the frequency of sample collection, the sampling method and the groundwater quality parameters measured.

National water quality guidelines place specific constraints on the quality of water intended for specific uses. The Guidelines for Groundwater Protection in Australia (ARMCANZ/ANZECC, 1995) provide a national framework for protecting groundwater from contamination. Many states and territories have used the national groundwater guidelines to develop groundwater policy and regulations designed to improve the management of groundwater resources.

A broad range of measures are currently implemented across all jurisdictions to protect groundwater water quality. Some of the national and state-wide policies and programs that are implemented are discussed below.

4.4.4 National Policies and Programs

National Water Quality Management Strategy (NWQMS): provides national policies, guidelines, information and tools to help government and communities manage water resources to meet current and future needs. It includes 24 nationally endorsed, non-mandatory guideline documents covering topics such as water quality management and monitoring, the treatment and management of sewage and groundwater protection. The Australian Government works collaboratively with the states and territories and the New Zealand Government to develop and implement the NWQMS.

Guidelines for Groundwater Quality Protection in Australia: provides a national framework for protecting groundwater from contamination in Australia. Many jurisdictions have used the Groundwater Guidelines to develop groundwater policy and regulations designed to improve the management of groundwater resources.

National Water Initiative: is the primary and enduring blueprint for the water reform agenda in Australia. The National Water Initiative (NWI) represents a shared commitment by all governments to increase the efficiency of Australia's water use, leading to greater certainty for investment and productivity, for rural and urban communities and for the environment.

Specific groundwater objectives under the NWI are:

- 23 (iv) Return over-allocated systems to environmentally sustainable levels of extraction
- 23 (x) Recognise connectivity between surface and groundwater and manage as a single resource
- 25 (iv) Provide adaptive management of surface and groundwater for productive, environmental and other public benefit outcomes
- 25 (x) Acknowledge, manage and protect groundwater systems of high conservation value
- 82 (iii) Accounting systems must integrate ground and surface water use where close interaction between groundwater aquifers and stream exists.
- 98 Knowledge and capacity building

Water for the Future: is the Australian Government’s framework to secure long-term water supply for all Australians. It is the first ever nationwide plan that addresses both rural and urban water. Water for the Future provides national leadership in water reform for all Australians

National Groundwater Action Plan: Through the $82 million National Groundwater Action Plan, the National Water Commission will undertake projects to address groundwater knowledge gaps and progress the groundwater reforms agreed to under the National Water Initiative. The plan consists of three major components:

- a National Groundwater Assessment Initiative ($50 million) to improve understanding of groundwater resources and support NWI implementation, harmonise groundwater terminology and foster best practice management;
- a National Centre for Groundwater Research and Training ($30 million) to develop research skills and expertise including the training of a new generation of groundwater managers and experts;
- a Knowledge and Capacity Building component ($2 million) to communicate learning from the Plan and raise public awareness of the challenges to adequately manage our groundwater resources; and

To reinforce the Groundwater Action Plan, the National Water Commission has developed the following themes under the National Groundwater Assessment Initiative:

- Harmonisation of groundwater definitions
- Northern Australia groundwater stock-take
- Managed Aquifer Recharge
- Groundwater Dependent Ecosystems
- Groundwater-surface water connectivity
- Strategic aquifer characterisation
- Deep fresh, saline and brackish groundwater
- Managing risks to groundwater quality

Great Artesian Basin Sustainability Initiative (GABSI): is the Australian Government initiative to accelerate work on the rehabilitation of uncontrolled artesian bores and the replacement of wasteful open earthen bore drains with piped water reticulation systems. The GABSI Initiative is being delivered through state agencies and the Australian Government makes its contributions jointly with other key stakeholders, state governments and pastoral bore owners.

Basin Salinity Management Strategy 2001–2015 (MDBMC 2001): includes important responses that will help to manage groundwater quality across states in the MDB.

4.4.5 State-wide Policies and programs

Various policies and programs have been implemented at state and territory level that provide a framework for improving groundwater quality across the jurisdictions. In general all states and territories have implemented the key elements of the groundwater quality protection guidelines. The groundwater protection strategies are set out in three frameworks, namely the:

- **Groundwater Management Framework**, which comprises legislation, regulation and policy about water management plans, allocation, bores, and public water supply;
- **Environment Protection Framework**, which comprises legislation, regulation and policy about waste management, environmental assessment, agricultural chemicals, dangerous goods, and environment protection in the resources industries; and
- **Land-Use Planning Framework**, which comprises legislation, regulation and policy about land use and development, and in some cases, land clearing.

5. Regulatory Review of Groundwater Quality Guidelines

5.1 REGULATORY REVIEW ANALYSIS PROCESS

The regulatory review analyses the laws, regulations and policies of the Australian Capital Territory, New South Wales, the Northern Territory, Queensland, South Australia, Tasmania, Victoria, Western Australia (the States) and the Commonwealth, as they stand at July 2009. The scope of the review does not include informal policies in the nature of information to the public, funding programs, by-laws and laws and policies at the sub-State level, or common law and legislation regarding the liability of authorities, land owners, operators and lenders for past contamination.

As outlined in the regulatory methodology (Chapter 3.2), the Regulatory Review collated the groundwater management, environment protection and land-use planning legislation, regulation and policy of each Australian jurisdiction, and analysed each item against the key elements of the Groundwater Guidelines. This chapter sets out the results of this process. Since the Framework Tables have some common elements—the underlying principles and forms of intervention—it considers these together, followed by the key elements of each standard Framework Table, in turn.

Developing three standard "Framework Tables", which categorise and set out important components of the Guidelines for the three broad types of legislation, regulation and policy, corresponding to the three major types of "protection strategies" described in the Groundwater Guidelines:

(i) **Groundwater Management Framework Table**, for analysing legislation, regulation and policy relating to groundwater allocation, use and management, including groundwater in the context of natural resource management, utilities and drinking water sources and supply;

(ii) **Environment Protection Framework Table**, for analysing legislation, regulation and policy relating to point source and diffuse pollution, waste management, environment protection in the resources industries, environmental impact assessment, contaminated sites, State of the Environment reporting, control of chemicals, and water quality objectives; and

(iii) **Land-Use Planning Framework Table**, for analysing legislation, regulation and policy relating to land use and development, land clearing, and Crown land administration.

Each Framework Table details how a jurisdiction has implemented a particular component of the Guidelines, with reference to the relevant provision of the legislation, regulation or policy. It also represents the extent of implementation of a particular component using the following symbols:
● meaning the Framework explicitly provides for this element of the Guidelines;
◐ meaning the Framework goes some way towards providing for this element of the Guidelines; and
○ meaning the Framework does not provide for this element of the Guidelines.

These standard Framework Tables are set out as Tables 5 to 7 below. Each row sets out the kinds of considerations which are relevant to determining whether, and how, a jurisdiction has implemented a particular component.

Appendix A shows the complete Framework Tables for each jurisdiction. Each main Framework Table is preceded by an introductory reference table, which sets out:

(1) the most important items of legislation, regulation and policy ("key items") and their abbreviated forms of reference; (2) other items of legislation, regulation and policy ("supplementary items"), and their abbreviated forms of reference; and (3) terminology and acronyms used in the main table which require explanation.

Important note: this methodology focuses on explicit recognition of groundwater quality issues. However, it is important to note that even if an item of legislation, regulation or policy does not explicitly or generally mention a groundwater quality matter (which may cause implementation to be assessed with the symbol ○, or ◐), this does not necessarily mean that groundwater quality impacts could not be taken into account, since in many decision-making scenarios they would be unlikely to be viewed as irrelevant considerations. Rather, the methodology stems from the objective of this Review to identify evidence that the jurisdictions have positively implemented the elements of the Groundwater Guidelines. Further, explicitly including groundwater quality as a decision-making consideration would help to focus the attention of decision-makers in a way which is more likely to lead to good groundwater quality outcomes.

Since the Framework Tables have some common elements—the underlying principles and forms of intervention—it considers these together, followed by the key elements of each standard Framework Table, in turn.

Table 5: Standard Groundwater Management Framework Table

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
1	Principles (primarily pp.9-13)	Precautionary principle (pp.11, 40)	Does the precautionary principle (or similar formulation) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers?
2		Polluter pays principle (p.11)	Does the polluter pays principle (or similar formulation) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Can the government take action in response to pollution and recover its costs from a person responsible for the pollution? Must a groundwater user provide a financial security? Are the full costs of managing groundwater recovered?
3		Equity considerations (p.12)	Do equity or fairness considerations appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Can equity considerations guide the balancing of competing interests relating to groundwater in other ways?
4		Beneficial uses and values (pp.10-12, 39-41)	Noting that environmental values and water quality objectives are generally set within the Environmental Protection Framework, are they nonetheless used or referred to in the Groundwater Management Framework?
5	Forms of intervention (pp.14-15)	Command (p.14)	At a general level, in what ways does the Groundwater Protection Framework directly control activities which are relevant to groundwater quality protection? (Note that specific types of control are dealt with later in this table – for example, see rows 25 to 29 in relation to well construction measures).
6		Market (pp.14-15)	How does the Groundwater Protection Framework provide for financial incentives to protect groundwater quality? Do financial incentives (or similar formulation) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? (Note that the market elements of groundwater management plans are dealt with in row 16 below).
7		Community participation and education (p.15)	Does community participation or education appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Do key actors have specific functions relating to community participation and education, where this would relate to groundwater quality protection? (Note that community participation processes of groundwater management plans are dealt with in row 14 below).
8	Reservation of special areas (p.16)	Stressed areas (p.16)	Is there provision for designating stressed areas which are being affected (including in relation to water quality) by groundwater extraction?
9		Public water supply areas (p.16)	Is there provision for designating public water supply areas for protection?
10		Other	Is there a provision for any other kind of area to be reserved to protect groundwater quality?
11	Management plans (pp.18-20)	Types of management plans for which the legislation or regulation provide	What are the main types of groundwater management plans (both statutory and non-statutory) and what is their general nature?
12	(that is, a plan for regulating individual behaviour once a groundwater body is being used by many competing users)	Component studies (p.18)	Is there a formal requirement to undertake component studies before preparing, or while preparing, a groundwater management plan? (Component studies may include an assessment of the resource base, water demands, and their location, appropriate methods of extraction, recharge and discharge characteristics, water quality variation, environmental and land subsidence issues, control of application rates and of contaminants and monitoring needs: Groundwater Guidelines, p.18)
13		Surface water – groundwater interaction (p.18)	Is there a formal requirement to address interaction between groundwater and surface water, or a formal acknowledgement of the potential for interaction?
14		Public consultation (p.19)	Is there a formal requirement to consult the public in relation to groundwater management plans, and, if so, what forms must any public consultation take?

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
15		Coordination with other agencies	Is there a formal requirement to consult other government agencies in relation to groundwater management plans, and, if so what forms must any consultation take?
16		Market incentives (p.19)	Are market incentives explicitly a component of a management plan?
17		Monitoring program (p.20)	Is there an explicit requirement to monitor the implementation of the groundwater management plan, or to review its effectiveness?
18		Enforcement (p.20)	Is the groundwater management plan enforceable? Is it directly binding, or are its provisions implemented in an indirect way (for example, must another instrument be consistent with the groundwater management plan)?
19	Controls on extraction (p.16) - Licences and permits	Groundwater quality considered in allocating groundwater (pp.9, 19)	Does the regime for authorising groundwater extraction provide for the decision-maker to consider the impacts on groundwater quality of the proposed extraction, when deciding whether to grant an authorisation?
20		Quality considered in setting conditions on taking water	Does the regime for licensing groundwater extraction provide for the decision-maker to consider groundwater quality when deciding whether to impose conditions on the authorisation, or when considering what conditions to impose?
21		Enforcement (p.20)	Are the requirements to obtain an authorisation to extract groundwater, and any condition imposed on such an authorisation, enforceable?
22	Other methods of limiting extraction	Method of limiting extraction	The Groundwater Guidelines suggest that resource allocation and resource protection are interdependent management tasks. Are there other methods of limiting extraction, in addition to licences dealt with in rows 19 to 21, above?
23		Water quality considerations (pp.9, 19)	Does the method of limiting extraction provide for the decision-maker to consider quality in deciding whether to impose the control?
24		Enforcement (p.20)	Is the method of limiting extraction directly binding or are its provisions implemented in an indirect way?
25	Well construction measures (p.16)	Bore licensing	The Groundwater Guidelines suggest that resource allocation and resource protection are interdependent management tasks, however it does not distinguish between resource allocation through licensing of bores and licensing of extraction. This row addresses the former, and the extent to which water quality is considered.
26		Driller licensing (pp.16, 25)	Are bore drillers required to be licensed?
27		Rules for bore construction (p.25)	Is there any formal requirement for bores to be constructed in a particular way?
28		Rules for operation and maintenance of bore (p.25)	Is there any formal requirement for a bore, once constructed, to be operated or maintained to a particular standard?
29		Enforcement (p.20)	Are the well construction measures binding and enforceable?
30	Water supply and protection of public water supply wells (pp.25-27)	Water supplier may control activities/ intervene in risky activities near bores (pp.16, 26)	Is a water supplier or related party empowered to control activities occurring near supply borefields, which may pose a threat to groundwater quality?
31		Protection zone around supply bores (p.26)	Is there provision for protection zones around drinking water supply bores?
32		Requirements to monitor up-gradient and within zone (pp.25, 26)	Is there a formal requirement for a water supplier to carry out monitoring of its raw water source bores and surrounding relevant areas?
33		Response plan in event of contamination (p.26)	Must a water supplier respond in a particular way to contamination incidents?
34		Reporting in the event of contamination (p.25)	Must a water supplier report a contamination incident to a relevant agency or person?
35		Enforcement (p.20)	Are these measures in relation water supply protection (rows 30 to 34 above), binding and enforceable?
36	Other well-related measures	Well abandonment requirements (pp.16, 25)	Do any formal requirements apply to abandoning or decommissioning a well?
37		Controls on disposal of waste via wells (p.16)	Do any formal requirements apply to disposing of waste via a well?

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
38	Gathering information	Strategic assessment of groundwater resources (p.38)	How does the Groundwater Management Framework provide for increasing knowledge about the condition of groundwater resources?
39		Monitoring of critical overdraw (p.16)	Is there a formal requirement to monitor critical over-extraction of groundwater resources?
40		Vulnerability mapping (pp.20-22)	Is there a formal requirement to undertake mapping of the vulnerability of a groundwater body to contamination?
41		Aquifer classification systems (pp.22-23)	Is there a formal requirement to develop or use systems for classifying aquifers according to specific attributes?

Table 6: Standard Environment Protection Framework Table

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
1	Principles (pp.9-13)	Precautionary principle (pp.11, 40)	Does the precautionary principle (or similar formulation) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers?
2		Polluter pays principle (p.11)	Does the polluter pays principle (or similar formulation) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Can the government take action in response to pollution and recover its costs from a person responsible for the pollution? Is there any requirement to provide a financial security in relation to an activity that poses a threat to groundwater? Can an agency which acts to protect groundwater recover the reasonable costs of doing so?
3		Equity considerations (p.12)	Do equity or fairness considerations appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Are proponents of projects required to have regard to equitable considerations?
4		Beneficial uses and values (pp.10-12, 39-41)	How are beneficial uses or environmental values generally provided for and used? (Note that these elements are discussed in detail below in rows 9 to 15).
5	Forms of intervention	Command (p.14)	At a general level, in what ways does the Environment Protection Framework directly control activities which are relevant to groundwater quality protection? In particular, what general duties and offences does it provide for? (Note that specific types of control are dealt with later in this table – for example, see below, row 17, in relation to licensing of point sources).
6		Market (generally pp.14-15)	How does the Environment Protection Framework provide for economic instruments that may be used to protect groundwater quality? For example, tradeable discharge permits (pp.45, 46) or taxes on contaminants (p.46)? Do financial incentives (or a similar term) appear in a statement of objectives or purpose which must, or may, be considered by decision-makers?
7		Community participation and education (p.15)	Does community participation or education appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Do key actors have specific functions relating to community participation and education, where this would relate to groundwater quality protection?
8	Water quality protection objectives and beneficial uses	Strategic assessment of groundwater resource (p.38)	How does the Environment Protection Framework provide for increasing knowledge about groundwater resources?
9		Define beneficial uses and values (pp.39-40)	How does the Environment Protection Framework define a beneficial use or environmental value? Does it define a "standard" set of beneficial uses and values, which may later be assigned to different water bodies? What does the standard set of beneficial uses and values include?
10		Identify beneficial uses (pp.40-41)	Which beneficial uses and values are assigned to groundwater bodies, and how are they assigned?
11		Apply criteria (narrative or prescriptive) (pp.41-42)	How is water quality criteria applied to a beneficial use or value? Are criteria narrative or prescriptive?
12		Points of application of criteria (pp.42-43)	Where are water quality criteria applied? At the boundary of a zone of discharge, at the boundary of the property upon which a contaminant is discharged, or at the point of discharge?
13		Monitoring and review program focusing on extent of implementation and extent to which goals are met (pp.46-47)	Is there an explicit requirement to monitor the implementation of beneficial uses and values, or to review their effectiveness?
14		Inter-agency coordination (p.48)	Is there a formal requirement for the "lead" government agency to consult other

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
			government agencies in relation to setting beneficial uses and values?
15		Enforcement of criteria for beneficial uses	Are water quality criteria in relation to beneficial uses and values directly binding and enforceable?
16	Controlling sources of contamination	Waste hierarchy (p.29)	Does the waste hierarchy (waste avoidance, re-use, recycling, treatment, and disposal) appear in a statement of objectives or purposes which must, or may, be considered by decision makers? Is the waste hierarchy applied directly in a way that may benefit groundwater protection?
17		Licensing of contaminants and point sources (p.30, App.1)	How are point sources of potential groundwater contamination licensed under general environmental protection laws, and (if applicable) under resource laws and laws relating to pesticides dangerous goods, and resources? What types of point sources must be licensed? Are the potential impacts on groundwater quality of the activity directly or indirectly considered in licensing decisions?
18		Inter-agency coordination (p.48)	In relation to licensing a point source, is there any formal requirement for the lead decision-making agency to consult other agencies?
19		Requirements for impact assessment (p.30)	For what types of potentially contaminating activities is an environmental impact assessment required? Does the process directly or indirectly address potential threats to groundwater quality?
20		Prescription of activities/discharges in protected areas (p.45)	Does the Environmental Protection Framework impose particular requirements in relation to understanding potentially contaminating activities within designated protection areas?
21		Monitoring requirements (p.46)	May, or must, potentially contaminating activities be subject to monitoring requirements?
22		Contingency measures, including clean-up requirements (pp.47-48) and levels of action required in response to contamination (pp. 23-25)	What tools may be used to respond to groundwater contamination? What action is required in response to contamination?
23		Controls on diffuse source contamination (pp.17, 30)	How are potentially diffuse sources of contamination controlled?

Table 7: Standard Land-Use Planning Framework Table

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
1	Principles (pp.9-13)	Precautionary principle (pp.11, 40)	Does the precautionary principle (or a similar term) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers?
2		Polluter pays principle (p.11)	Does the polluter pays principle (or a similar term) appear in a statement of objectives or purposes which must, or may, be considered by decision-makers?
3		Equity considerations (p.12)	Do equity or fairness considerations appear in a statement of objectives or purposes which must, or may, be considered by decision-makers?
4		Beneficial uses and values (pp.10-12, 39-41)	Are beneficial uses and values (which are generally set within the Environmental Protection Framework) used or referred to in the Land-Use Planning Framework?
5	Forms of intervention	Command (p.14)	How does the Land-Use Planning Framework directly control the development and use of land for activities that have the potential to pollute groundwater?
6		Market (generally pp.14-15)	How does the Land-Use Planning Framework provide for economic instruments that may be used to protect groundwater quality? For example, do financial incentives appear in a statement of objectives or purposes which must, or may, be considered by decision-makers?
7		Community participation and education (p.15)	Does community participation or education appear in a statement of objectives or purposes which must, or may, be considered by decision-makers? Do key actors have specific functions relating to community participation and education, where this would relate to groundwater quality protection? (Note that specific public consultation requirements in relation to key planning documents are set out below, row 20).
8	Specific approaches to protection	Vehicle for protection	What are the main types of land-use planning instruments (statutory and non-statutory) used to protect groundwater quality, and what is their general nature?
9		Use of land-use risk matrix to judge compatibility of land uses with water quality protection (p.44)	Is there provision for developing or using a matrix of land-use types and risk of groundwater contamination? Do other provisions provide for considering land capability or suitability for the proposed activity, in a way that may protect groundwater quality?
10		Land zoning taking into account underlying groundwater (pp.43-44)	Is there provision for land zoning to take into account the need to protect the quality of underlying groundwater resources?
11		Protection for water supply protection areas (p.27)	Is there provision for protecting groundwater supply protection areas?
12		Protection of groundwater recharge zones (p.28)	Are there controls on the types of activities which may occur in groundwater recharge areas?
13		Controls on land clearing due to connection with groundwater quality (p.28)	How is land clearing controlled, and do these controls consider the potential impacts of land clearing on groundwater quality?
14		Controls on land development due to connection with groundwater quality (p.28) For example controls on mining, quarrying, waste disposal (p.28)	In general, how does the Land-Use Planning Framework control the use and development of land for activities that may potentially contaminate groundwater? Are groundwater quality impacts explicitly relevant considerations in relation to decisions to authorise use and development?
15		Controls on rural and urban runoff (p.28)	Are controls applied to urban and rural runoff?
16		Controls over use of sewage effluent (p.44)	Are controls applied to the use of sewage effluent? (Note that the Environment Protection Framework may also apply controls through licensing requirements for potentially polluting activities).
17		Manage land uses to reduce risks of contamination (p.44)	How may permissible types of uses and developments be managed to reduce risks of groundwater contamination?
18		Veto or referral rights for water and environment agencies in relation to land development (p.45)	May water and environment agencies, or other agencies which have functions relevant to protecting groundwater quality, comment on, impose requirements on, or prohibit, a particular land use or development?
19		Other inter-agency coordination (pp.28,	Are water and environment agencies, or other agencies which have functions

	Form of protection suggested by the Guidelines, and page references		Considerations relevant to whether the element has been implemented
		35)	relevant to protecting groundwater quality, otherwise involved in preparing or commenting on the instrument?
20		Public consultation (p.28)	Is there a formal requirement to consult the public in relation to the formulation of statutory or non-statutory instruments?
21		Monitoring and review (pp.46-47)	Is there a formal requirement to monitor the implementation of a statutory or non-statutory instrument, or to review its effectiveness?
22		Enforcement (p.20)	Are policies in relation to land use and development binding and enforceable?

