



Government of Western Australia  
Department of Water

# Broome Water Reserve

## Drinking water source protection plan

*Broome town water supply*



*Looking after all our water needs*

Water resource protection series  
Report WRP 100  
December 2012



# Broome Water Reserve drinking water source protection plan

Providing water to Broome

Looking after all our water needs

Department of Water

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Report no. 100

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# Preface

## ***How do we protect public drinking water source areas?***

The Australian drinking water guidelines (ADWG) (NHMRC & NRMCC 2011) outline how we should protect drinking water in Australia. The ADWG recommends a 'catchment to consumer' framework that uses a preventive risk-based, multiple-barrier approach. A similar approach is recommended by the World Health Organization in other countries worldwide.

The catchment to consumer framework applies across the entire drinking water supply system, from the water source to the tap. This ensures a holistic assessment of risks to water quality to maximise the delivery of safe drinking water to consumers.

A preventive risk-based approach means that we look at all the different risks to water quality, and how to address them. A multiple-barrier approach means that we use different barriers against contamination at different stages of a drinking water supply system. The first barrier is protecting the catchment or recharge area. This plan helps to do that. Other barriers against contamination include:

- storage of water in tanks
- treating the water (e.g. chlorination)
- maintenance of pipes
- monitoring of water quality in the catchment and in the distribution system.

As water treatment practices evolve, it is understandable to think that we no longer need to protect the catchment because we can 'engineer out the risks'. However, nothing could be further from the truth (Krogh et al. 2008). Recent research and experience shows that a combination of catchment protection and water treatment is safer than relying on either barrier on its own. That's why this drinking water source protection plan is important. It's about protecting the catchment's water quality now and in the future. By protecting the catchment's water quality we are also protecting public health. It should also be noted that water taken from a low risk water source will result in a lower cost public water supply because less treatment is required.

In Western Australia, the Department of Water protects PDWSAs by implementing the ADWG, writing reports, policies and guidelines, and providing input into land-use planning.

The *Metropolitan Water Supply Sewerage and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* allow us to protect drinking water sources. We proclaim PDWSAs under these Acts so that we can apply the legislation to protect water quality. Education, awareness, surveillance and enforcement measures are used to help us deliver a reliable, safe good quality drinking water to consumers.

The ADWG outlines 12 elements to protect drinking water. We implement element two (assessment of the drinking water supply system) and element three (preventive measures for drinking water quality management) by writing drinking water source protection plans (DWSPPs). DWSPPs have been, or are being, written for all PDWSAs around the state. They give an overview of a drinking water source and outline the risks to water quality and how to address them. We work with the community, other state and local government agencies and landowners to put the recommendations in each DWSPP into practice.

For each DWSPP we define specific priority areas and protection zones that occur within the boundary of the PDWSA.

- There are three different priority areas, each recognising a different level of potential risk to water quality. These priority areas help guide land-use planning and development by state and local government planners.
- Protection zones surround drinking water extraction points, so that the most vulnerable areas can be protected from contamination. Under legislation, some activities are restricted in protection zones.

If you would like more information about how we protect drinking water in Western Australia, go to <<http://drinkingwater.water.wa.gov.au>>.



The following table outlines the stages involved in the preparation of this DWSPP:

Stages in development of this plan		Comment
1	Assess ongoing validity of existing <i>Broome Water Reserve water source protection plan</i> (WRP 41), published in 2001.  (May 2009)	Catchment survey, review of land-use changes, changes in water requirements and additional information gathering.
2	Conduct stakeholder consultation.  (June 2009)	Advice sought from key stakeholders using the existing document and additional information as a tool for discussion.
3	Prepare update of 2001 drinking water source protection plan.  (July 2009-May 2010)	Updated protection plan developed taking into account input from stakeholders and any additional information.
4	Release draft drinking water source protection plan.  (May 2010)	Updated protection plan distributed for stakeholder comment.
5	Amended protection plan released for public comment; subsequent discussions with stakeholders.  (2011-2012)	In response to information received in the 2010/11 comment period and subsequent groundwater modelling; additional discussions with the Departments of Planning and Regional Development and Lands, and LandCorp; the 2010 proposed Broome Water Reserve plan and boundary was amended.
6	Finalise drinking water source protection plan.  (December 2012)	Protection plan published after considering comments received. Includes recommendations on how to protect water quality. The 2010 Broome Water Reserve boundary is proposed to be reduced based on additional data and groundwater modelling in 2011.



## Summary

Broome is located on the Broome Peninsula in Western Australia's Kimberley region. The town relies on groundwater for its potable water supply. The water supply wellfield for Broome, operated by the Water Corporation, is located about 12 km north-east of the town site.

The wellfield currently comprises 18 production bores drawing water from the highly transmissive Broome Sandstone Aquifer. As demand is increasing, the wellfield is being extended north of Crown reserve 25716, with recent bores located in a northerly line (on the former Waterbank Station, a Crown allotment now managed by the Department of Planning).

The by-laws of the *Country Areas Water Supply Act 1947* apply within the Broome Water Reserve to control activities with the potential to contaminate this public drinking water supply. This drinking water source protection plan (DWSPP) updates the 2001 DWSPP and recommends an extension to the existing water reserve to better protect water quality for current and future development in Broome.

The Broome Water Reserve was first proclaimed in 1986 and amended in 2002. The Draft DWSPP released in May 2010 proposed to extend the existing water reserve to the north-east. In response to additional information received during the comment period, and subsequent groundwater modelling, the recommended Broome Water Reserve is now smaller than that proposed in 2010 but larger than the current proclaimed water reserve.

Because the Broome Sandstone Aquifer is unconfined, it is vulnerable to contamination from inappropriate surface-based land uses and activities.

The following strategies are recommended to protect water quality within the Broome Water Reserve:

- Amendment of the Broome Water Reserve boundary to reflect current data and groundwater modelling.
- The water reserve should be managed as a Priority 1 area.
- Removal of the Priority 3 area south of Broome Road.
- Alignment of the water reserve's western boundary adjacent to the eastern boundary of the Broome – Cape Leveque Road reserve.
- Activities that occur in the water reserve should adopt best practice management to protect water quality of this drinking water source.



# 1 Drinking water source overview

## 1.1 Existing water supply system

Broome is located on the coast of Western Australia's Kimberley region (Figure A1). The main part of Broome's water supply wellfield is found in Crown reserve 25716 – Lot 301 (Figure A2), and recent bores have been added along a line north of this Crown reserve. The wellfield, located about 12 km north-east of the town site, currently comprises 18 production bores drawing water from the unconfined Broome Sandstone Aquifer.

The abstraction of water is evenly distributed between the bores and the scheme is licensed to abstract 5400 ML per year.

As demand is increasing, the wellfield is being extended to the north. Bore locations are aligned parallel with groundwater-level contours and perpendicular to the direction of the groundwater flow. This maximises the amount of water that the bores are able to intercept.

There are also six monitoring bores near the wellfield including two that were purpose-built for monitoring the saline interface.

The original Broome Water Reserve was proclaimed in 1986 and amended in 2002 (see Figure A2). The by-laws of the *Country Areas Water Supply Act 1947* apply within the water reserve to control activities with the potential to contaminate the public water supply.

## 1.2 Water treatment

Water is pumped from the production bores to a 2250 m<sup>3</sup> storage tank located in the wellfield. The water is treated in a pH correction facility, chlorinated, fluoridated, and transferred under gravity or via the boosters (depending on reticulation demand) to the Cable Beach storage tank and the light industrial area elevated tank (Water Corporation 2008).