5.2 REGULATORY REVIEW ANALYSIS AND RECOMMENDATIONS

A summary of the findings and recommendations of the Regulatory Review is set out below, organised according to the key areas of the Guidelines: the underlying principles, the forms of intervention, and the three legislative areas, being the Groundwater Management Framework, the Environment Protection Framework and the Land-Use Planning Framework. A more detailed summary is available in Nelson (2009).

Note that the Regulatory Review's findings are based on how the Guidelines are implemented through the text of law, regulation, and policy, rather than on an empirical assessment of how these practices are implemented on the ground. The findings and recommendations are based on the state of the legislation, regulation and policy as they stood in July 2009.

5.2.1 Underlying Principles

5.2.1.1 Precautionary principle

General finding: The jurisdictions generally adopt the precautionary principle in their Groundwater Management and Environment Protection Frameworks, and to a lesser extent, in their Land-Use Planning Frameworks. They generally require either all or some decision-makers to have regard to the precautionary principle as an element of the principle of ecologically sustainable development (ESD), when exercising all or certain of their functions, including functions that have the potential to affect groundwater quality.

Recommendation: The Groundwater Guidelines mention the precautionary principle mainly in the context of deliberately allowing aquifer contamination. A future revision of the Guidelines should significantly expand the role of the precautionary principle to reflect the prominence of the principle in modern legal frameworks that have the potential to affect groundwater quality, and the greater role that most jurisdictions give to the principle in the context of groundwater management.

5.2.1.2 Polluter pays principle

General finding: The jurisdictions generally adopt the polluter pays principle in their Groundwater Management and Environment Protection Frameworks, but only rarely in their Land-Use Planning Frameworks. They commonly require either all or some decision-makers to have regard to the polluter pays principle as an element of the principle of ESD, when exercising all or certain of their functions, including functions that have the potential to affect groundwater quality. It is also common to implement the polluter pays principle through requiring a financial assurance before issuing a licence to undertake certain activities, linking licence fees to the potential for pollution, and allowing a specified agency to recover the reasonable costs associated with remedying environmental harm, including harm to a protected environmental value of groundwater.

Recommendation: A future revision of the Groundwater Guidelines could provide further detail on how the polluter pays principle may be implemented, using the many examples provided by current legislation, regulation and policy. The Guidelines may also benefit from re-visiting the precise intended meaning of the polluter pays principle, since the jurisdictions differ in relation to what costs, and how much of these costs, the principle requires a polluter to bear.

5.2.1.3 Equity considerations

General Finding: Since the Groundwater Guidelines were published, the concept of intergenerational equity has become a well-entrenched element of water management and environment protection laws throughout most Australian jurisdictions. This concept may well prove very useful in the context of protecting groundwater quality, given the long time-frames involved in cleaning up contamination.

Recommendation: A future revision of the Groundwater Guidelines could consider updating the comments in relation to "equitable considerations" to reflect the concept of intergenerational equity, and discuss further how this concept should take effect in the context of groundwater quality protection.

5.2.1.4 Beneficial uses and values (now termed environmental values)

General Finding: Each jurisdiction has adopted the concept of beneficial uses and values. NSW relies mainly on a policy mechanism, whereas other States use a statutory mechanism. The concept of beneficial uses is implemented, to varying degrees, through the Groundwater Management Frameworks, Environment Protection Frameworks, and Land-Use Planning Frameworks. The general method of implementing beneficial uses is to require an authorisation or plan under these Frameworks to be prepared consistently with, or having regard to, beneficial uses.

Recommendation: A future revision of the Groundwater Guidelines could describe the ways in which beneficial uses and values may be implemented, using examples from modern Australian legislation, regulation and policy.

5.2.2 Forms of Intervention

General Findings: Most jurisdictions use a combination of command, market, and public participation approaches to groundwater protection across their Groundwater Management, Environment Protection and Land-Use Planning Frameworks. Of these three approaches, market approaches are used least, although they are often referred to at a high level. Flexible and adaptable approaches to command intervention have developed since the publication of the Groundwater Guidelines, overcoming some of the constraints of what can sometimes be a rigid approach. Public participation and education are very commonly used in relation to instruments that are relevant to groundwater quality protection, but legal or policy requirements for specific education programs in relation to groundwater quality are relatively rare.

Recommendation: A future revision of the Groundwater Guidelines may assist jurisdictions by further describing the ways in which the different forms of intervention may be implemented, using examples from modern Australian legislation, regulation and policy. In particular, a future revision could describe modern, flexible approaches to intervention by command, and further examples of market mechanisms.

5.2.3 Groundwater Management Framework

5.2.3.1 Reservation of special areas

General Findings: The jurisdictions provide well for the reservation of special areas for groundwater protection, both in the cases of stressed areas, where water quality may be at risk due to groundwater use, and also in the case of public water supply areas.

5.2.3.2 Management plans

General Findings: The jurisdictions generally implement the Groundwater Guidelines in relation to groundwater management plans very well. There are numerous different types of management plans in use, at different geographical levels, throughout the jurisdictions. Each of these may deal with groundwater quality in different ways, for example, affecting authorisations to take groundwater, or setting objectives and implementation plans in relation to groundwater quality. It is likely that the

Basin Plan under the Commonwealth Water Act, will, over time, significantly change the form and enhance the legal effect of local water management plans for groundwater resources in the Murray-Darling Basin.

Recommendation: A future revision of the Groundwater Guidelines should take account of the greatly expanded Commonwealth influence on groundwater management planning, which occurs through the Basin Plan under the Commonwealth Water Act, and the requirements that the Basin Plan will set for water resource plans at the local level.

5.2.3.3 Controls on extraction

General Findings: Generally, the Groundwater Management Frameworks of the jurisdictions link groundwater extraction to groundwater quality very well, by: (1) providing for decision-makers to consider groundwater quality when they consider an authorisation to take groundwater; and (2) empowering decision-makers to limit groundwater extraction temporarily or permanently, or to require bore owners to take specified actions to protect groundwater quality.

Recommendation: A future revision of the Groundwater Guidelines should reflect the ways of linking groundwater extraction with groundwater quality considerations, which appear in modern Australian legislation, regulation and policy. It should also investigate the related concept of setting aside water for environmental purposes related to protecting groundwater quality, which may be possible, though it is often not explicit, in the jurisdictions' legislation, regulation and policy.

5.2.3.4 Well construction measures and other well-related measures

General Findings: The Groundwater Management Frameworks of the jurisdictions all impose requirements in relation to licensing bore drillers, and in relation to authorisations to construct either all, or some types of bores. However, few jurisdictions apply "default" standard rules to the full range of activities relating to bores—construction, operation, maintenance and abandonment or decommissioning. In some cases, these matters may be dealt with through other means (including conditions on authorisations and management plans), but this may risk an *ad-hoc* and inconsistent approach.

Recommendation: The Groundwater Guidelines should retain a focus on the need to protect groundwater by regulating the construction, operation, maintenance and abandonment or decommissioning of bores.

5.2.3.5 Water supply and the protection of public water supply wells

General Findings: The jurisdictions have implemented the public water supply protection aspects of the Groundwater Guidelines to differing degrees. Water suppliers do not uniformly have powers to control activities that may contaminate water supply bores, although these powers are frequently given to public health officials and ministers. The obligations of water suppliers to monitor the quality of raw groundwater sources and up-gradient areas, and to report and respond to contamination also differ widely between jurisdictions. This is a rapidly changing area, with some jurisdictions planning to overhaul their legislation.

Recommendation: The Groundwater Guidelines should retain a focus on public water supply aspects of groundwater quality protection.

5.2.3.6 Gathering groundwater information

General Findings: The jurisdictions (including the Commonwealth) provide for the assessment of groundwater resources through granting an entity a function related to assessing the condition of the environment or natural resources, State of the Environment reporting, and in some cases, specific water or groundwater quality assessment programs. Relatively few jurisdictions provide formally for specific programs such as monitoring critical overdraw, aquifer classification and vulnerability mapping.

Recommendation: A future revision of the Groundwater Guidelines should reflect the introduction of the Commonwealth Water Act, which has seen a significant increase in the legislative focus on gathering information relating to water resources at the Commonwealth level, through the Bureau of Meteorology and the Murray-Darling Basin Authority (MDBA). It should also reflect emerging concerns about the impact of climate change on groundwater quality and associated GDEs.

5.2.4 Environment Protection Framework

5.2.4.1 Water quality protection objectives and beneficial uses

General Findings: The jurisdictions generally implement the concepts of beneficial uses or environmental values well, although they tend not to determine them on an aquifer-specific basis, as was the intention of the present Guidelines. The application of criteria, and monitoring programs for the implementation of beneficial uses and values, tend not to be specified in detail. Beneficial uses and environmental values are used, and may be enforced, in the context of conditions on authorisations to take water and to undertake potentially polluting activities, and also in relation to pollution offences. They are also used as mandatory or discretionary considerations for decision-makers. The terminology used in relation to beneficial uses and values and criteria varies widely across the jurisdictions.

Recommendation: A future revision of the Groundwater Guidelines should consider the expanded list of beneficial uses/environmental values used by current legislation, regulation and policy, which goes beyond the five classes set out in Appendix II of the Groundwater Guidelines. It may also assist the jurisdictions to set out examples from current legislation, regulation and policy, of the ways in which criteria may be implemented or enforced.

5.2.4.2 Waste hierarchy

General Findings: The jurisdictions have generally implemented the waste hierarchy well, using specific waste legislation as well as general environment protection legislation. Although not specific to groundwater, the measures adopted seem likely to reduce groundwater pollution in the long term.

Recommendation: A future revision of the Groundwater Guidelines may assist the jurisdictions by providing some examples as to how the waste hierarchy has been adopted.

5.2.4.3 Licensing of point sources and discharges in protected areas

General Findings: The general environmental protection legislation in all jurisdictions requires certain activities that are potentially polluting (and in some cases, the construction of works for the activities) to be authorised, usually if the activities are carried out at a particular intensity or are of a particular size, or if they have a particular level of impact. Special legislation is used for issuing authorisations in relation to mining, quarrying, pesticides, hazardous chemicals, petroleum, dangerous goods, agricultural chemicals, geothermal energy and greenhouse gas sequestration and storage.

Recommendation: A future revision of the Groundwater Guidelines could be updated to consider authorisations that apply to new industries such as geothermal energy and greenhouse gas sequestration and storage.

5.2.4.4 Environmental impact assessment

General Findings: All jurisdictions provide for environmental impact assessment (EIA), though they use different triggers for assessment, and provide for different levels of assessment. Some jurisdictions which guide proponents as to the factors which they must consider in preparing EIA documents specifically mention groundwater quality and GDEs. A higher-level variant of EIA—strategic impact assessment—is in its early stages of development and may prove useful in dealing with diffuse sources of pollution.

Recommendation: A future revision of the Groundwater Guidelines should investigate and discuss the potential for a relatively new and developing technique, strategic impact assessment, to assist in groundwater quality protection.

5.2.4.5 Monitoring requirements

General Findings: The jurisdictions implement monitoring requirements through numerous instruments under their Environment Protection Frameworks, including conditions on authorisations, agreements with State EPAs, and directions to remedy pollution or environmental harm. The legislation provides for imposing monitoring requirements, but does not include detailed considerations as to monitoring points, frequency, etc.

5.2.4.6 Contingency measures

General Findings: The jurisdictions have a large number of tools available to them to direct a person to clean up pollution or contaminated land, rectify environmental harm, or cease or modify an activity which is polluting or causing environmental harm.

Recommendation: A future revision of the Groundwater Guidelines should be updated to reflect the fact that stronger contingency measures are now available in all jurisdictions.

5.2.4.7 Controlling diffuse sources

General Findings: The jurisdictions have developed the tools available to address diffuse source pollution since the Groundwater Guidelines were published, and now emphasise the use of market incentives and "best practice management". However, the tools available do not capture a complete range of potentially problematic activities, nor are they available in all jurisdictions.

Recommendation: A future revision of the Groundwater Guidelines should retain a focus on diffuse sources of pollution, but should provide further detail on the types of modern tools available to address diffuse sources, both in Australia and also (given the need for further development of this area in Australia) overseas. It should also discuss the issue of acid sulphate soils, which many jurisdictions now address.

5.2.5 Land-Use Planning Framework

5.2.5.1 Land zoning and land-use risk matrices

General Findings: Although the jurisdictions' Land-Use Planning Frameworks rarely explicitly use the concept of a land use-risk matrix, zoning provisions and considerations relevant to granting a planning authorisation refer to land capability and suitability in ways which may protect groundwater.

Recommendation: In considering a future revision of the Groundwater Guidelines, it may be useful to consider the utility and practicality of the concept of a land-use risk matrix, and the likely reasons for low levels of implementation.

5.2.5.2 Protection for drinking water sources and recharge zones

General Findings: The jurisdictions protect groundwater supplies and recharge zones through their Land-Use Planning Frameworks in various ways, including through zoning, linking planning schemes with elements of the Groundwater Management Framework, and provisions in relation to assessing proposed developments.

Recommendation: A future revision of the Groundwater Guidelines may assist the jurisdictions by providing some examples of the mechanisms used to protect drinking water sources and recharge zones.

5.2.5.3 Controls on particular developments and risky activities

General Findings: Land-Use Planning Frameworks use State plans, planning schemes, and conditions on planning authorisations to apply various controls to potentially polluting developments, land clearing and runoff production. While there are particularly valuable examples of such measures, they do not appear to be uniformly applied across the jurisdictions. However, some jurisdictions may rely on the discretion exercised by a planning decision-maker to refuse a development, or to apply suitable conditions.

Recommendation: The Groundwater Guidelines should retain a focus on the importance of Land-Use Planning Frameworks to control risky developments.

5.2.5.4 Measures related to the development and administration of planning tools

General Findings: The jurisdictions generally use strong public consultation and referral provisions in their Land-Use Planning Frameworks, enabling agencies and entities with functions relating to health, catchment management, water, and the environment to provide comments or impose requirements in relation to planning authorisations. However, requirements to monitor and review planning tools tend to be less robust, and rarely explicitly require a review of the effectiveness of the tool in the context of environmental protection.

Recommendation: A future revision of the Groundwater Guidelines should highlight examples of effective monitoring and review provisions, and provisions which encourage planning tools to align with elements of Groundwater Management Frameworks.

5.3 REGULATORY REVIEW – KEY FINDINGS BY THE JURISDICTIONS

This section sets out a brief summary of key points in the implementation of the Groundwater Guidelines in each jurisdiction, with cross-references to the Framework Tables in Appendix A. In each case, this is followed by diagrams which summarise how each Groundwater Management Framework, Environment Protection Framework and Land-Use Planning Framework reflects the Guidelines.

For a detailed description of how each jurisdiction implements the Groundwater Guidelines, see Appendix A.

5.3.1 Commonwealth

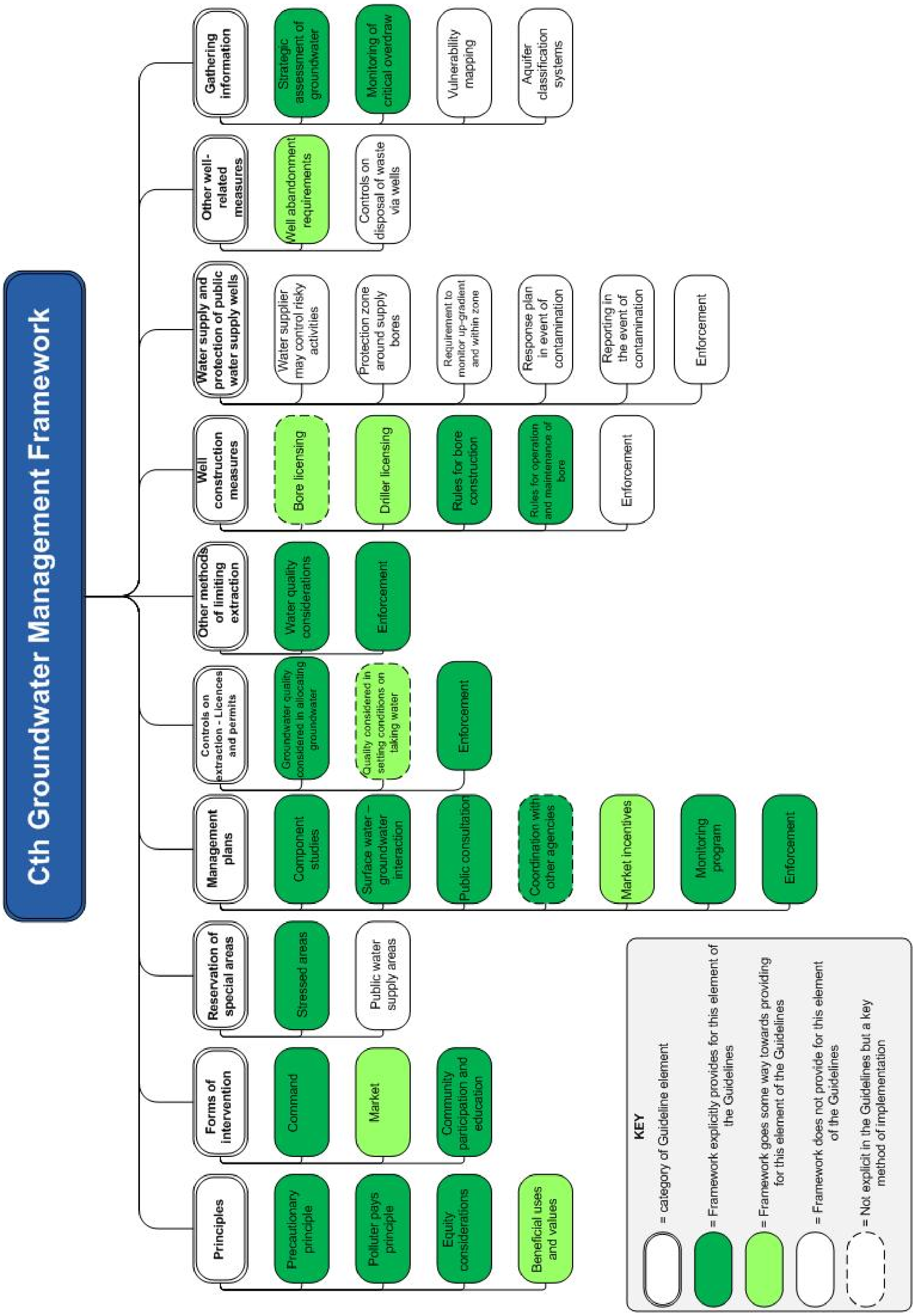
The regulatory framework for protecting groundwater in Commonwealth legislation, regulation and policy generally implements the Guidelines well. The nature of Commonwealth implementation is, however, significantly different from that of the States, given its different legislative responsibilities. The Commonwealth has implemented the Guidelines in the following key ways:

(a) through the Commonwealth Water Act requiring that the water quality and salinity management plan component of the Basin Plan for the MDB be prepared having regard to the NWQMS (rows 16 and 17, Commonwealth Groundwater Management Framework Table);

(b) through the GAB Strategic Management Plan (prepared in coordination with the GAB States), which provides for many aspects of groundwater quality protection, and which is implemented by the signatory States; and

(c) through the National Environment Protection (Assessment of Site Contamination) Measure, which includes a guideline on the risk-based assessment of groundwater contamination, and which each State implements.

Recent Commonwealth legislation, regulation and policy emphasise the importance of water-dependent ecosystems, indigenous uses of water and collecting groundwater information (see, for example, the Commonwealth Water Act), and strategic assessment (see for, example, the Environment Protection Biodiversity Conservation Act). These developments should be reflected in a future revision of the Groundwater Guidelines.


Cth Groundwater Management Framework
Principles
Precautionary principle
Polluter pays principle
Equity considerations
Beneficial uses and values
Forms of intervention
Command
Market
Community participation and education
Reservation of special areas
Stressed areas
Public water supply areas
Management plans
Component studies
Surface water – groundwater interaction
Public consultation
Coordination with other agencies
Market incentives
Monitoring program
Enforcement
Controls on extraction - Licences and permits
Groundwater quality considered in allocating groundwater
Quality considered in setting conditions on taking water
Enforcement
Other methods of limiting extraction
Water quality considerations
Enforcement
Well construction measures
Bore licensing
Driller licensing
Rules for bore construction
Rules for operation and maintenance of bore
Enforcement
Water supply and protection of public water supply wells
Water supplier may control risky activities
Protection zone around supply bores
Requirement to monitor up-gradient and within zone
Response plan in event of contamination
Reporting in the event of contamination
Enforcement
Other well-related measures
Well abandonment requirements
Controls on disposal of waste via wells
Gathering information
Strategic assessment of groundwater
Monitoring of critical overdraw
Vulnerability mapping
Aquifer classification systems
KEY
= category of Guideline element
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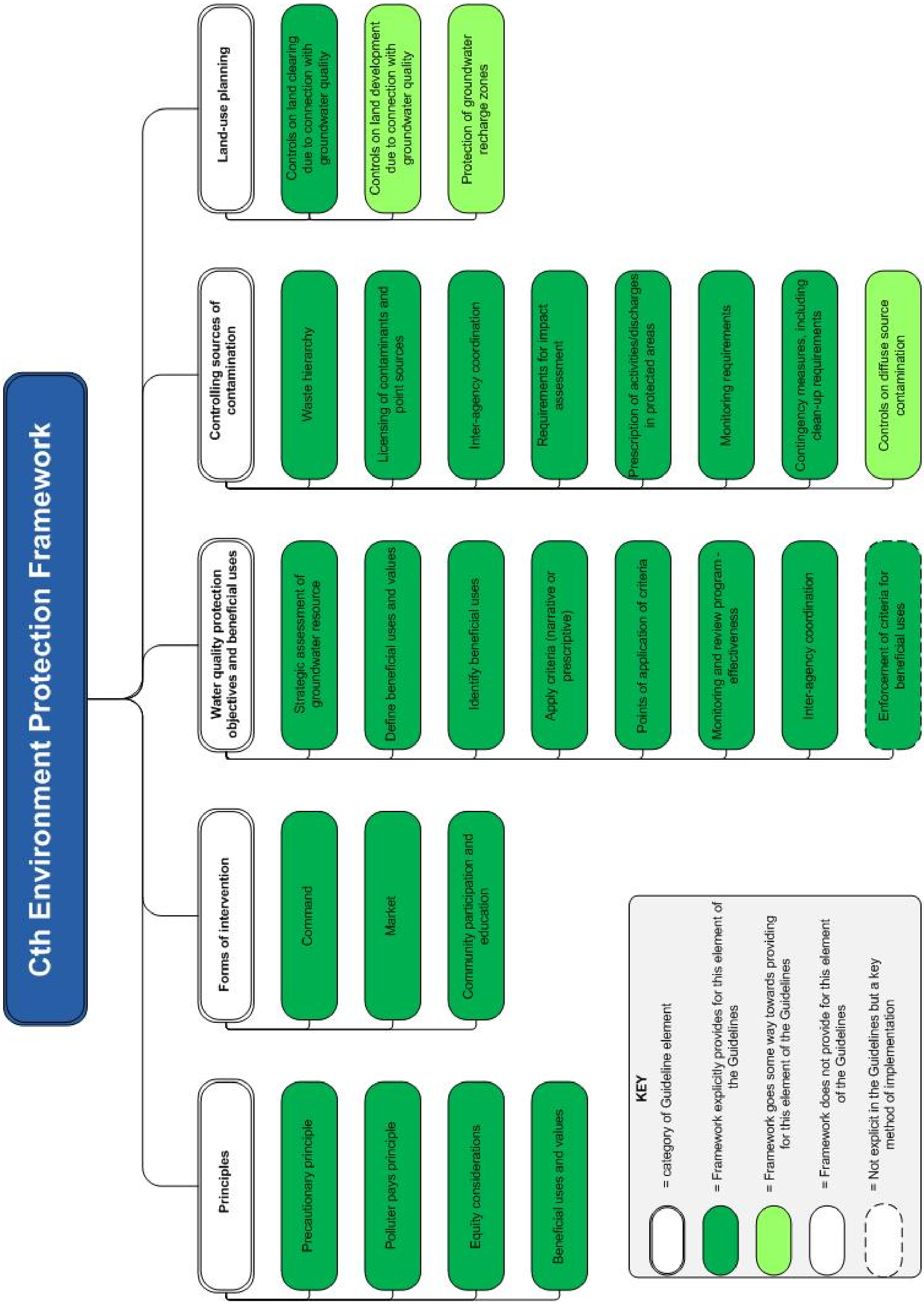
= Framework does not provide for this element of the Guidelines
= Not explicit in the Guidelines but a key method of implementation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Monitoring and review program - effectiveness
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Waste hierarchy
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Monitoring requirements
Contingency measures, including clean-up requirements
Controls on diffuse source contamination
Land-use planning
Controls on land clearing due to connection with groundwater quality
Controls on land development due to connection with groundwater quality
Protection of groundwater recharge zones
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5.3.2 Australian Capital Territory

5.3.2.1 Implementing the Guidelines – key areas of strength

The regulatory framework for protecting groundwater in the ACT generally implements the Guidelines well. Although ACT legislation, regulation and policy generally do not focus on groundwater, they provide a system for protecting groundwater quality, should the ACT choose to exploit this resource to a higher degree. Areas of particular strength are:

(a) protecting drinking water quality (noting that the ACT does not presently use groundwater for public water supply). This includes developing Strategic Water Quality Improvement Plans, and formal information exchange with catchment agencies in relation to water quality impacts in catchments (row 33, ACT Groundwater Management Framework Table);

(b) establishing a regulatory basis for market instruments that could be used in the groundwater quality context, such as tradeable permit schemes and "bubble licence schemes" (row 6, ACT Environment Protection Framework Table);

(c) controlling stormwater quality, by requiring developments within particular planning zones to provide modelled studies of pollutant loads (although the focus tends to be on surface water) (row 15, ACT Land-Use Protection Framework Table); and

(d) providing a comprehensive referral system for developments (row 18, ACT Land-Use Protection Framework Table).

5.3.2.2 Opportunities for further implementation of the Guidelines

Some aspects of the ACT regulatory framework provide further scope to implement the Guidelines. Matters to consider include:

(a) clarifying the application of ambient environmental standards to groundwater, and where relevant, using environmental values and ambient environmental standards in the Groundwater Management Framework, to ensure decision-making about water allocation considers water quality; and

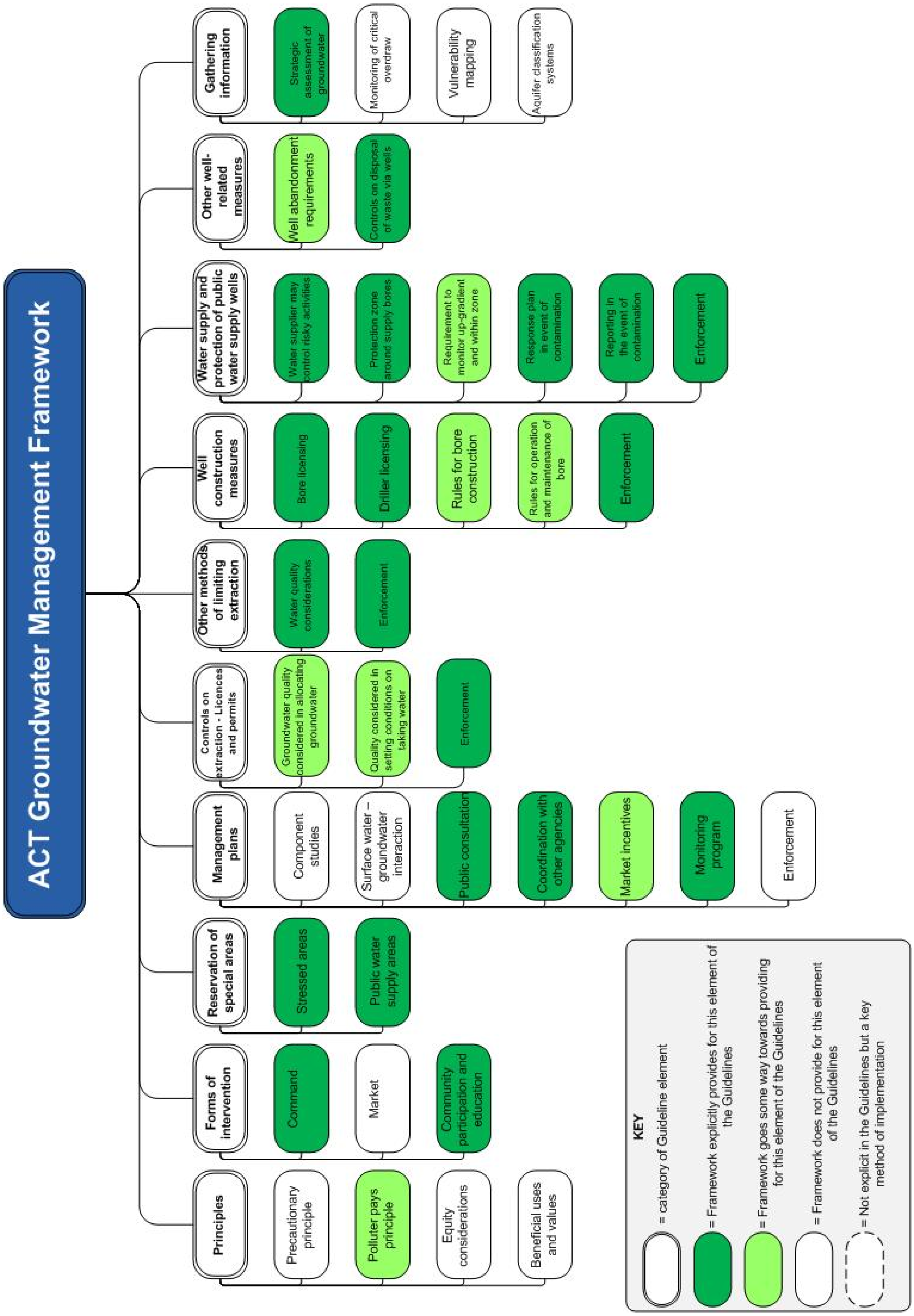
(b) enhancing the legislative, regulatory and policy framework for groundwater quality monitoring (see rows 39 to 43, ACT Groundwater Management Framework Table).

5.3.2.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the ACT regulatory framework for groundwater present ways of protecting groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

(a) establishing licenses for groundwater recharge activities under the Water Resources Act (row 38, ACT Groundwater Management Framework Table); and

(b) providing for strategic environmental assessments of major policy initiatives, as well as assessments of the environmental impacts of individual developments (row 19, ACT Environment Protection Framework Table).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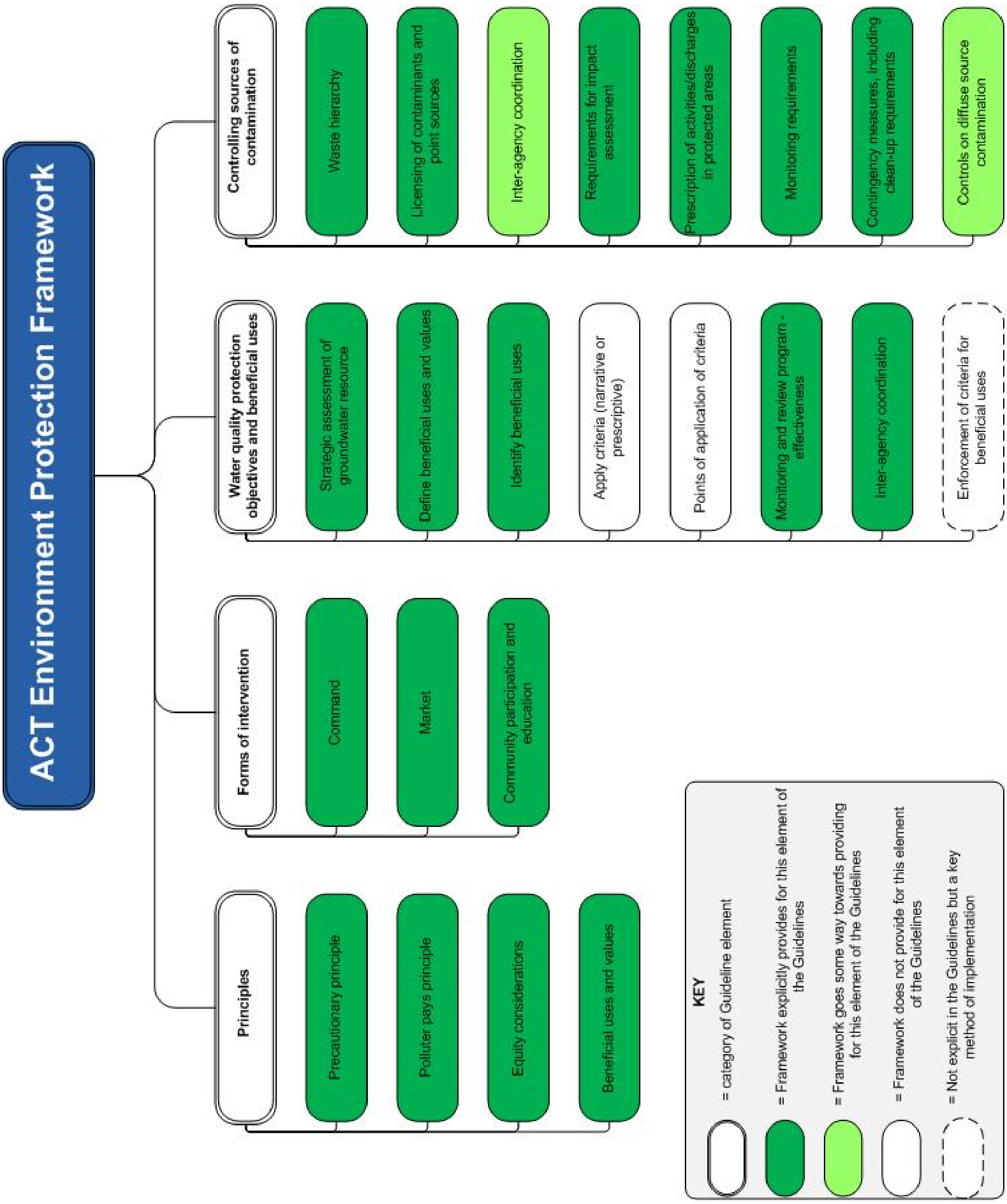
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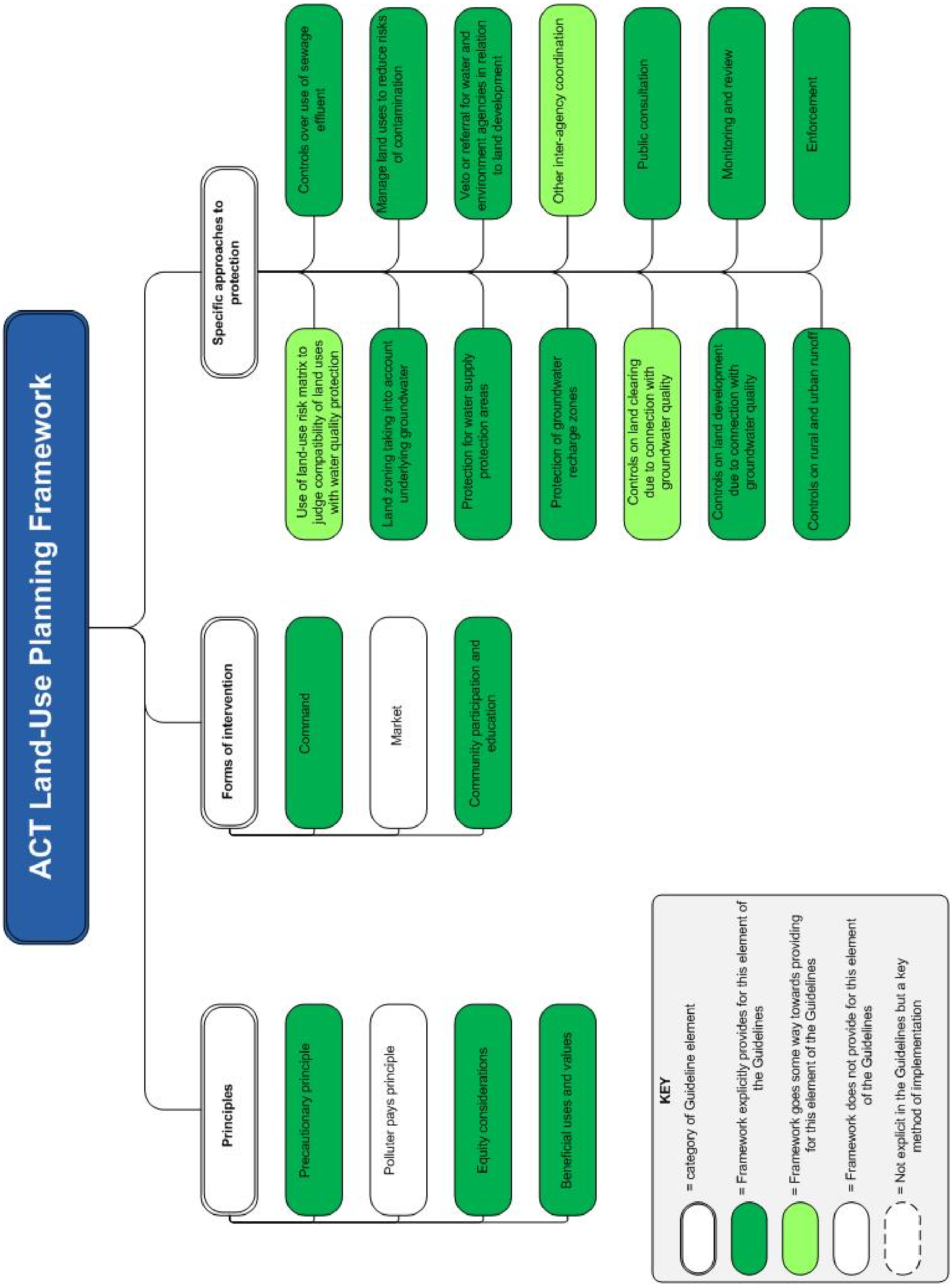
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Controls on rural and urban runoff
Controls over use of sewage effluent
Manage land uses to reduce risks of contamination
Veto or referral for water and environment agencies in relation to land development
Other inter-agency coordination
Public consultation
Monitoring and review
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5.3.3 New South Wales

5.3.3.1 Implementing the Guidelines – key areas of strength

The regulatory framework for protecting groundwater in NSW generally implements the Guidelines very well, although it has taken a significantly different approach to other jurisdictions in relation to the beneficial use principle. NSW has adopted community-driven water quality objectives through non-statutory policy, which is not intended to be enforceable directly. Particular areas of strength within the NSW regulatory framework include:

(a) directly translating the Guidelines into the formal NSW State Groundwater Policy. This allows concepts such as vulnerability mapping and aquifer classification to operate within the support (and perhaps the added stability) of a formal policy framework, which this Review has found to be relatively rare;

(b) strongly connecting water quality considerations to water sharing decisions through the NSW State Groundwater Policy, and the provisions of the Water Management Act, which provide for the State Water Management Outcomes Plan and management plans for particular water sources (rows 11 to 18, NSW Groundwater Management Framework Table);

(c) using overarching “water management principles”, which include principles in relation to protecting and enhancing water quality and minimising cumulative impacts, to guide the exercise of every function under the Water Management Act (rows 5, 11, 17, 19, 23, 25, 40, NSW Groundwater Management Framework Table);

(d) strongly connecting land use and water management, by enabling water management plans directly to control developments (row 5, NSW Land-Use Protection Framework Table); and

(e) establishing a regulatory basis for market instruments such as tradeable emissions schemes and green offsets in the Environment Protection Act (row 6, NSW Environment Protection Framework Table).

5.3.3.2 Opportunities for further implementation of the Guidelines

Some aspects of the NSW regulatory framework provide further scope to implement the Guidelines. Matters to consider include: the need for a formal program or structure for reviewing the community-based water quality objectives and evaluating their effectiveness; and the need to provide more regulatory or policy detail in relation to groundwater quality monitoring. It is also noted that a key regulatory document which uses the water quality objectives—the State Water Management Outcomes Plan—is no longer in effect.

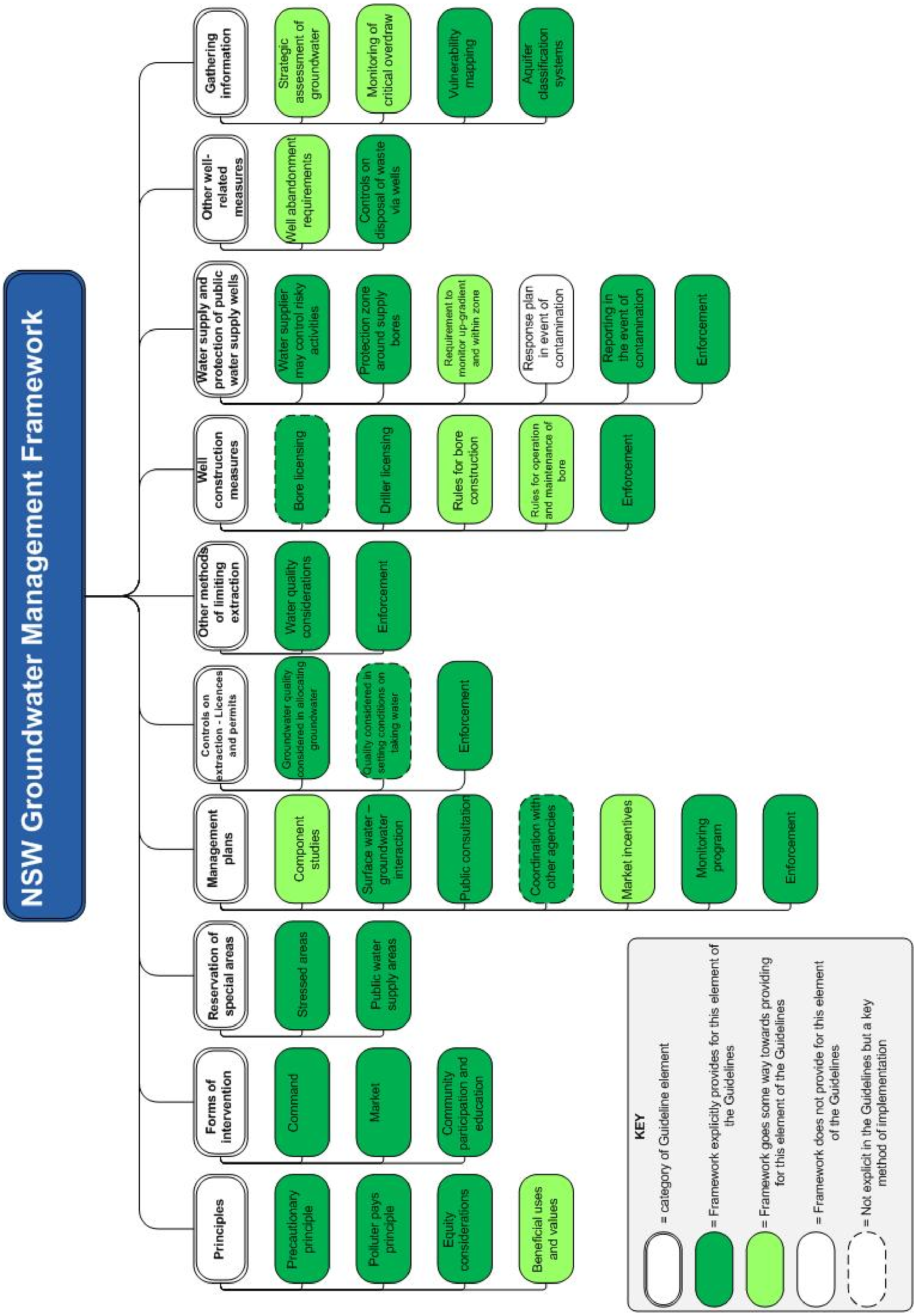
5.3.3.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the New South Wales regulatory framework for groundwater present ways of protecting groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

(a) regulating “aquifer interference activities” (for example, sand mining) which may have an impact on groundwater quality, but which would not otherwise be controlled within a bore licensing or water allocation system (row 6, NSW Groundwater Management Framework Table);

(b) introducing a state-wide policy on GDEs, which recognises the need to consider water quality (row 11, NSW Groundwater Management Framework Table); and

(c) introducing a state-wide policy on diffuse pollution, focusing on market instruments such as incentives for best management practices, while simultaneously formally recognising the need to strengthen environmental legislation to address diffuse pollution (rows 6 and 23, NSW Environment Protection Framework Table).