It should be recognised that although treatment and disinfection are essential barriers against contamination, management of the wellfield's recharge area is the first step in protecting water quality and ensuring a safe drinking water supply. This approach is endorsed by the *National water quality management strategy: Australian drinking water guidelines (ADWG) 6* (NHMRC & NRMCC 2011) and reflects a preventive risk-based, multiple-barrier approach for providing safe drinking water to consumers. This combination of catchment protection and water treatment will deliver more reliable, safer and lower-cost drinking water to consumers than either approach could achieve individually.

## 1.3 Catchment details

### 1.1.1 Physiography

Broome is located on the Broome Peninsula on the Kimberley region's coast. The water reserve begins about 12 km inland from the town site.

The land surface rises gently to the north-east from about 20 m AHD in the water reserve's south-west corner to more than 200 m AHD in its north-east. Drainage in the reserve is not developed and local run-off only occurs after very heavy rainfall. The soil type is described as 'pindan sand plain': a light, clayey, fine-grained non-water-repellent sand to silt, which is characteristically deep red in colour due to the iron oxide staining of the quartz grains. The name pindan is taken from the vegetation that covers the area, which consists of grassland with scattered trees, generally eucalypts, with a variably dense middle layer of acacia thickets (Department of Conservation and Land Management 1996).

### 1.1.2 Climate

Broome lies at the intersection of three climatic regions: the northern, the dry interior, and the north-western. While exhibiting characteristics of each region, it is a climate that is essentially tropical – with a distinct wet season from December to March and a dry season that extends from April to November, although the start and end of this period can still be hot and humid (Laws 1991a).

Winter is characterised by low rainfall and moderate temperatures. In summer, the southward movement of tropical cyclones and thunderstorms bring higher rainfall, temperatures and humidity.

The average annual rainfall is about 595 mm, which generally occurs during intense, short events related to summer tropical lows crossing the coastline between December and March. This can result in localised flooding. However, if the wet season fails to materialise, the total rainfall for the year can be very low. For example, only 131.2 mm was recorded in 1992. Pan evaporation rates are high and average about 2950 mm per year. The variation in average monthly maximum temperature is small, ranging from 28 to 34°C, but variation in daily temperatures and average monthly minimums are more pronounced. The prevailing winds are mostly from the west-south-west and east-south-east.

### 1.1.3 Hydrogeology

Several regional groundwater exploration programs have been undertaken in and around Broome, as well as inland from the town. These programs, together with information from the town water supply wellfield, have enabled us to have a good understanding of Broome's hydrogeology. The geology, hydrogeology and aquifer have been well documented in reports by Department of Water (2012a), Laws (1985,

1987, 1990, 1991a and 1991b) and the former Water Authority of Western Australia (WAWA1994).

Broome is located within the Canning Basin, a large sedimentary basin covering an onshore area of more than 450 000 km<sup>2</sup> – a large part of the state. It spans from the Pilbara Craton in the south-west to the King Leopold and Halls Creek Orogens in the north-east. The basin comprises sequences of folded sedimentary rocks up to 18 km thick (Laws 1987 1990).

The Dampier Peninsula is underlain by a series of sedimentary rocks. Superficial sands and pindan soils of Quaternary age unconformably overlie the Broome Sandstone of Cretaceous age. The Broome Sandstone comprises fine- to coarse-grained sandstone with minor beds of pebble conglomerate, grey siltstone and claystone. The Broome Sandstone outcrops over the entire area and ranges in thickness from less than 5 m to about 300 m.

The Broome Sandstone conformably overlies the Jarlemai Siltstone of Late Jurassic age, which in turn, overlies the Alexander Formation (a fine- to coarse-grained sandstone with interbedded siltstone and shale), and subsequently the Wallal Sandstone of early to late Jurassic age (also a fine- to coarse-grained sandstone).

These sediments overlie an eroded, folded sequence of sediments of Permian age. Together, they form the northern margin of the Canning Basin and lie within what is known as the Fitzroy Trough.

#### 1.1.4 Groundwater occurrence

The Broome Sandstone Aquifer is the main aquifer at Broome and provides the water supply for the town. It contains a substantial groundwater resource.

Generally, groundwater in the Broome aquifer is fresh inland, becoming marginal to saline at the coast (Department of Water 2012a). It is a highly transmissive aquifer, particularly in the coarse-grained sand and gravel sequences occurring between 40 to 100 m below the ground surface. Groundwater flow is from the north-east to the south-west (see Department of Water's 2012a *Groundwater resource review Dampier Peninsula*).

Groundwater moves under the influence of gravity down the hydraulic gradient, west towards the ocean, south-west towards the town site, and south towards Roebuck Bay.

Groundwater discharges to the Indian Ocean and to Roebuck Bay over a saline interface. As a result, careful management of abstraction is required to ensure the saline interface is not destabilised and drawn further inland.

Recharge to the aquifer system is by infiltration from direct rainfall from monsoonal and cyclonic rainfall events. Recharge is estimated to be about 4 to 5 per cent of the average annual rainfall (Laws 1987). However, if the wet season fails, or if rainfall is

not intense, recharge may not occur for some years. Heavy monsoonal or cyclonic rainfall may produce recharge events greater than the average figures.

The sustainable yield of the present town wellfield is estimated to be 10 600 ML per year based on a recharge rate of 5 per cent and an average hydraulic conductivity of 28 m per d (Water Authority of Western Australia 1994).

Because the Broome Sandstone Aquifer is unconfined, it is considered vulnerable to contamination from inappropriate land uses and activities.

Careful management and protection of the aquifer is essential, because the deeper aquifers (Alexander Formation and Wallal Sandstone) would require desalinisation before use.

## 1.4 Future water supply requirements

The latest scheme review estimates total water consumption will be about 5600 ML per year by 2017–18. Assuming unaccounted water use remains at its present rate, total abstraction could reach 6100 ML per year (Water Corporation 2008).

Additional bores were drilled in 2008 (numbers 2/08, 3/08 and 4/08). It is anticipated more bores will be drilled along a northerly line, to intersect the optimal groundwater flow in the aquifer.

## 1.5 Existing drinking water source protection

The Broome Water Reserve was originally proclaimed in 1986 under the *Country Areas Water Supply Act 1947* for the purpose of public drinking water source protection. By-laws created under this Act enable the Department of Water to influence and control activities to prevent, avoid, minimise or manage water quality contamination risks.

The Department of Water has delegated powers of monitoring and by-law enforcement to the Water Corporation for some public drinking water source areas (PDWSAs). Section 4.7, *Surveillance and by-law enforcement*, provides more information.

The original water reserve was proposed to be amended in the 2001 source protection plan (Water and Rivers Commission 2001). This document recommended that the water reserve boundaries be extended to encompass much of the recharge area and the immediate capture zone of the wellfield, based on Geological Survey of Western Australia hydrogeological mapping (Laws 1987). The original water reserve boundary was subsequently de-proclaimed and a new boundary was proclaimed in 2002 (see Figure A2).



This drinking water source protection plan (DWSPP) updates and builds on the 2001 plan and assesses the ongoing protection requirements for the Broome Water Reserve. It recommends an extension to the existing water reserve based on recent groundwater modelling that more accurately identifies the recharge area and capture zones of the wellfield.

Land-use activities in the water reserve are limited by a number of measures. The wellfield is mostly contained in Crown reserve 25716, which is vested for water supply purposes.

Land uses are also regulated by the provisions of the Shire of Broome's *Town planning scheme (TPS) no. 4*. The current scheme area does not extend fully into the water reserve. The TPS notes that the Broome Water Reserve is located on the scheme area's eastern boundary and extends outside the scheme's boundary. It also notes that protection of the water reserve is essential to preserve the town's only water supply. The *Waterbank structure plan* (Department of Land Administration 2000) reinforces the protection and extension of the water reserve.