NSW Groundwater Management Framework
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Precautionary principle
Polluter pays principle
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Community participation and education
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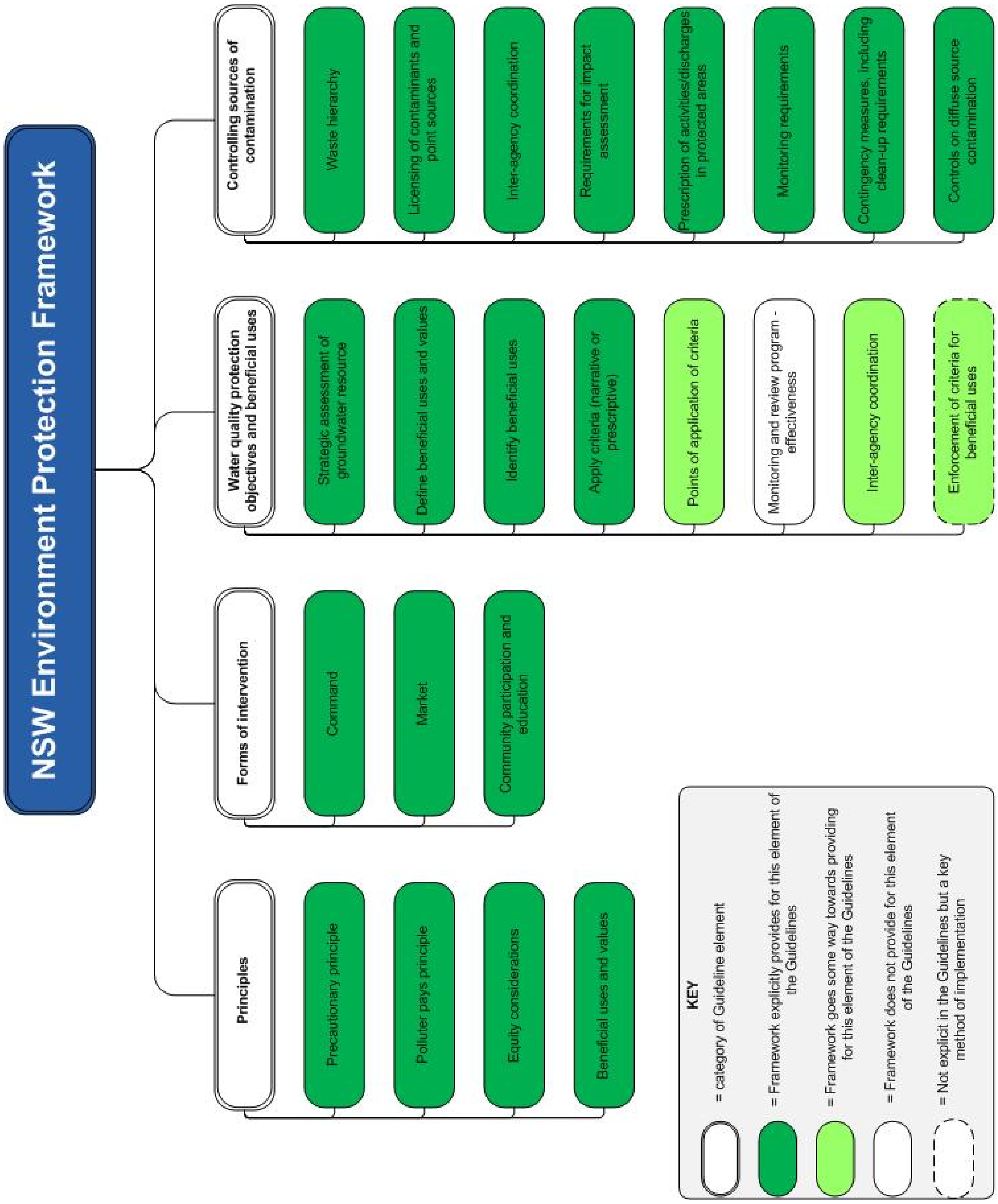
NSW Environment Protection Framework
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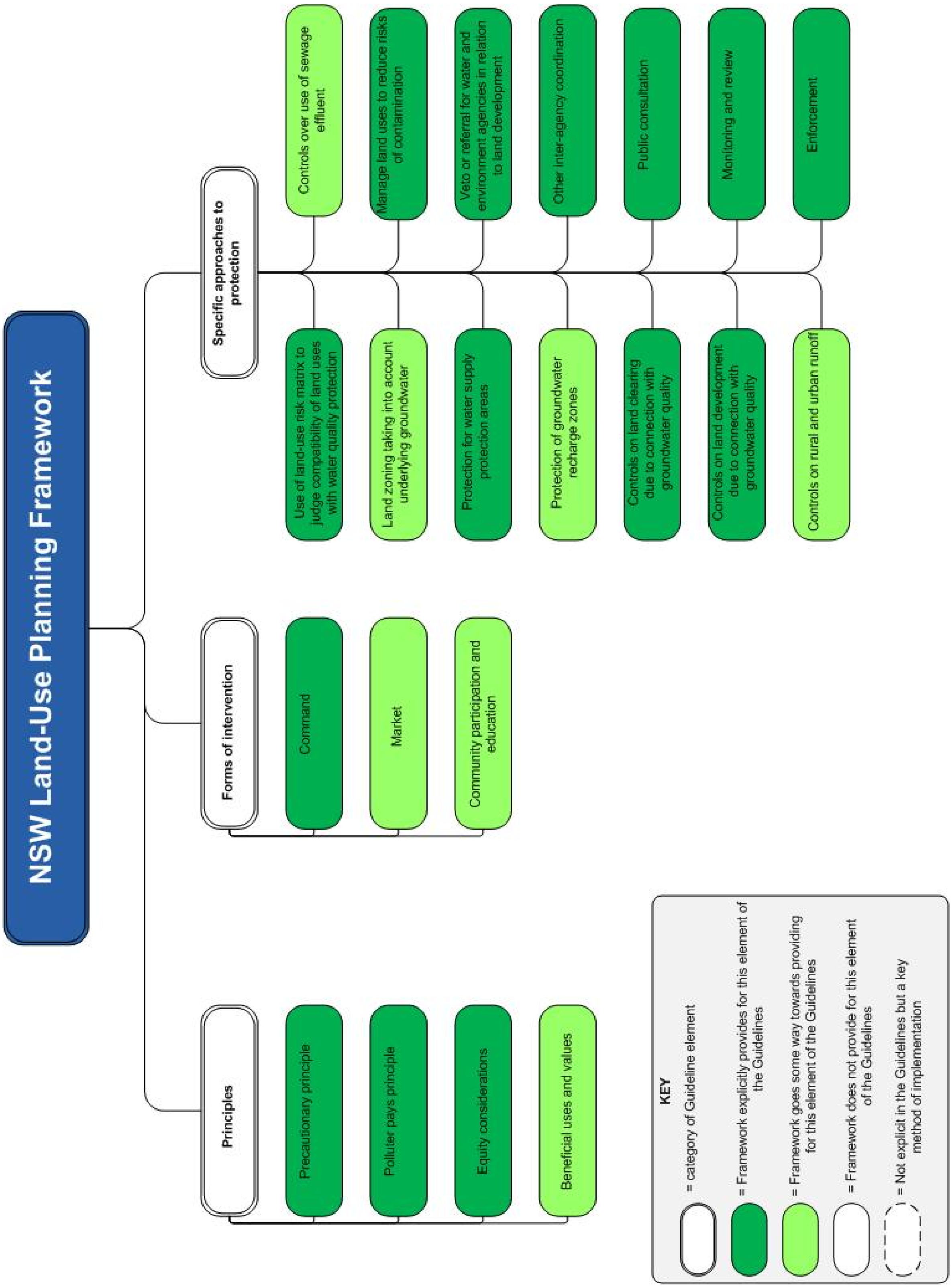
NSW Land-Use Planning Framework
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5.3.4 Northern Territory

5.3.4.1 Implementing the Guidelines – key areas of strength

The NT generally implements the key elements of the Guidelines. Particular areas of strength include:

(a) strongly integrating the protection of beneficial uses between Groundwater Management, Land-Use Planning and Environment Protection Frameworks, by explicitly requiring decision-makers to consider the applicable beneficial uses and quality criteria in relation to each of the following matters:
 (i) water licences (row 19, NT Groundwater Management Framework Table);
 (ii) environment protection licences (row 15, NT Environment Protection Framework Table); and
 (iii) development applications (row 11, NT Land-Use Protection Framework Table).

(b) using strong yet flexible "command" regulation to impose a general environmental duty to take all measures that are reasonable and practicable to prevent or minimise pollution or environmental harm, with supporting codes of practice (row 5, NT Environment Protection Framework Table);

(c) establishing general environmental duties, as well as licensing requirements, in the context of mining and other resources operations (row 5, NT Environment Protection Framework Table); and

(d) providing for automatic licence conditions that protect beneficial uses (row 15, NT Environment Protection Framework Table).

5.3.4.2 Opportunities for further implementation of the Guidelines

Some of the principles underlying the Guidelines (the precautionary principle, polluter pays principle, and equitable considerations) could be further developed in NT legislation, regulation and policy. The NT could pursue further implementation of the Guidelines through introducing quality-related considerations in relation to water allocation plans, enhancing the powers and duties of drinking water suppliers in relation to supply borefields, and gathering information related to groundwater quality. The NT may also consider more detailed provisions in relation to criteria for beneficial uses and control of diffuse sources.

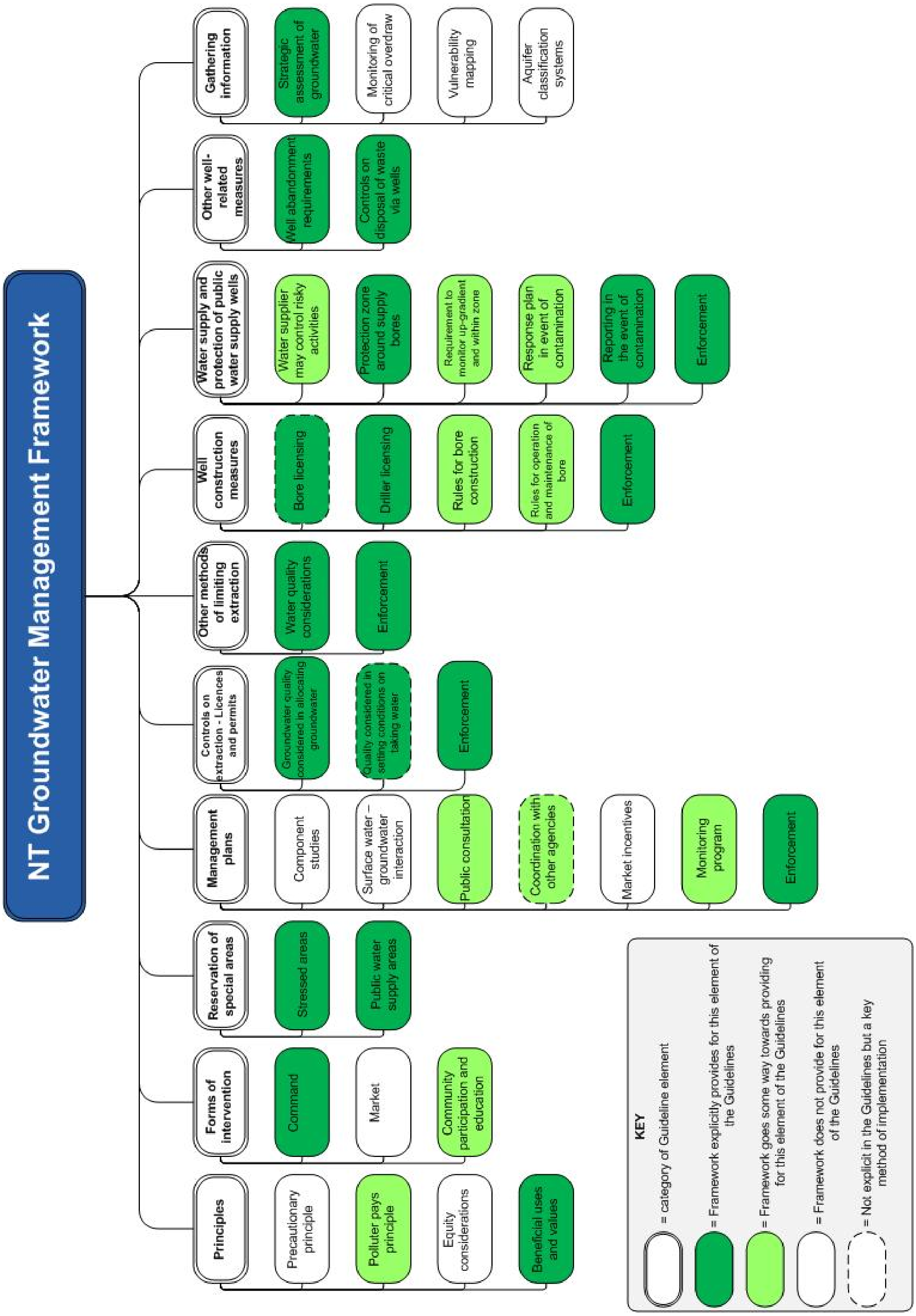
5.3.4.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the NT regulatory framework for groundwater present ways of protecting groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

(a) requiring the decision-maker in relation to water licences to publicise information on how water quality is considered in relation to a licence to take groundwater—this provides a strong incentive to consider water quality rigorously in such decisions (row 19, NT Groundwater Management Framework Table);

(b) establishing a licensing structure for groundwater recharge activities (recharge licences under the Water Act), which involves considering groundwater quality (row 39, NT Groundwater Management Framework Table); and

(c) providing for market incentives in the context of environment protection licensing by reducing or waiving fees for licence holders who demonstrate best practice and environmental performance beyond regulatory requirements (row 6, NT Environment Protection Framework Table).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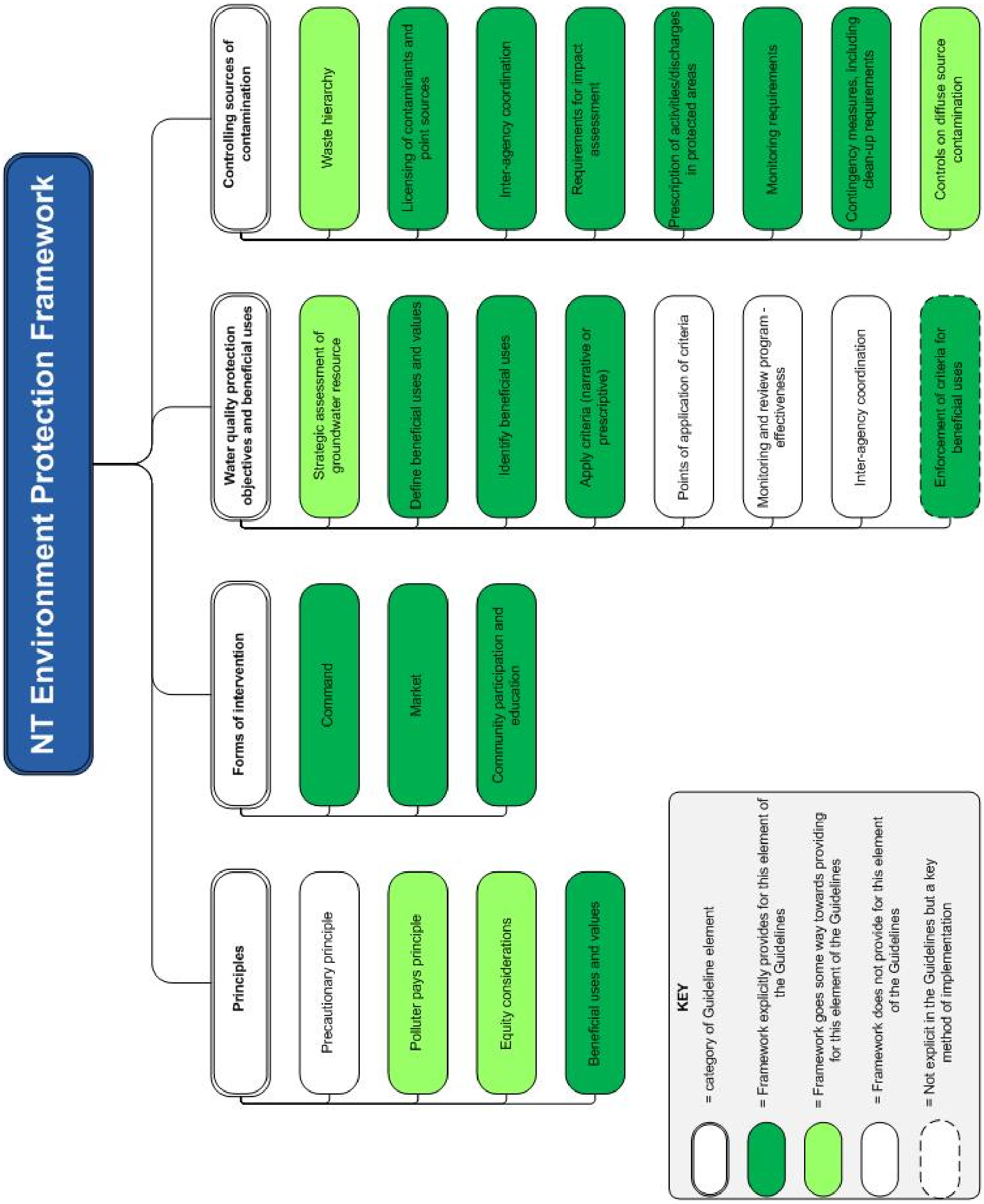
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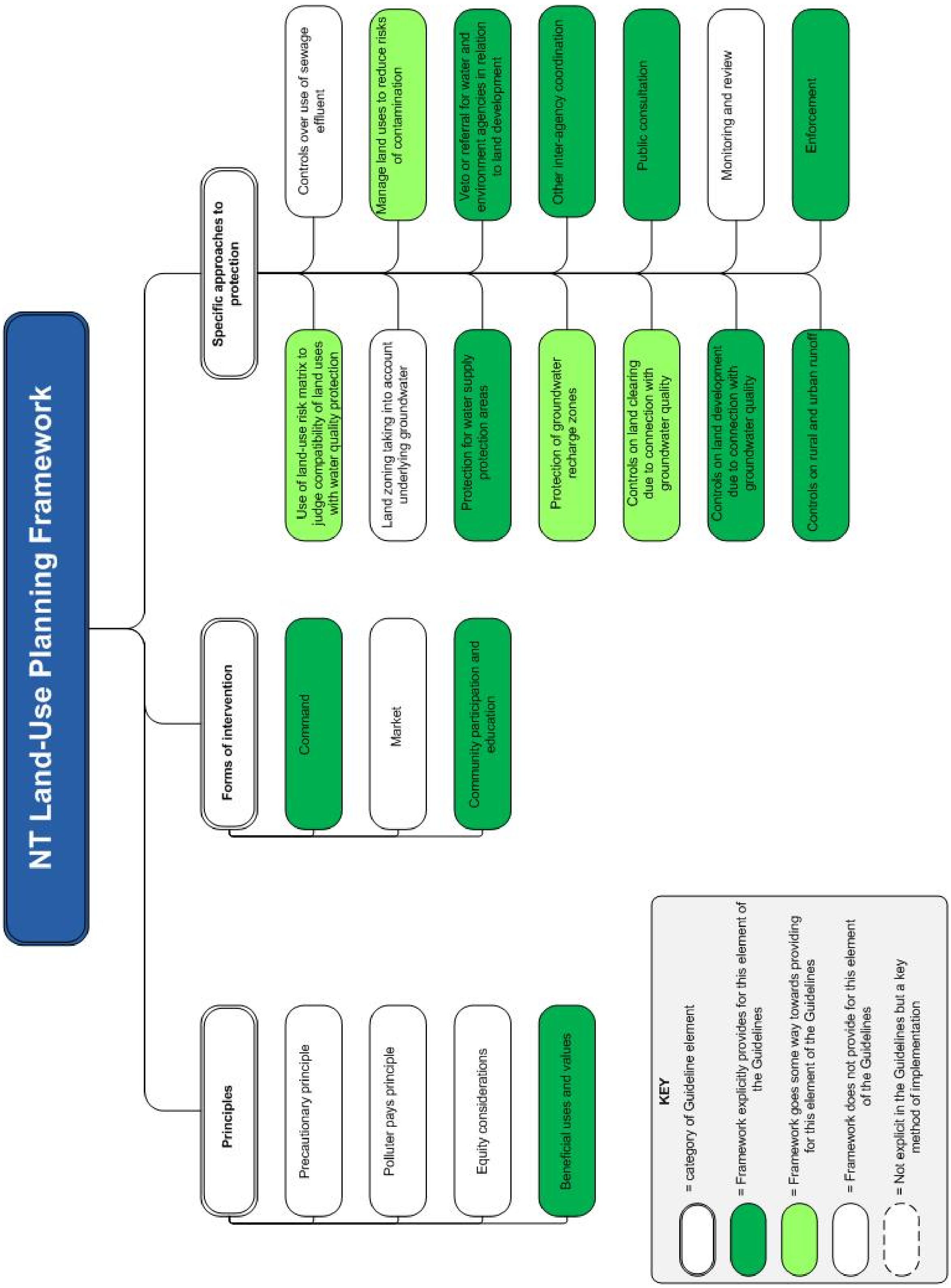

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5.3.5 Queensland

5.3.5.1 Implementing the Guidelines – key areas of strength

Queensland's regulatory framework for protecting groundwater generally implements the Guidelines very well. Particular areas of strength include:

(a) strong monitoring and reviewing provisions in relation to water resource plans, water use plans, and resource operations plans, which encompass water and natural ecosystem monitoring; periodic reporting; and assessing the effectiveness of a water resource plan in achieving its outcomes (row 17, Qld Groundwater Management Framework Table);

(b) provisions relating to protecting drinking water supplies, and requiring a drinking water service provider to have a risk-based drinking water management plan (rows 30-35, Qld Groundwater Management Framework Table);

(c) strongly linking environmental values and quality objectives to the making of environmental management decisions (row 4, Qld Environment Protection Framework Table);

(d) detailed requirements to take account of environmental values and groundwater quality impacts in the generic terms of reference for preparing an environmental management plan as part of the EIA process (row 19, Qld Environment Protection Framework Table); and

(e) specific bore construction standards that exceed the national standards (see row 27, Qld Groundwater Management Framework Table).

5.3.5.2 Opportunities for further implementation of the Guidelines

Some aspects of Queensland's regulatory framework provide further scope to implement the Guidelines. This is the case in relation to the use of market instruments and economic incentives, requirements for the strategic assessment of groundwater resources (row 8, Qld Environment Protection Framework Table), and monitoring the effectiveness of the Environment Protection Policy, which provides for environmental values for groundwater (row 13, Qld Environment Protection Framework Table).

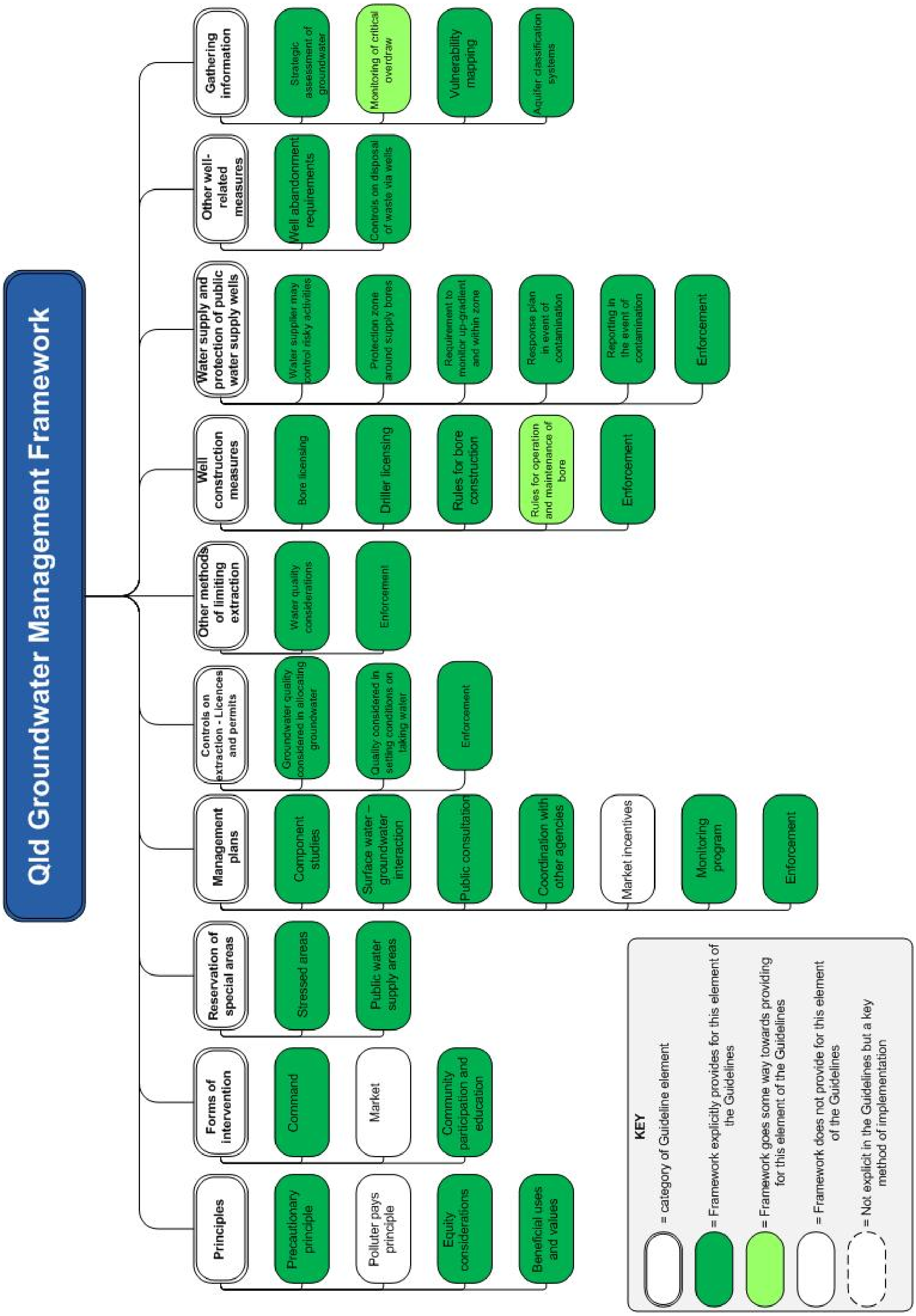
5.3.5.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the Queensland regulatory framework for groundwater present ways of protecting groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

(a) including as a protected environmental value, the cultural and spiritual values of a water, means "places, objects, or uses, in or near the water, that have anthropological, archaeological, historic, sacred or scientific significance or value" (row 10, Qld Environment Protection Framework Table);

(b) the concept of "best practice environmental management", which is relevant to environmental management plans for mining activities, and to numerous other activities, since it is included in "standard criteria" which are used for many environmental decisions (rows 17 and 18, Qld Environment Protection Framework Table); and

(c) a State Planning Policy for acid sulfate soils, which deals with the impacts of groundwater extraction on the release of acid and associated metal contaminants, and which is implemented through planning schemes (row 9, Qld Land-Use Protection Framework Table).


Qld Groundwater Management Framework
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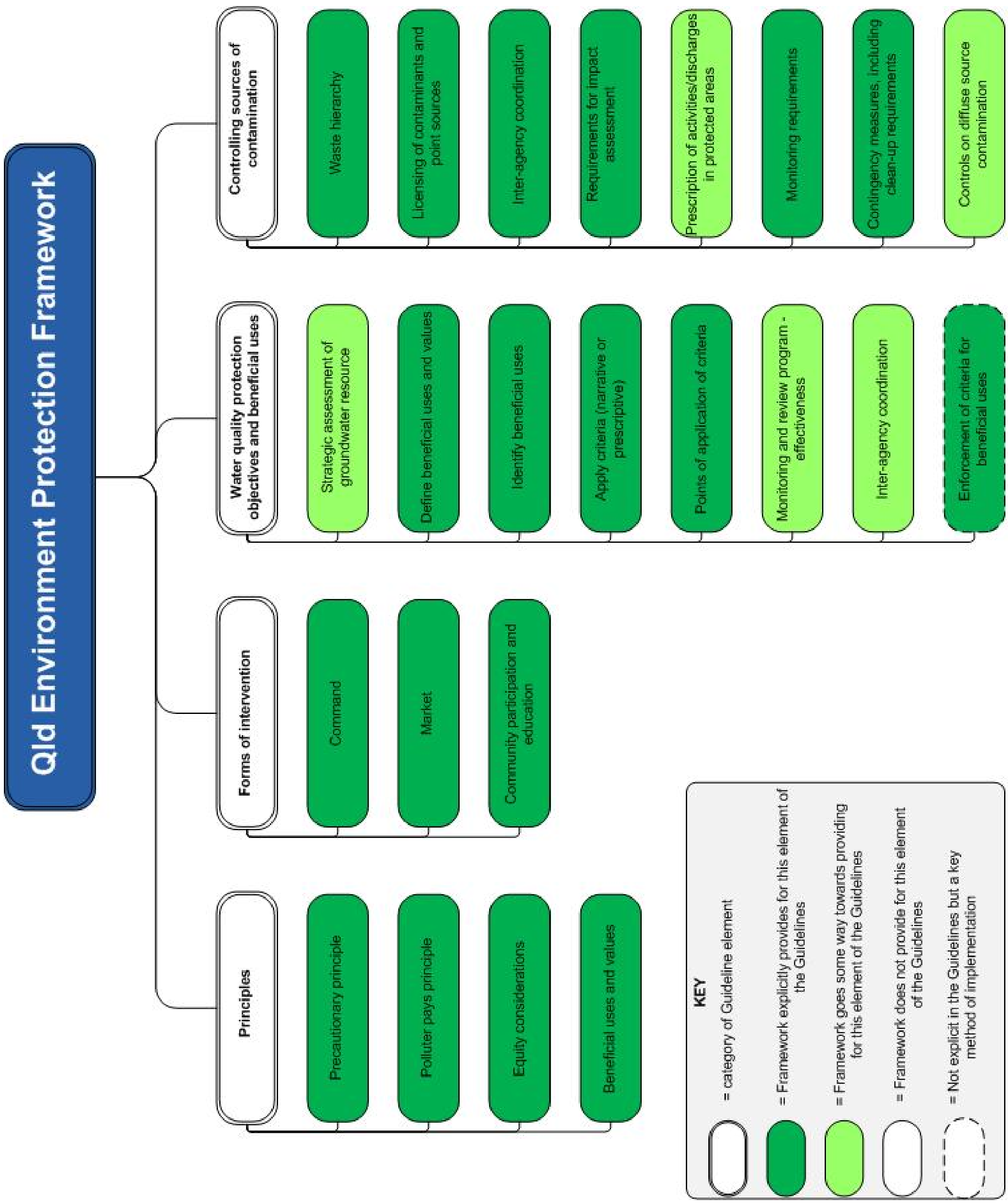
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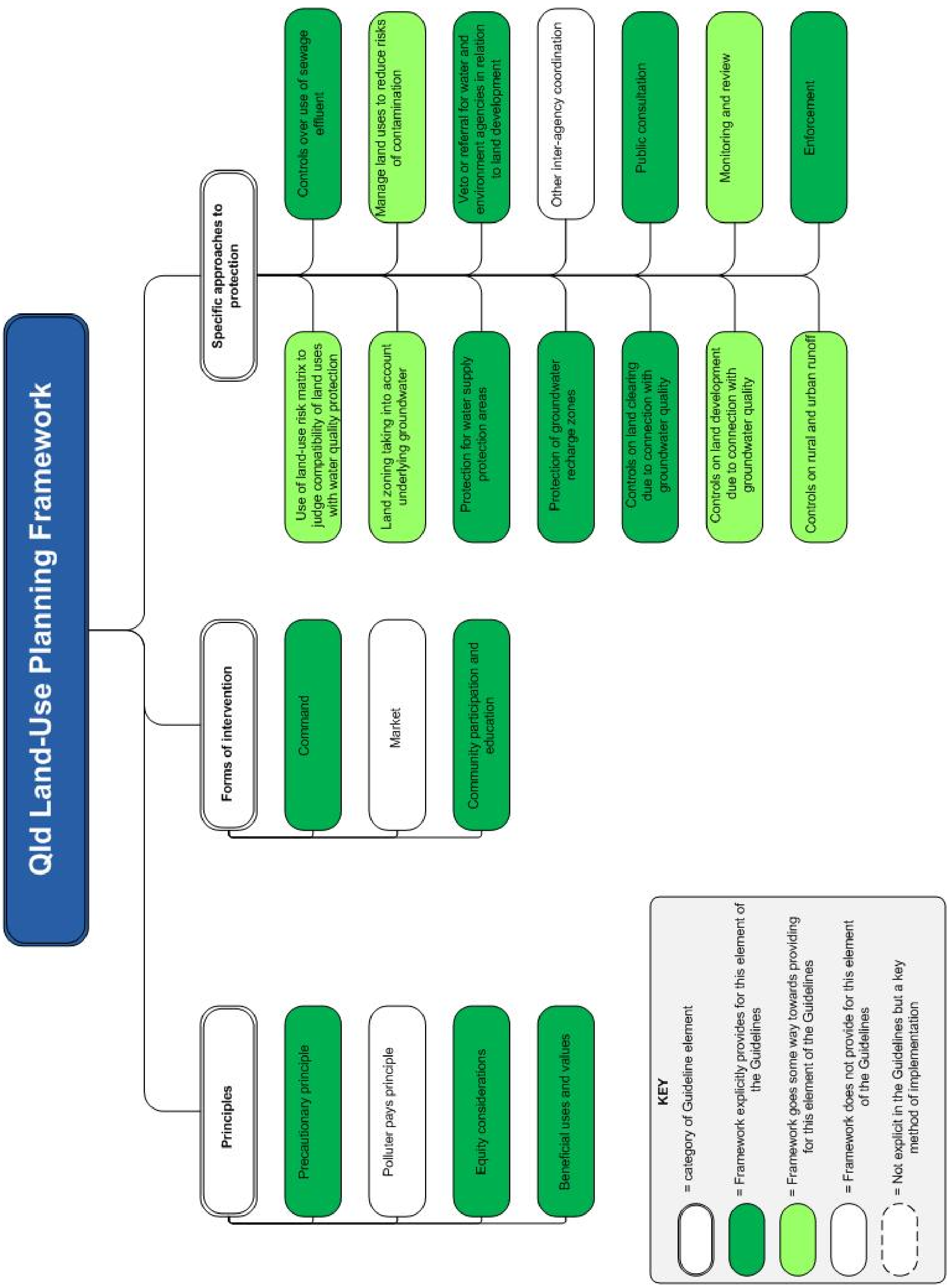
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5.3.6 South Australia

5.3.6.1 Implementing the Guidelines – key areas of strength

South Australia's regulatory framework for protecting groundwater generally implements the Guidelines very well. Particular areas of strength include:

(a) adopting the principles underlying the Guidelines (the polluter pays principle, etc). For example, persons exercising functions under particular acts (such as the NRM Act) must have regard to these principles in exercising their functions, which include making natural resource and water allocation plans (rows 1-3, SA Groundwater Management Framework Table);

(b) using and further developing market measures in relation to groundwater quality, including: management agreements under the River Murray Act, which may provide incentives to landowners to enhance groundwater (row 6, Groundwater Management Framework Table); and environmental performance agreements under the Environment Protection Act (row 3, SA Environment Protection Framework Table);

(c) adopting flexible yet strong "command" options, including: a general duty on well owners to ensure that wells are properly maintained (rows 23 and 28, SA Groundwater Management Framework Table); and a general duty on every person to take "all reasonable and practicable measures" to prevent or minimise environmental harm when undertaking an activity that pollutes, or might pollute, the environment (row 3, SA Environment Protection Framework Table); and

(d) adopting a detailed and legally robust framework for environmental values and criteria (rows 5 and 15, SA Environment Protection Framework Table).

5.3.6.2 Opportunities for further implementation of the Guidelines

Some aspects of South Australia's regulatory framework provide further scope to implement the Guidelines. This is most notably the case in relation to drinking water supply protection. South Australia is presently awaiting the introduction of a Safe Drinking Water Bill, which will remedy existing gaps in the framework, and allow water suppliers more proactively to manage water quality, through risk management plans and monitoring plans (rows 31 to 35, SA Groundwater Management Framework Table).

5.3.6.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the South Australian regulatory framework for groundwater present ways to protect groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

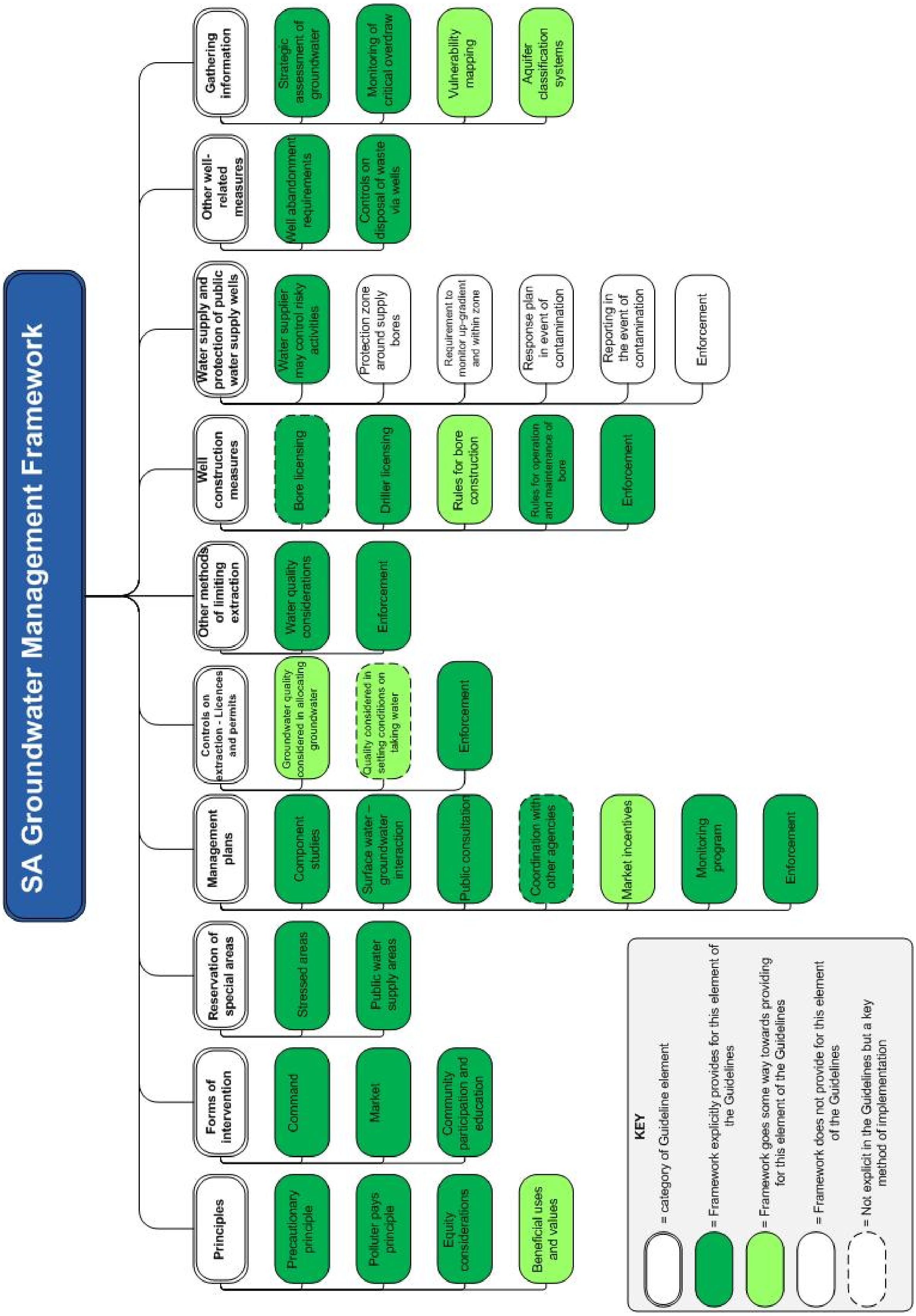
(a) providing explicitly for water allocation plans under the NRM Act to assess the quality of water needed by both surface water and groundwater dependent ecosystems (row 12, SA Groundwater Management Framework Table);

(b) providing explicitly for connected water resources, which affect each other in terms of quality, within water allocation plans under the NRM Act (row 13, SA Groundwater Management Framework Table);

(c) adopting an enforceable code of practice in relation to aquifer water storage and recovery schemes (row 38, SA Groundwater Management Framework Table);

(d) introducing a "cultural and spiritual" environmental value (row 10, SA Environment Protection Framework Table); and

(e) allowing for groundwater remediation over wide areas ("special management areas"), in addition to site-specific requirements (row 22, SA Environment Protection Framework Table).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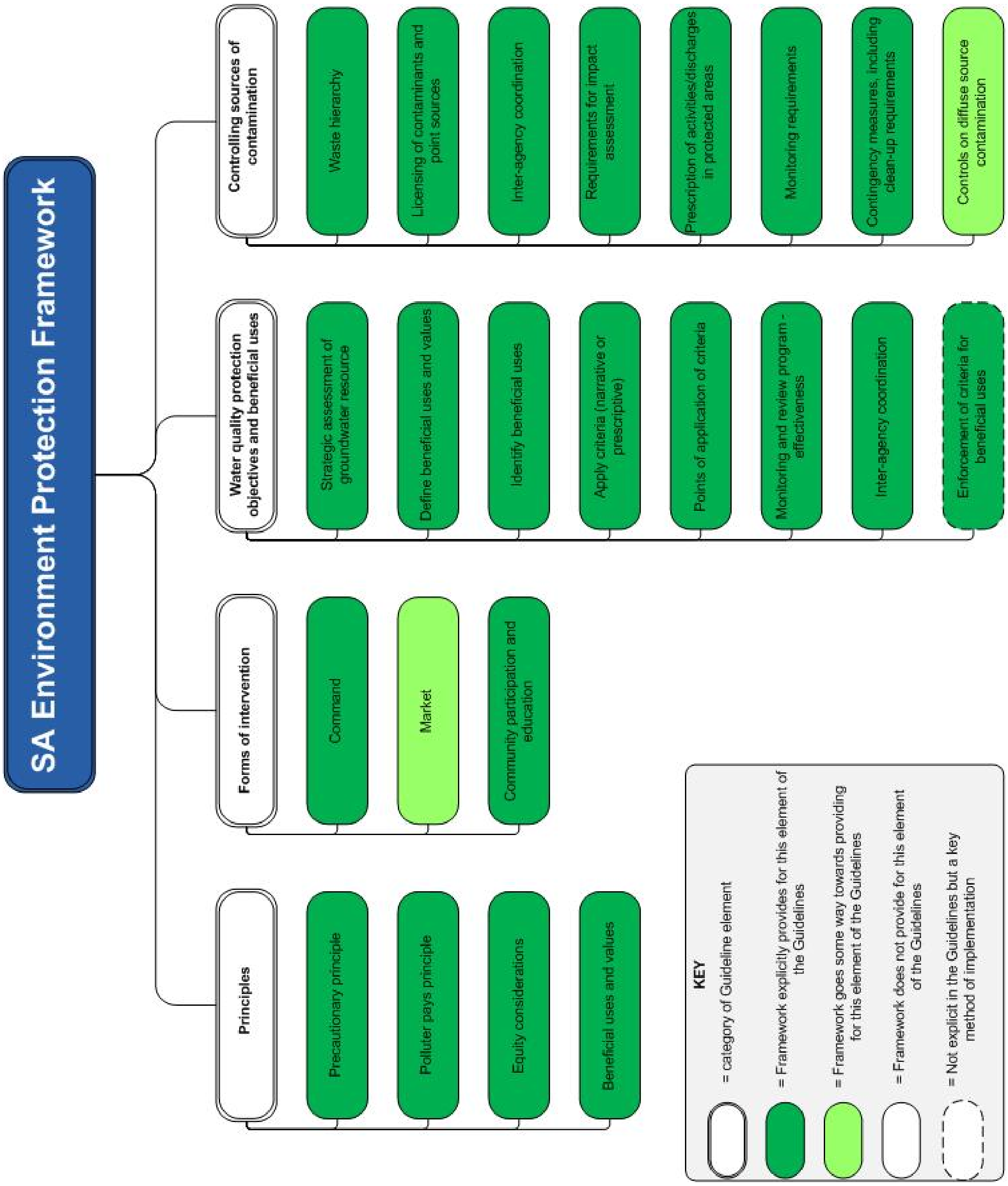
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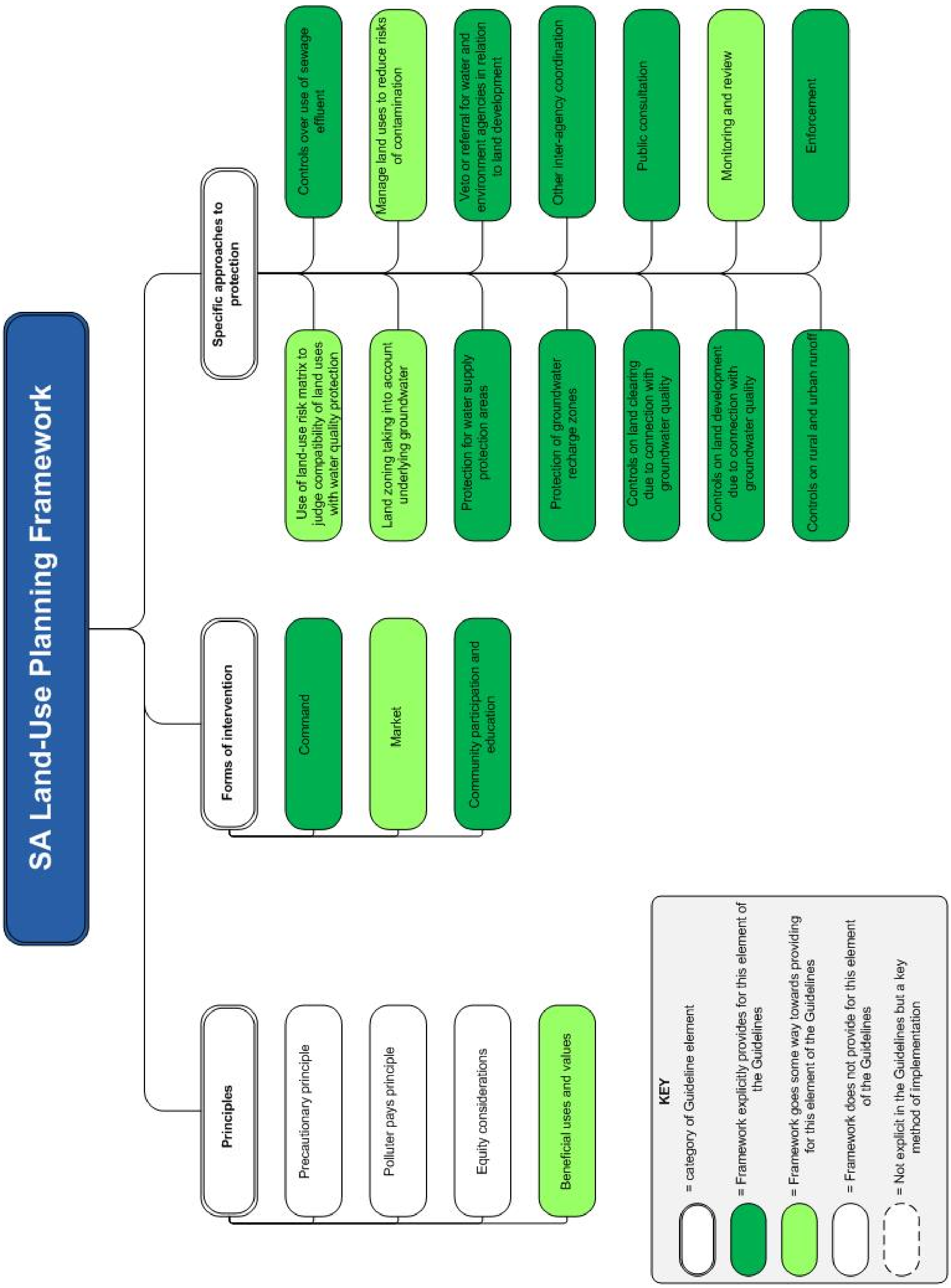
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5.3.7 Tasmania

5.3.7.1 Implementing the Guidelines – key areas of strength

Tasmania's regulatory framework for protecting groundwater generally implements the Guidelines well. Particular areas of strength include:

(a) protecting drinking water supplies, and requiring a water supplier to have a risk-based Drinking Water Management Plan to deal with issues such as monitoring, testing and incident responses (rows 30-35, Tas Groundwater Management Framework Table);

(b) strong provisions for considering groundwater quality impacts in relation to a decision to grant a groundwater licence and relevant conditions to be applied; and a decision to grant a permit to construct a bore (rows 19 and 20, Tas Groundwater Management Framework Table); and similarly, detailed requirements to take account of groundwater quality impacts in the guidelines for preparing an environmental management plan as part of the EIA process (row 19, Tas Environment Protection Framework Table); and

(c) protecting groundwater under the State Policy on Water Quality Management, which includes detailed provisions on how to determine an attenuation zone, and explicitly recognises the potential for poor quality groundwater to affect surface water (row 12, Tas Environment Protection Framework Table).

5.3.7.2 Opportunities for further implementation of the Guidelines

Some aspects of Tasmania's regulatory framework provide further scope to implement the Guidelines. Matters to consider include:

(a) using the State Policy mechanism to identify protected environmental values for groundwaters (row 10, Tas Groundwater Management Framework Table); and

(b) improving inter-agency coordination in the Land-Use Protection Framework Table (noting that this was also a recommendation of a recent review into Tasmania's planning system).

5.3.7.3 Beyond the Guidelines – innovative regulatory responses

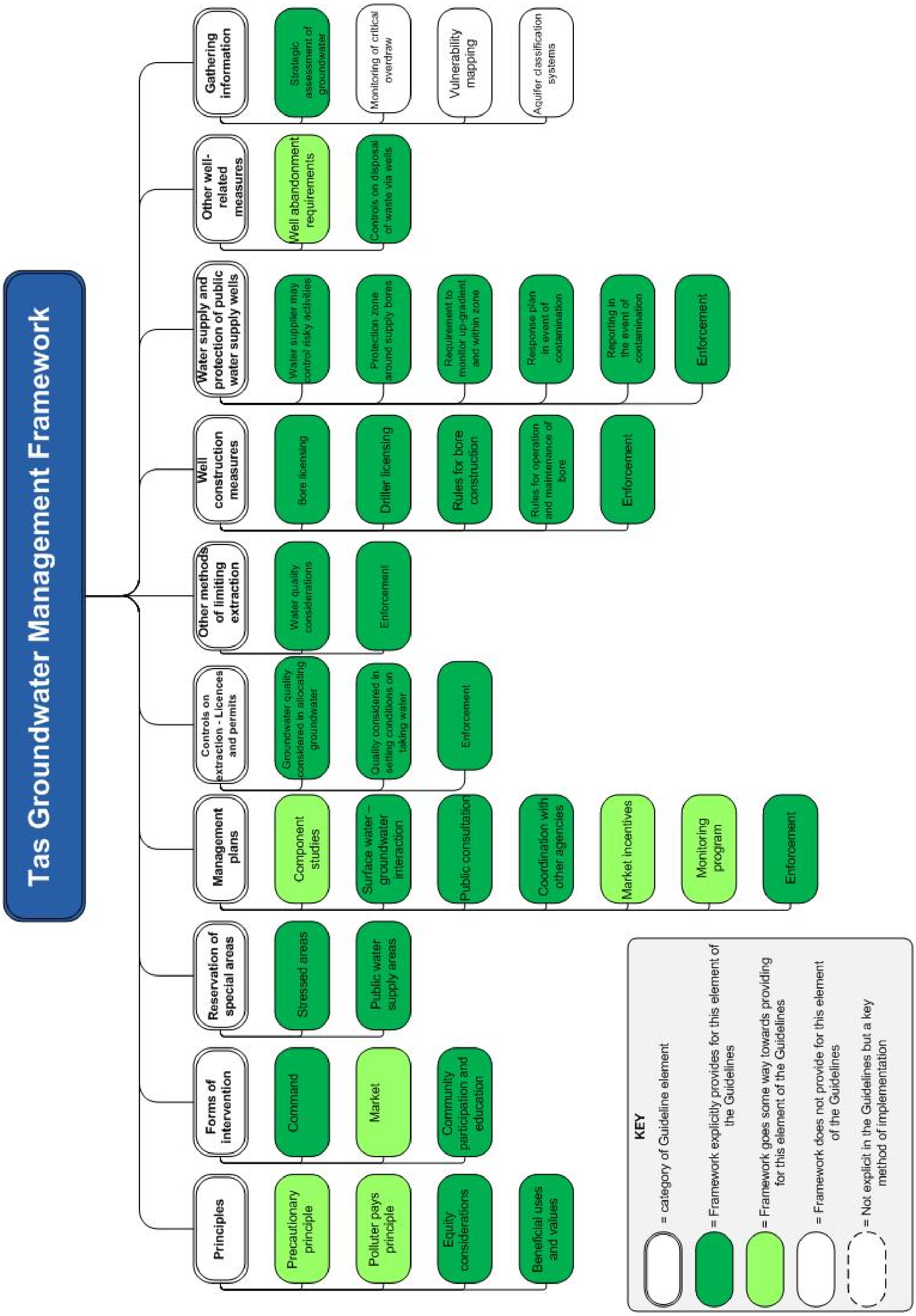
Some aspects of the Tasmanian regulatory framework for groundwater present ways to protect groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

(a) the concept of "best practice environmental management", which is relevant to setting an attenuation zone in relation to a polluting activity, and to the EIA process (see generally, Tas Environment Protection Framework Table); and

(b) clear and strong legislative links between environmental values, which may be established under the State Policy on Water Quality Management, and both:

  (i) the Groundwater Management Framework Table, for example water management plans which provide for the allocation of water, through generic principles for preparing water management plans (row 11); and

  (ii) the Land-Use Protection Framework Table, since a planning scheme must be prepared in accordance with the State Policy. If a State Policy is inconsistent with a provision of a planning scheme, the former prevails, and the planning scheme must be amended to remove inconsistency (row 4).


Tas Groundwater Management Framework
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Equity considerations
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Community participation and education
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Management plans
Component studies
Surface water – groundwater interaction
Public consultation
Coordination with other agencies
Market incentives
Monitoring program
Enforcement
Controls on extraction - Licences and permits
Groundwater quality considered in allocating groundwater
Quality considered in setting conditions on taking water
Enforcement
Other methods of limiting extraction
Water quality considerations
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Well construction measures
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Rules for operation and maintenance of bore
Enforcement
Water supply and protection of public water supply wells
Water supplier may control risky activities
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Requirement to monitor up-gradient and within zone
Response plan in event of contamination
Reporting in the event of contamination
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Strategic assessment of groundwater
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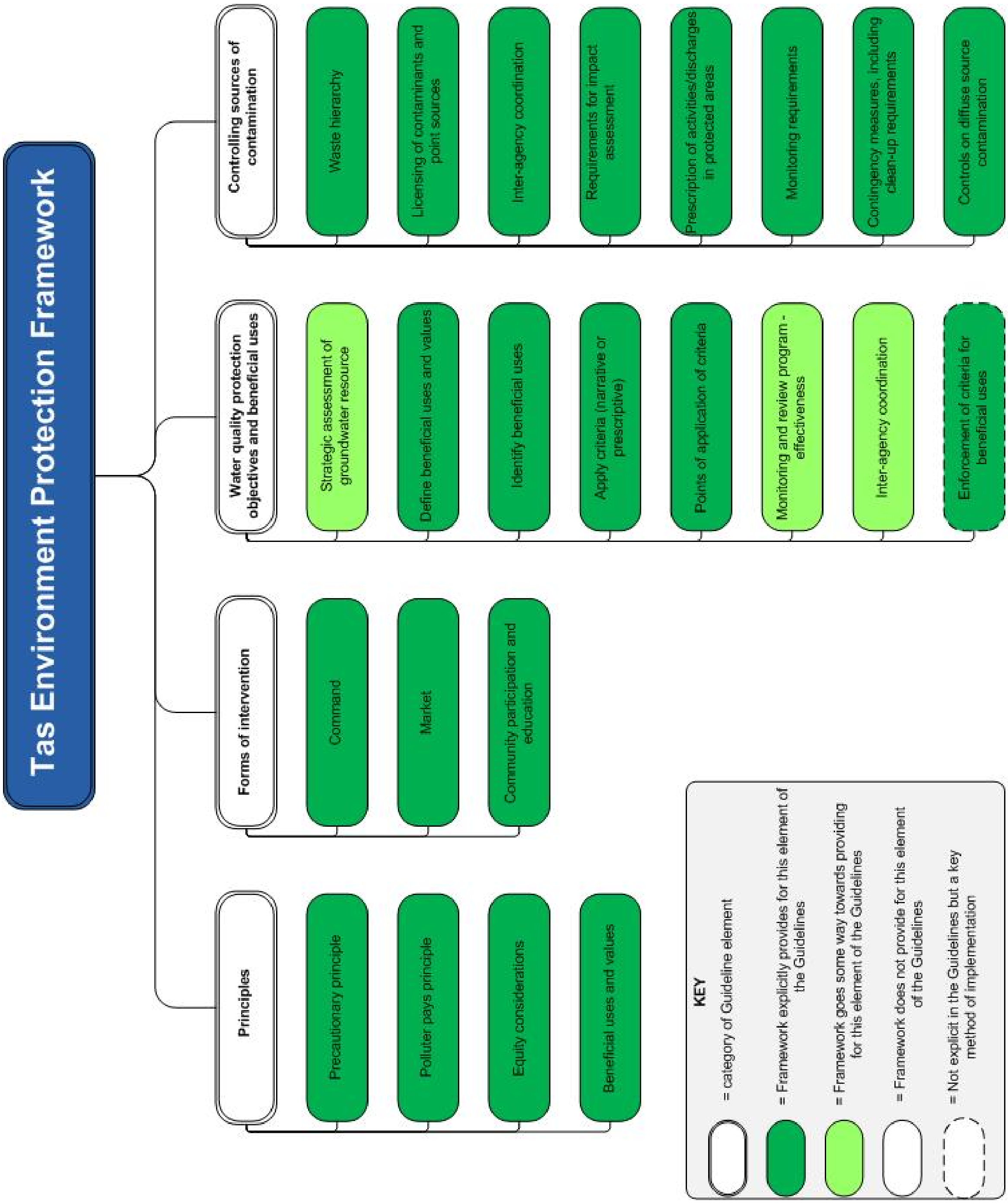
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Water quality protection objectives and beneficial uses
Strategic assessment of groundwater resource
Define beneficial uses and values
Identify beneficial uses
Apply criteria (narrative or prescriptive)
Points of application of criteria
Monitoring and review program - effectiveness
Inter-agency coordination
Enforcement of criteria for beneficial uses
Controlling sources of contamination
Waste hierarchy
Licensing of contaminants and point sources
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Requirements for impact assessment
Prescription of activities/discharges in protected areas
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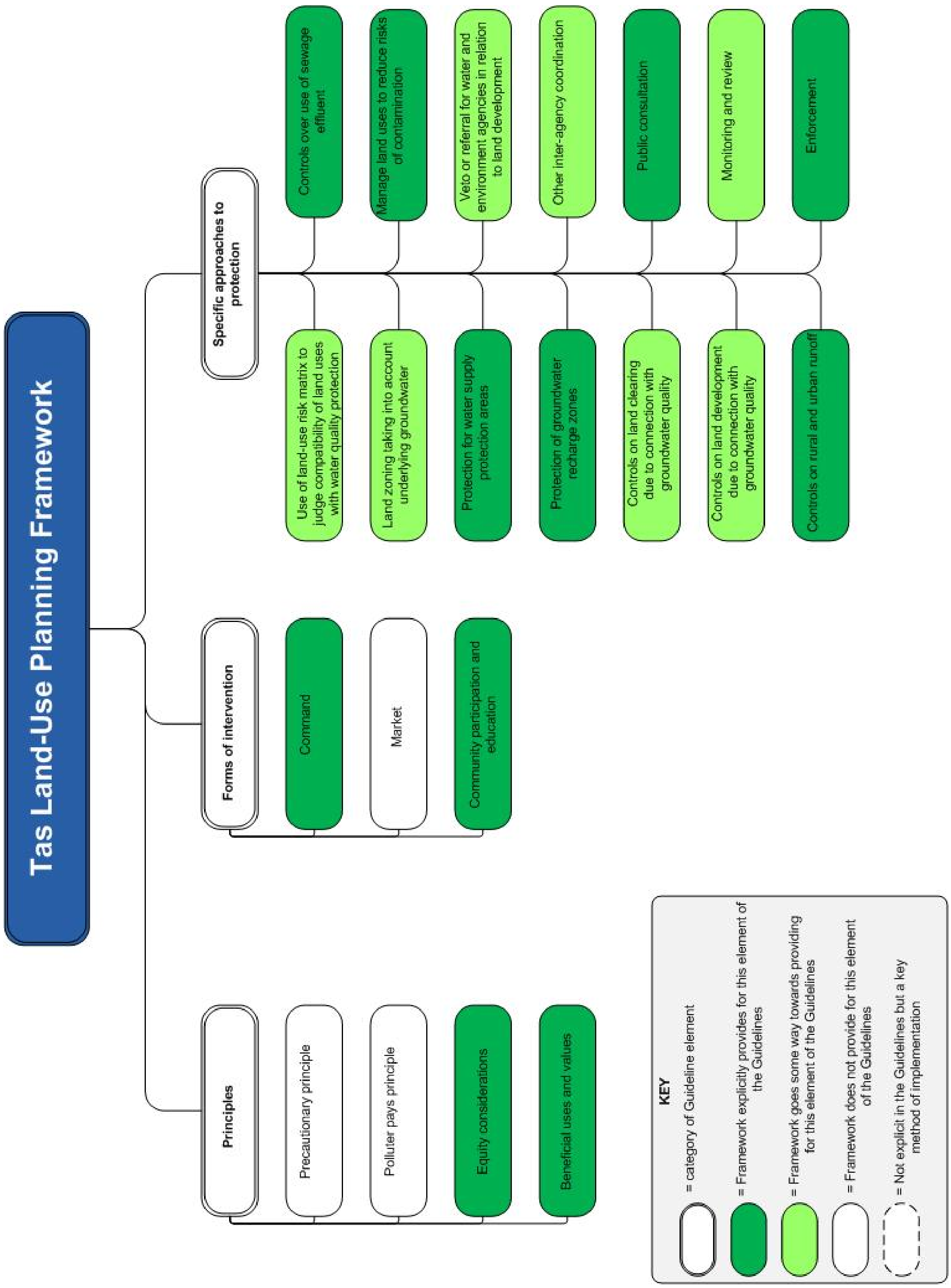

Tas Land-Use Planning Framework
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Specific approaches to protection
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Controls on land development due to connection with groundwater quality
Controls on rural and urban runoff
Controls over use of sewage effluent
Manage land uses to reduce risks of contamination
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5.3.8 Victoria

5.3.8.1 Implementing the Guidelines – key areas of strength

Victoria's regulatory framework for protecting groundwater generally implements the Guidelines very well. Particular areas of strength include:

(a) applying public consultation processes throughout the Groundwater Management Framework in the areas of water allocation and planning, each of which may influence groundwater quality (rows 7 and 14);

(b) providing comprehensively for inter-agency coordination, and for some types of groundwater management plans to be incorporated into environment and land-use plans (rows 15 and 18, Vic Groundwater Management Framework Table; row 18, Vic Environment Protection Framework Table; rows 18 and 19, Vic Land-Use Protection Framework Table);

(c) explicitly and comprehensively providing for groundwater quality considerations within the water allocation process, including through conditions on authorisations (rows 19 and 20, Vic Groundwater Management Framework Table);

(d) applying best practice requirements to the construction of bores (row 27, Vic Groundwater Management Framework Table);

(e) comprehensively considering groundwater quality within the State-standard land-use planning provisions (rows 8 to 22, Vic Land-Use Protection Framework Table);

(f) imposing on water suppliers detailed requirements in relation to source monitoring and risk management planning (rows 32 and 33, Vic Groundwater Management Framework Table); and

(g) providing for continuous and long-term water quality assessments, including in relation to attaining water quality objectives (row 39, Vic Groundwater Management Framework Table; row 8 , Vic Environment Protection Framework Table).

5.3.8.2 Opportunities for further implementation of the Guidelines

Some aspects of Victoria's regulatory framework provide further scope to implement the Guidelines. Matters to consider include:

(a) further implementing the principles underlying the Guidelines within the Land-Use Planning Framework; and

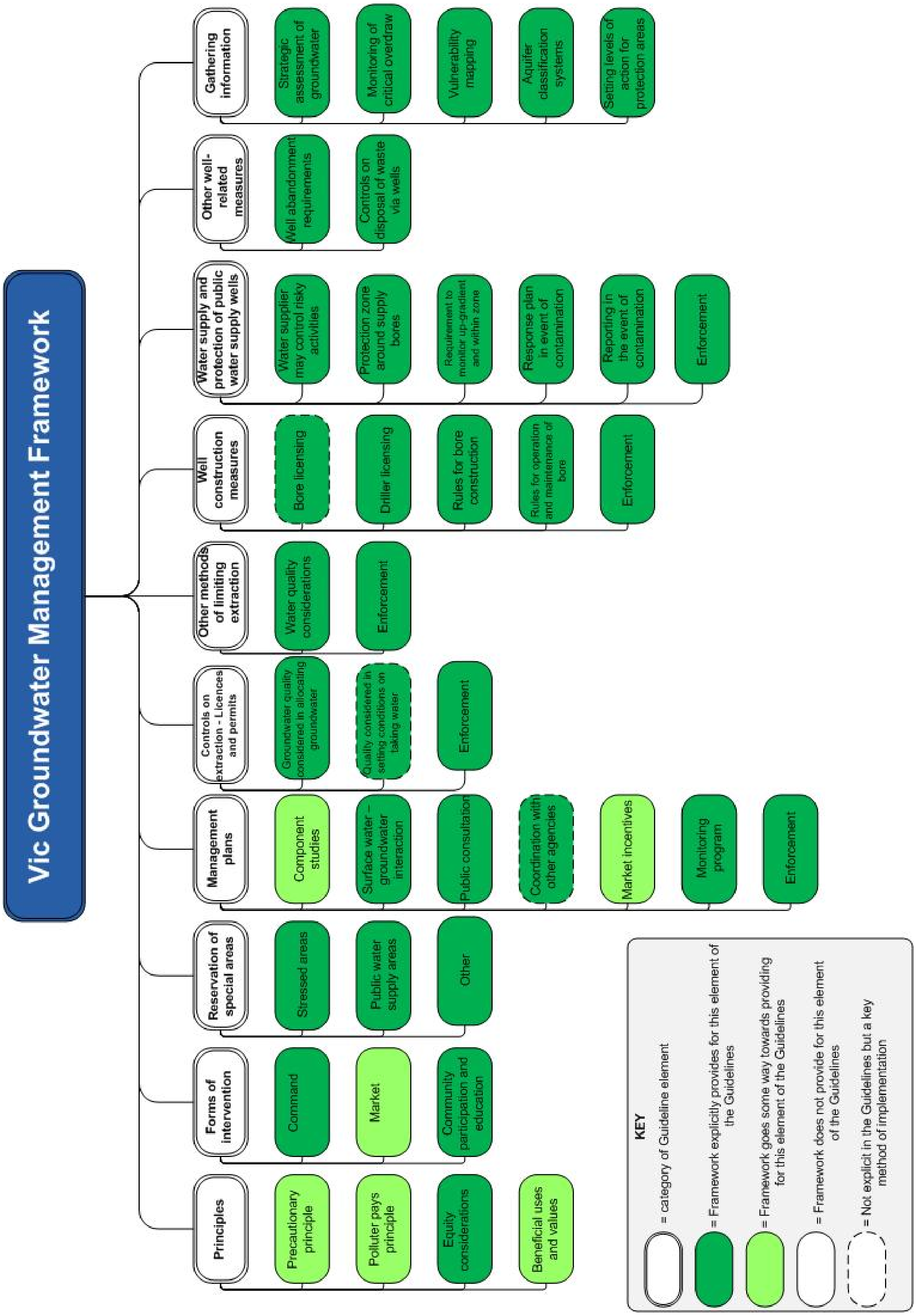
(b) requiring regular review of the key State-standard planning provisions against the objectives of the planning framework, which include ensuring the sustainable use of land and the maintenance of ecological processes.

5.3.8.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the Victorian regulatory framework for groundwater present ways to protect groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

(a) requiring licences not only to take groundwater, but also to use groundwater for irrigation, and applying standardised conditions to licences for irrigation water use. These include a requirement for an irrigation and drainage plan, which is aimed at protecting groundwater quality and avoiding salinity (rows 2 and 19, Vic Groundwater Management Framework Table); and

(b) establishing an environmental water reserve, in which water (including groundwater) is held for environmental purposes, including for the purposes of preserving water quality for dependent ecosystems (row 19, Vic Groundwater Management Framework Table).


Vic Groundwater Management Framework
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Setting levels of action for protection areas
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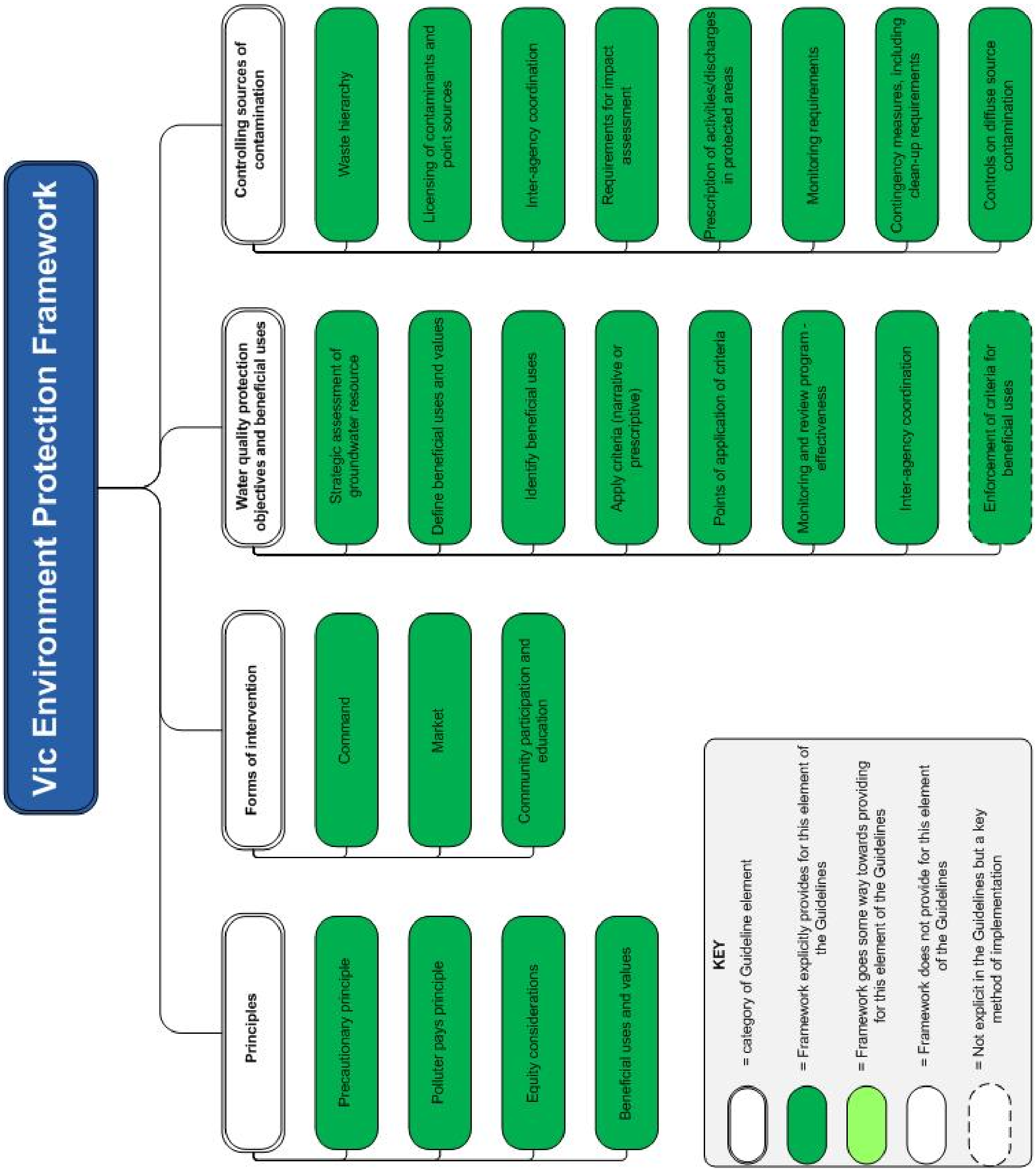
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Waste hierarchy
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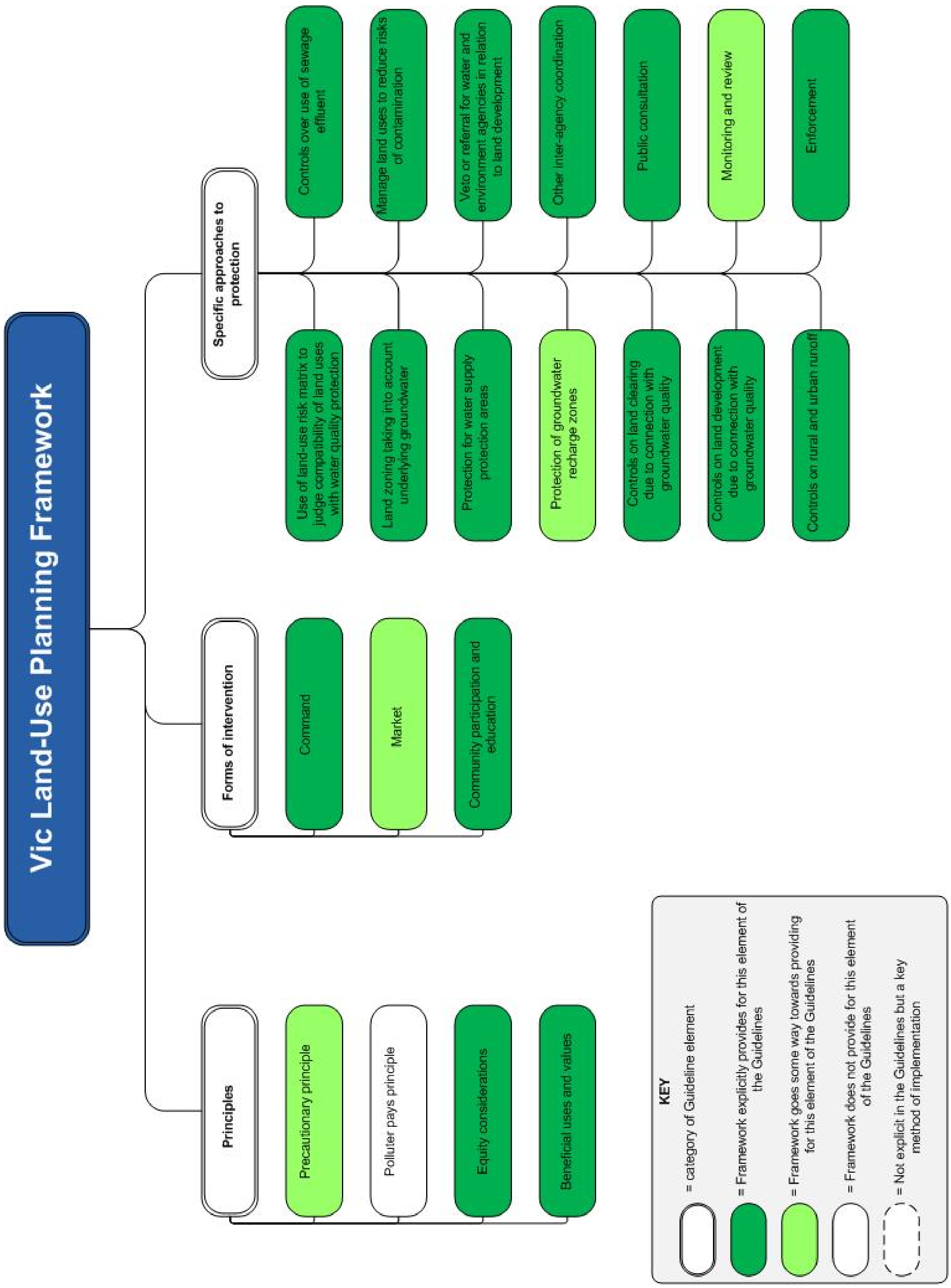
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5.3.9 Western Australia

5.3.9.1 Implementing the Guidelines – key areas of strength

The regulatory framework for protecting groundwater in WA generally implements the Guidelines very well, although in relation to groundwater management, it uses a complex framework comprising numerous legislation. It is intended that this framework undergo wide-ranging reform, although no Bill has yet been introduced. Particular areas of strength within the current framework include:

(a) adopting strong "command" mechanisms, including a general duty to take all reasonable steps to minimise degradation to a water resource, backed by a power of the Water Minister to give related binding directions (rows 5 and 23, WA Groundwater Management Framework Table);

(b) establishing strong links between land-use planning and water management in relation to groundwater quality, through the State Water Strategy and State Water Plan (row 11, WA Groundwater Management Framework Table) and State Planning Policies (row 8, WA Land-Use Protection Framework Table);

(c) adopting a comprehensive regime for considering groundwater quality monitoring requirements in the context of groundwater allocation, through a non-statutory Hydrogeological Reporting Policy (row 19, WA Groundwater Management Framework Table); and

(d) developing an aquifer classification system in relation to drinking water sources (row 42, WA Groundwater Management Framework Table).

5.3.9.2 Opportunities for further implementation of the Guidelines

Some aspects of the regulatory framework in WA provide further scope to implement the Guidelines. The State is yet to explore market mechanisms relating to groundwater quality, although the State Water Quality Management Policy mentions these. Further, although they do not yet apply to groundwater on a state-wide basis, WA legislation provides for environment protection policies to adopt legally binding environmental values. Finally, the WA Land-Use Planning Framework is yet to adopt the principles underlying the Guidelines, such as the precautionary principle and the polluter pays principle.

5.3.9.3 Beyond the Guidelines – innovative regulatory responses

Some aspects of the WA regulatory framework for groundwater present ways of protecting groundwater quality which go beyond the requirements of the Guidelines, and provide material to consider in a future revision of the Guidelines. Such measures include:

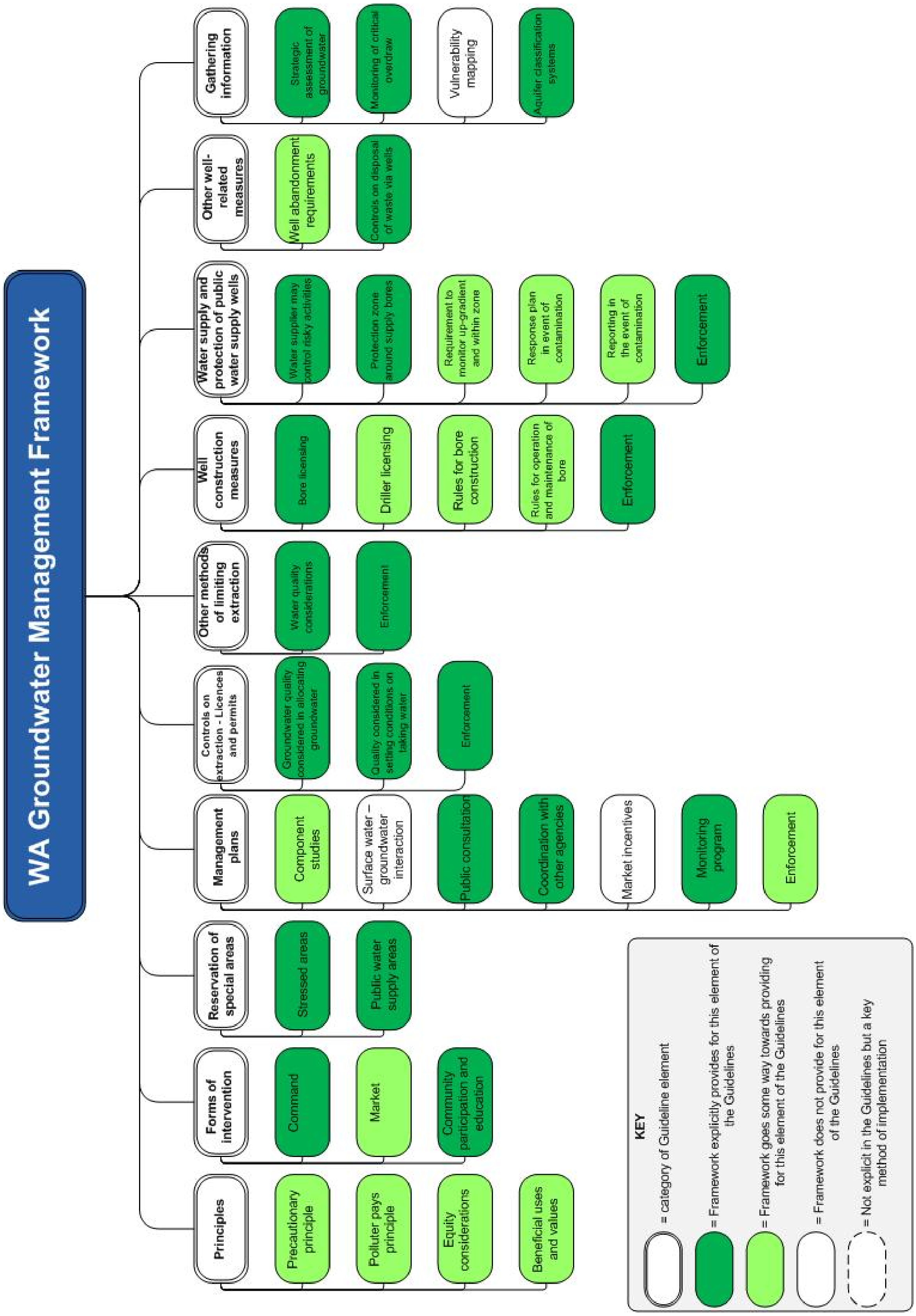
(a) a policy which sets out processes for considering the water quality requirements of GDEs (row 4, WA Groundwater Management Framework Table);

(b) innovative approaches to waste management, which move beyond the principle of waste minimisation, and include product stewardship plans and extended producer responsibility schemes to prevent the generation of potential groundwater contaminants (row 16, WA Environment Protection Framework Table);

(c) recognition of the need to protect stygofauna by providing appropriate groundwater quality, in the EIA context (row 19, WA Environment Protection Framework Table);

(d) a risk-based approach to dealing with potential contamination risks through environmental management plans for petroleum activities (row 17, WA Environment Protection Framework Table); and

(e) providing for the EPA to undertake an environmental assessment of planning instruments themselves – a form of strategic assessment (row 18, WA Land-Use Protection Framework Table).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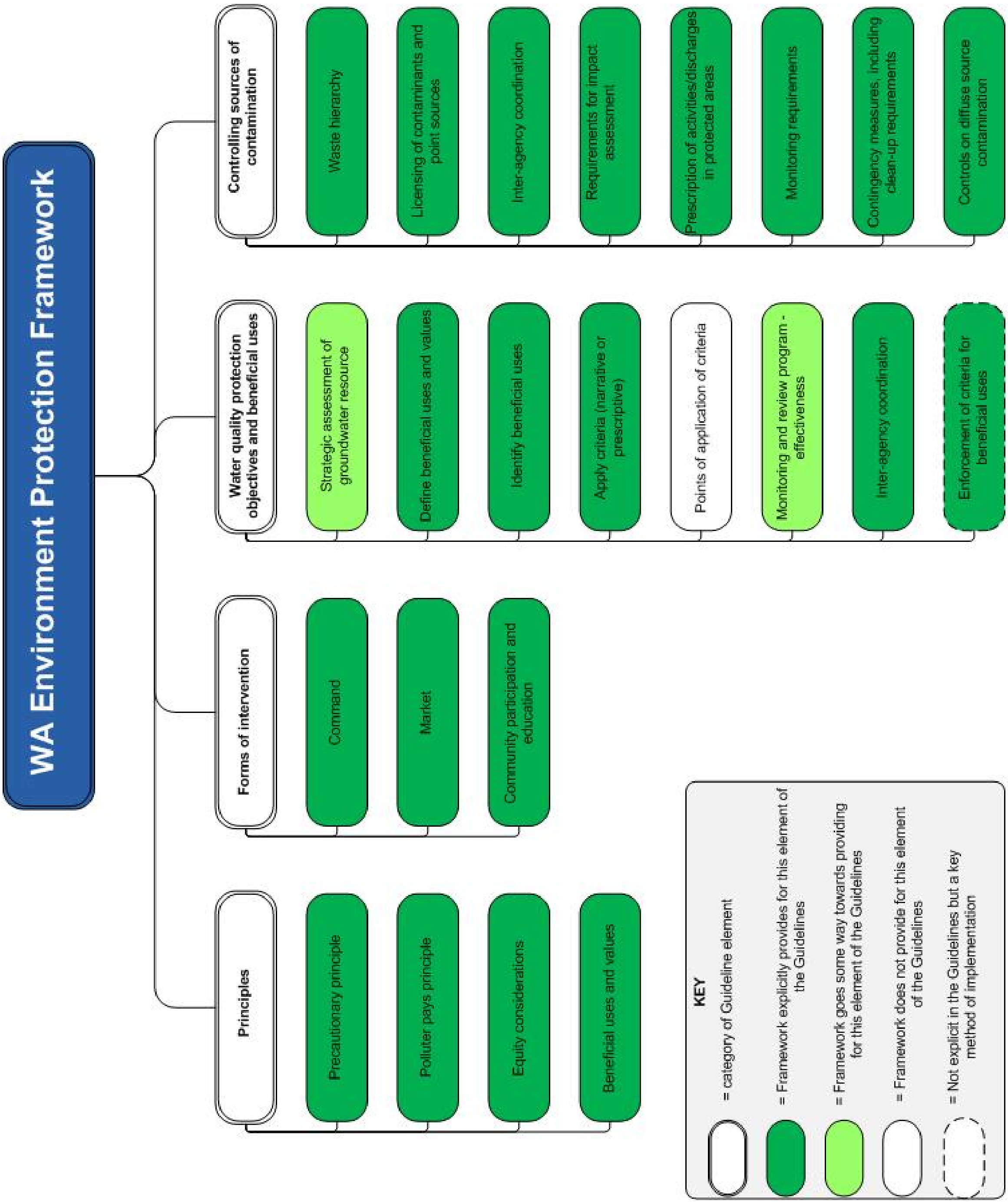
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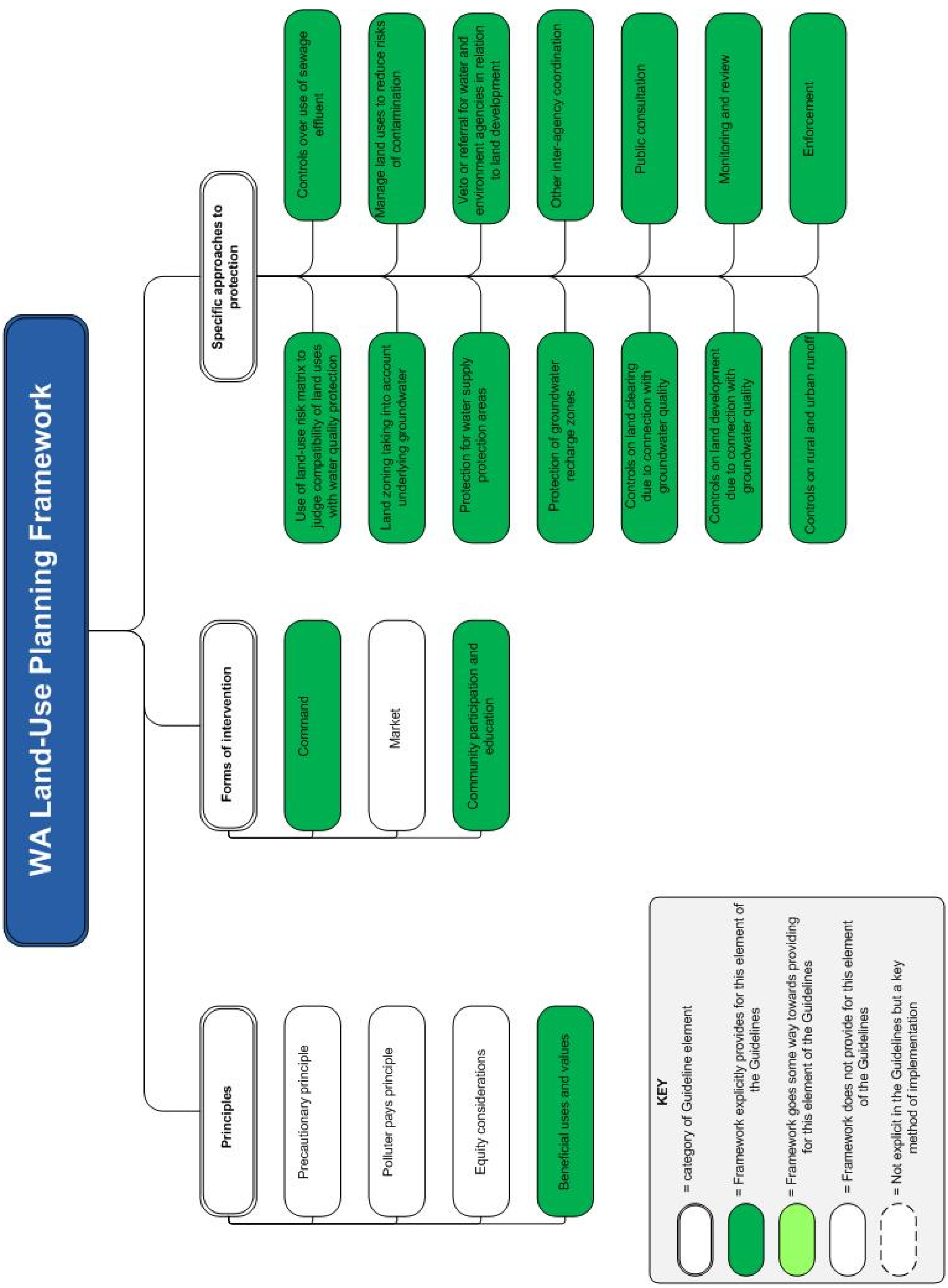
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6. End-user Survey Findings

6.1 END-USER SURVEY QUESTIONNARIE

An end-user survey questionnaire was developed in consultation with, and with endorsement by, DEWHA. The aim of the questionnaire was to get the maximum feedback and to get consistent responses from the end-users. The questionnaires also encouraged respondents to provide additional feedback on the use of the current groundwater quality guidelines, in particular, the need to update the guidelines.

The end-user survey questionnaire on the Groundwater Quality Guidelines sought feedback with specific questions including:

- Do you or your organisation use the Groundwater Guidelines?
- How relevant and useful are the Groundwater Guidelines as a key reference document for the protection of the quality of groundwater from contamination?
- Are the Groundwater Guidelines adequate for managing groundwater quality?
- Do the Groundwater Guidelines adequately address issues such as surface and subsurface groundwater dependant ecosystems, connected surface and groundwater resources and other current and emerging groundwater quality issues?
- Do the Groundwater Guidelines interface well with other NWQMS Guidelines?
- Do the Groundwater Guidelines interface well with State and Territory guidelines and are there links that should be included in the Groundwater Guidelines?
- Is there a need for updating the current Groundwater Guidelines?
- What type of information would you like to see updated?

Assessment of the information from the end-user survey questionnaire provided constructive inputs to the level of groundwater quality guidelines implementation and future directions.

6.2 SURVEY RESPONDENTS

The questionnaire was sent via email to sixty five end-user groups. This includes six government agencies, five research organisations, twenty four natural resource management groups and thirty catchment management authorities. Natural resource management groups represented the largest proportion of the total end-users surveyed.

6.3 STAKEHOLDERS USE AND VIEWS

The feedback received from the end-user survey is presented in Appendix C. In general the end-user groups have found the Guidelines for Groundwater Protection in Australia to be a useful reference document for providing overall guidance on groundwater protection. One of the Catchment Management Authority (CMA) respondents indicated that they use the Guidelines as a reference document to ensure that the appropriate guiding principles are applied in broader plans that promote coordinated natural resource management. One NRM agency used the guidelines for setting indicators and targets for work in the field, and as a reference document to research data collection for developing regional water management strategies.

The end-user perspectives presented in this report agree with the earlier report by Bennett (2009). While the Guidelines have proved to be a useful reference document for overall groundwater protection, the end-users identified a number of matters for revision, including:

- Improve the current groundwater guidelines using a risk-based approach to management and incorporating the findings of studies over the last decade;

- Update some of the terminologies in the guidelines and make it consistent with that accepted in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000);

- Current regulatory situation regarding environmental values – lack of consistency in the methods being used by State jurisdictions and recommended a single nationally endorsed approach to derive guidelines for environmental values;

- Consideration and guidance needs to be given to groundwater sampling and analysis in the guidelines. This needs to ensure that the results reflect the environment being protected, i.e., groundwater in its aquifer state or groundwater as an input to receiving surface waters, or for use in its oxidised state;

- The use of attenuation zones where water quality may exceed water quality objectives. A proposed solution is the use of three different management contexts: (i) MAR guideline usage (excluding waste disposal); (ii) areas exempt from protection (including managed waste disposal); and (iii) natural attenuation zones (where water quality naturally recovers towards water quality objectives);

- Groundwater extraction policies need to link more closely with GDEs and the Groundwater Guidelines could suggest ways in which allocations could take account of GDEs;

- Research is needed to clarify whether terrestrial vegetation is protected by current guidelines relevant to primary industries; terrestrial fauna (not an ecosystem type per se) may also be protected by water quality guidelines for stock watering, but given the large size difference between domestic cattle and many native animals, this may need some review;

- Inclusion of guidelines for non-surface expressed GDEs in accordance with the existing guidelines for aquatic ecosystem protection (ANZECC and ARMCANZ 2000), including trigger values for physico-chemical stressors and toxicants based on an understating of the related hydrogeology;

- Methods of accounting for impacts on streamflow in connected streams could be provided, or linkages made to 'connected waters' website;

- There needs to be an appropriate cross-reference to the Managed Aquifer Recharge guidelines (#22 – Module 2);

- Consider the impacts of stock and domestic wells and wells in urban areas (where the density of wells can exceed the rate of aquifer replenishment);

- Consider emerging water quality issues such as acid sulfate soils, surface water-groundwater interactions, mining impacts, managed aquifer recharge and climate change;

- Link to groundwater modelling guidelines developed by the Murray-Darling Basin Commission; and

- Update groundwater use information, recent references, water quality standards and state and territory legislation regarding development etc.

7. Summary of Results and Key Recommendations

7.1 SUMMARY OF RESULTS

Key groundwater quality issues in Australia

- Monitoring of groundwater quality in Australia is limited and carried out in an *ad hoc* manner. There is no consistent national program on groundwater quality monitoring and much of the monitoring has been short-term. Therefore, there is no national perspective on groundwater quality or any sense of long term trends in groundwater quality.

- Salinity is the major groundwater quality issue, particularly in south-west WA and south-east Australia. Groundwater salinity has increased in some regions due to continued pressure from increased extractions and poor irrigation practices. Groundwater salinity is increasing in coastal catchments due to seawater intrusion.

- Wetlands and surrounding native vegetation, wetland habitats and species are at particular risk from saline groundwater intrusion. For example, Victoria has 11 Ramsar wetland sites and five of these (45%) may be at risk of damage from salinity and shallow saline groundwater by 2020. Input of saline groundwater is also a substantial threat to the biodiversity of surface wetlands and rivers in south-west WA.

- Nitrate is the most widespread contaminant in groundwater. Nitrate levels exceed the Drinking Water Health Guideline and ANZECC ecosystem protection guidelines in some irrigated catchments. Time-series groundwater data are mostly inadequate to establish seasonal and other variability of nitrate contamination potential.

- Results from various groundwater quality studies conducted during 1996-2008 showed detections for 9 herbicides along with two insecticides in groundwater. Atrazine herbicide has been detected in a most of the studies.

- Arsenic, boron, barium, iron, manganese, lead, iron, selenium, uranium and fluoride have been detected in groundwater across Australia. Trace element concentrations exceeded the Drinking Water Health Guideline and ANZECC ecosystem protection guidelines in some locations.

- Acidification of groundwater is an emerging and significant environment issue in Australia. Groundwater in some parts of the WA wheatbelt and some coastal groundwater are highly acidic with pH commonly between 3 and 4. Several wetlands in WA are now permanently acidified.

- Organic and inorganic contaminants are likely to be a widespread threat to groundwater, mostly from industrial sites around urbanised areas.

Key groundwater quality issues in New Zealand

- Groundwater quality monitoring is routinely carried out in 15 regional councils and also by the National Groundwater Monitoring Programme (NGMP) in NZ.

- High salinity in coastal aquifers is a serious issue in regions such as Northland, Bay of Plenty and Horowhenua due to seawater intrusion.
- Nitrate contamination is a major groundwater quality issue, particularly in shallow groundwater. Of the 956 sites investigated, 4.9% exceeded the Maximum Acceptable Value (MAV) based on the Drinking Water Standards for New Zealand (DWSNZ), 10.3% exceeded the trigger value (TV) for ecosystem protection based on the ANZECC guidelines, and none exceeded the ANZECC TV for stock drinking-water.
- Trace elements such as iron, manganese and arsenic have been detected in many locations, mainly in deep groundwater systems.
- Previous national and regional groundwater surveys have shown low-levels of pesticides in some groundwater systems, particularly those shallow groundwater that are vulnerable to pollution.

Emerging groundwater quality issues

- Increased levels of groundwater extraction have resulted in decreased groundwater quality in a number of areas in Australia and New Zealand.
- Both surface and subsurface Groundwater Dependent Ecosystems (GDEs) are threatened by over-extraction and poor groundwater quality in some areas. Particular groundwater quality threats include increases in salinity, trace elements, acidity and nitrates that have impacted on groundwater-dependent wetlands and woodlands in a number of locations.
- Climate change is likely to increase the stress on groundwater already under pressure from salinity, over-allocation and declining water quality. Higher water temperatures and reduced stream flows will tend to adversely affect groundwater quality. Shallow aquifers will be more vulnerable to changes in recharge, temperatures and sea level rise, these will ultimately affect water quality.
- Increased extraction and sea level rise will result in increased salinisation of coastal fresh groundwater, resulting in reduced groundwater quality, and possibly threatening GDEs associated with coastal aquifers.
- A broad range of national and state-wide policies and programs are currently implemented across all states and territories to protect groundwater from contamination.
- Some of the current and emerging groundwater quality issues are not adequately addressed in the current national guidelines.

Regulatory issues

- The key elements of the Guidelines are generally well implemented through the legislation, regulation and policy of the Australian jurisdictions, albeit often without explicitly referring to the Groundwater Guidelines.
- Most jurisdictions use a combination of command, market, and public participation approaches to groundwater protection. Of these three approaches, the jurisdictions favour command

approaches. Flexible and adaptable approaches to command intervention have developed since the publication of the Groundwater Guidelines. Public consultation and education are commonly used, but they are rarely required by law or policy. Market approaches are used least.

- The jurisdictions all apply the concept of beneficial uses or environmental values for groundwater, though they have applied these concepts to differing degrees.

- There are significant differences in how the jurisdictions implement the Guidelines. These differences relate to the precise range of elements of the Guidelines which they adopt, whether a particular tool is mandatory or discretionary within their legislation, and whether a particular tool is adopted in a legally enforceable instrument as opposed to a statutory policy.

- Of all of the tools set out in the Guidelines, tools to address diffuse pollution and market incentives for the protection of groundwater offer the greatest opportunities for further implementation.

- The legislation, regulation and policy of the jurisdictions in relation to groundwater quality protection has advanced significantly since the Guidelines were published, such that the Guidelines no longer adequately reflect currently accepted principles and practices.

7.2 RECOMMENDATIONS

The literature review, regulatory review and the end-user survey recommends that the current Groundwater Quality Guidelines be revised to incorporate current and emerging groundwater quality issues. Addressing these issues will ensure that the Groundwater Guidelines remain relevant into the future, and provide a useful source of guidance for jurisdictions to effectively manage risks to groundwater quality.

The key recommendations are, in summary:

- update groundwater use information which has become obsolete in relation to urban and community reliance on groundwater in Australia and overseas;
- ensure the Guidelines more effectively address current and emerging issues such as groundwater-surface water connectivity, acid sulfate soils, surface and sub-surface groundwater dependent ecosystems, managed aquifer recharge and climate change;
- include appropriate links to other NWQMS guidelines;
- include discussion on recent Australian Government water policy initiatives such as the NWI, Water for the Future, Water Act 2007, National Groundwater Action Plan, and also directions undertaken at the State and Territory levels;
- update Tables in Appendices;
- update bibliography and include references since the Guidelines were published;
- develop as an interactive online document with links to other relevant websites so that users can easily access linked material such as ANZECC Drinking Water Quality Guidelines;
- expand the existing discussion in relation to the precautionary principle, the polluter pays principle and equitable considerations (in the form of intergenerational equity);
- expand the existing discussion in relation to intervention by “command” to include modern tools of best practice environmental management and waste minimisation;;
- include modern examples of Australian best practice in relation to market incentives, controlling diffuse sources of pollution and waste minimisation;
- include discussion of the following “new” issues in groundwater protection law and policy: (a) water quality requirements of groundwater dependent ecosystems, including stygofauna; (b) the potential threat to groundwater quality posed by climate change; (c) “cultural and spiritual

values" as a beneficial use; (d) regulation of geothermal energy and greenhouse gas sequestration; (e) regulation of water use as well as abstraction; (f) managed aquifer recharge; (g) acid sulfate soils; and (h) strategic impact assessment; and

- include discussion of the significantly expanded role of the Commonwealth in the area of water management and water quality legislation, regulation and policy.

8. References

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Appendix C: Summary of stakeholders' comments on Guidelines for Groundwater Protection in Australia

End-users	General Comments	Process Matters	Policy Matters	Technical Matters
Research Body #1	The current Guideline was released in 1995 and therefore predate the major revision to the ANZECC/ARMCANZ water quality guidelines (WQGs) that were released in 2000. They therefore fail to include the major new approaches of these revisions, namely the risk-based framework and the closer integration of biological and chemical effects. Any revision should address these issues both in terms of the overall framework but also in the derivation of the actual guideline values. NZ is not mentioned in the Guideline, and consistent with the other NWQMS documents, there should be some consideration of expanding the scope to include NZ. In a number of jurisdictions, stock and domestic wells are capable of harming groundwater-dependent ecosystems simply because these are exempted from extraction constraints and, in urban areas, the density of wells can exceed the rate of aquifer replenishment. Consideration needs to be given as to whether this situation is desired and appropriate statements made in the revised Guideline on the decision. It is suggested that this Guideline cross-reference the guidelines for managed aquifer recharge (MAR). Because the MAR guidelines appear under water recycling guidelines, where they are most appropriate, those who are using natural water and treated drinking waters for MAR may need a cross-reference to help them find these guidelines.	A major limitation of the current regulatory situation regarding environmental values is the lack of consistency in the methods being used by state jurisdictions. Basing environmental values on ambient (groundwater) quality and historical use as outlined in the NWQMS Policies and Principles, seems to have been overlooked or ignored in some states. For example, in SA, the Code of Practice for Water Quality Protection set default environmental values and the process for changing these values has taken more than five years and has been a major deterrent to Managed Aquifer Recharge in brackish aquifers. In contrast, the method adopted by Victoria has saved considerable time by both proponents and regulators. We recommend that more specific guidance be provided in the Guideline on how guidelines for environmental values should be developed. We believe that a single nationally endorsed approach to deriving guidelines for environmental values that includes the derivation of site-specific guidelines (as with the WQGs) should be determined and a set of default guideline values established in any revision of the Guideline In order to address the potential issue of the surface water WQGs not being appropriate, it is suggested that: i) a framework to derive guidelines for toxicants and physicochemical properties should be developed that incorporates riskbased principles and a hierarchy for the use of data and methods to derive the guidelines (similar to the framework used to derive the WQGs). It is recommended that the method adopted should be as close as scientifically justifiable to that used in the most recent Australian WQGs for surface waters (this is currently ANZECC and ARMCANZ, 2000 but this could change as this document is also under review). ii) a review of the available sensitivity of groundwater organisms to toxicants and physicochemical properties should be conducted to determine if guidelines can be derived. iii) using the method adopted in (i) guideline values for a suite of toxicants should be developed. Ideally, guidelines should be derived for the same toxicants that have	The WQGs (ANZECC and ARMCANZ, 2000) recommend that the numerical limits presented therein "should apply to the quality both of surface water and of groundwater since the environmental values which they protect relate to above-ground uses. Hence groundwater should be managed in such a way that when it comes to the surface, whether from natural seepages or from bores, it will not cause the established water quality objectives for these waters to be exceeded, nor compromise their designated environmental values." Whether this over-arching philosophy is still the most appropriate should be carefully considered and the results of the consideration be incorporated into any revision of the Guideline. In the Managed Aquifer Recharge (MAR) Guidelines, there is the concept of a finite and transient attenuation zone where water quality may fall outside the objectives for the ambient environmental values. However the ambient environmental values must be achieved continuously outside the attenuation zone, and within the attenuation zone, beyond a short period after cessation of recharge. The MAR guidelines explicitly include the requirement of recovery of water for beneficial use or of intentional aquifer protection (e.g. from saline intrusion). It explicitly excludes waste disposal. This is a very different concept to indefinite aquifer attenuation zones as currently apply in Victoria, which are areas annexed from an aquifer where the function of the aquifer is deemed to be to allow waste disposal, and in such an area the aquifer is exempt from protection and so is allowed to be polluted for an indefinite time into the future. The correct term for these areas is not attenuation zones but areas exempted from protection. There are also cases where natural attenuation has been approved as a means of allowing an area to recover from historical pollution. Such zones	Much of the terminology in the Guideline needs to be updated to make it consistent with that accepted in WQGs (ANZECC and ARMCANZ, 2000). The WQGs (ANZECC and ARMCANZ, 2000) include a statement 'that different conditions and processes operate in groundwater compared with surface waters and these can affect the fate and transport of many organic chemicals' which may have implications for the application of guidelines and management of groundwater quality. Careful consideration and guidance needs to be given to how groundwater samples are collected and stored in order to prevent oxidation of the samples. Similarly, consideration and guidance must be given as to how testing of the groundwater (both chemical and ecotoxicological) should be conducted so that the results reflect the environment we are seeking to protect, i.e. groundwater in its aquifer state or groundwater as an input to receiving surface waters, or for use in its oxidised state. These factors are largely ignored in the current guidelines.

		guideline values in the Australian and New Zealand surface water guidelines (ANZECC and ARMCANZ, 2000). Again, developing a nationally agreed definition of what constitutes groundwater dependent ecosystems (GDEs) would help make applications consistent across states, e.g. in dealing with protection of terrestrial phreatophytic vegetation. Groundwater extraction policies need to link more closely with GDEs and the Guideline could suggest ways in which allocations could take account of GDEs. Methods of accounting for impacts on streamflow in connected streams could be provided, or linkages made to Geoscience Australia's 'connected waters' website.	could be ascribed a third name to describe that in these zones ultimately the original environmental values will be restored. However this process may take many years, unlike the attenuation zones in MAR which are well defined in areal extent and typically have attenuation periods of less than 12 months. It is suggested that a nationally consistent set of terms for the above scenarios be identified and distinguished so as to avoid confusion. This would support maximal beneficial uses of aquifers via Managed Aquifer Recharge, and cost-effective remediation of contaminated groundwater where 'natural attenuation' is viable.	
Research body #2	There is a need for updating the current Groundwater Quality Guidelines.			Consider issues such as acid sulphate soils, surface water-groundwater interactions and mining impacts during revision. Link to the Murray-Darling Basin groundwater modelling guidelines. Update water quality standards, state and territory legislation re: development, etc, etc. Update groundwater use information.
Research body #3	It is now timely to consider the ecological aspects of groundwater (non-surface expressed) in any revision of the protection guidelines. The need for groundwater specific guidelines is provided under technical matters A unified framework for water quality for ecosystem protection is provided under process matters Research needs to develop groundwater quality guidelines were also provided. Research is needed to clarify whether terrestrial vegetation is protected by guidelines relevant to Primary Industries. Terrestrial fauna (not an ecosystem type per se) may also be protected by water quality guidelines for stock watering, but given the large size difference between domestic cattle and many native animals, this may need some review.	Water quality guidelines for aquifer ecosystems should be developed in accordance with the existing framework for aquatic ecosystem protection (ANZECC/ARMCANZ 2000). Trigger values should be derived for both physico-chemical stressors and toxicants. Any trigger values for groundwater should adopt a similar riskbased approach, using reference site data for physico-chemical stressors, and toxicity test data and species sensitivity distribution modelling for toxicants. Trigger values for physico-chemical stressors may be readily determined by collating water quality information from the many groundwater monitoring programs currently underway in Australia. Particularly important here is that local hydrology must be considered, as changes in depth, flow and local geology may strongly influence many physico-chemical variables in groundwater. It is clear that maintenance of water quality alone is insufficient for protecting groundwater ecosystems and other GDEs and that maintaining the groundwater regime, comprising the flow, pressure, depth and timing of water availability of groundwater is also essential. The		The (current Guideline) focus ignores aquifer (subterranean) ecosystems and other groundwater dependent ecosystems (GDEs) reliant on subterranean water. It is clear that maintenance of water quality alone is insufficient for protecting groundwater ecosystems and other GDEs and that maintaining the other aspects of the whole groundwater regime, comprising the flow, pressure, depth and timing of water availability of groundwater is also essential. These other aspects of the groundwater regime should also be considered in the proposed revision of the guidelines. Methods for determining groundwater regimes are described elsewhere and will not be considered further in this submission. Instead, this submission will focus on the water quality needs of aquifers and GDEs. Importantly however, water quality guidelines for aquifers will feed directly into the setting of environmental water requirements for aquifers and GDEs. The existing guidelines for aquatic ecosystems are unlikely to protect groundwater ecosystems because: a. Groundwater ecosystems contain a unique fauna not found in surface waters, which have not been used in the derivation of trigger values and which may respond differently to toxicants b. Unique environmental conditions in aquifers may alter the toxicity or speciation of chemicals and/or the

		groundwater regime needed to maintain aquifer ecosystems and other GDEs should be considered in the proposed revision of the guidelines for groundwater protection.		response of biota. Globally, aquifers are being recognised as hotspots of biodiversity(Sket 1999; Humphreys 2006) comprising species that are adapted to the groundwater environment and are not found in surface waters. Groundwater macrofaunas are dominated by crustaceans, but also include gastropods, oligochaetes, mites and occasional insects (see review by Humphreys 2006). The foundation of the ecosystem is the microbial assemblages that, through heterotrophic or chemotropic pathways, capture energy and form biofilms. These are grazed by the macrofauna, and meiofauna such as turbellarians, rotifers, nematodes and protozoa (Humphreys 2006). Importantly, groundwater ecosystems rarely support vertebrates and generally lack primary producers (such as plants or algae that cannot grow in the dark) (Humphreys 2006). As a result, trigger values based on toxicity data for vertebrates and primary producers may not be relevant for groundwater environments, and future trigger value determinations must include toxicity data for microbial and meiofaunal assemblages and groundwater adapted macroinvertebrates. Considering the truncated diversity of groundwater leads to different trigger values than for the full range of surface species, and further, suggests that groundwater ecosystems may be more sensitive to some pesticides than surface assemblages (Hose 2005). In contrast, recent toxicity data using local groundwater species suggests that groundwater invertebrates are more tolerant of metals than surface-water invertebrates (Hose unpub data). The physical environment of aquifer and cave ecosystems is very different from the surface environment and may alter the toxicity of pollutants. The nature of groundwater ecosystems will also influence the fate and toxicity of chemicals in that environment. The underlying geology will influence the particle size and chemical nature of the substrate, which in turn influences the porosity of the aquifer (and rate of water movement), the speciation or absorption of pollutants and background water quality. As a result, there is an acute need for toxicity information that is site and ecosystem specific.
NRM agency #1	The guidelines are used only for the purpose of setting indicators and targets for work in the field and as a reference document to research data collection we are assembling for the purpose of developing a water management strategy for the region before we proceed to prescription			