## 1.6 Department of Water management

### 1.6.1 Current allocation licence

Water resource use and conservation in Western Australia is administered by the Department of Water in accordance with the *Rights in Water and Irrigation Act 1914*. Under the Act, the right to use and control surface and groundwater is vested with the Crown. This Act requires licensing of groundwater abstraction (pumping water from a bore, spring or soak) within proclaimed groundwater areas.

The Broome Water Reserve is located within the Broome Groundwater Area (BGA), which is proclaimed under the *Rights in Water and Irrigation Act 1914*. Under the provisions of sections 26D and 5C of the Act, a licence is required to construct a bore or abstract water within a proclaimed area, unless exempt under the Rights in Water and Irrigation Exemption and Repeal (Section 26C) Order 2011 or the Rights in Water and Irrigation Exemption and Repeal (Section 26C) (Dewatering) Order 2010.

The Water Corporation is licensed to abstract 5400 ML per year.

### 1.6.2 Broome Groundwater Area management plan

Figure A2 shows the location of the current BGA which was originally proclaimed in 1974 to protect the town water supply. The BGA was extended in 1982 to enable better management of groundwater use in the Cable Beach subdivision, and further extended in 1986 to its present size of 175 000 ha. The 1986 extension allowed for management of the Coconut Wells subdivision, the 12 Mile area, and the then-proposed Skuthorpe area.

An earlier *Broome groundwater management plan* in 1991 subdivided the BGA into seven subareas, one of which encompassed the town water reserve (as it was at that time). A detailed *Groundwater management plan* was prepared by Water Authority Western Australia (1994) which described the resource and provided details of abstraction from it. It also developed groundwater management policies for each of the subareas. The plan considered that maintaining the integrity of the BGA's groundwater resources was vital to the sustainability and future existence of the Broome community.

A recommendation of the 1994 management plan – to base limits on extractable volumes from each subarea – was subsequently implemented by the Broome Groundwater Advisory Committee. The 1994 plan is still being used for management of the BGA. It will be reviewed in line with Department of Water allocation planning priorities.

## 1.7 Consultation

During the update of this DWSPP, a series of meetings with stakeholders were held in Broome.

In all cases there was strong support for source protection and for an extension of the source protection area to the north-east. Many stakeholders believed this would not only provide stronger protection for the public drinking water source but also offer greater security of quality and quantity to private water supplies in rural subdivisions south and west of the water reserve.

An amended draft protection plan was released in November 2010. Comments were sought from a wide range of stakeholders over an extended public comment period (government agencies, Water Corporation, the Indigenous community, the Shire of Broome and other regional stakeholders). In response to information received during the comment period; the results of new groundwater modelling; additional discussions with the Department of Planning, Department of Regional Development and Lands and LandCorp; the 2010 proposed Broome Water Reserve boundary was modified.

## 2 Common contamination risks

Land development and land- or water-based activities within a water reserve can directly affect the quality of drinking water and its treatment. Contaminants can reach drinking water sources through run-off over the ground and infiltration through soil. A wide range of microbiological, chemical and physical contamination risks can impact on water quality and therefore affect the provision of safe, good quality drinking water to consumers.

Some contaminants in drinking water can affect human health. Other impurities can affect the water's aesthetic qualities, including its appearance, taste, smell and 'feel' but are not necessarily hazardous to human health. For example, cloudy water with a distinctive odour or strong taste may not be harmful to health, but clear, pleasant-tasting water may contain harmful, undetectable microorganisms (NHMRC & NRMCC 2011). Contaminants can also interfere with water treatment processes, and damage water supply infrastructure (such as iron corroding pipes).

The ADWG (NHMRC & NRMCC 2011) outlines criteria for acceptable drinking water quality to protect human health, manage aesthetics and maintain water supply infrastructure.

Some commonly seen contamination risks relevant to groundwater drinking water sources are described below.

The Water Corporation regularly monitors the quality of raw water from the Broome Water Reserve for microbiological, health-related and aesthetic (non-health-related) characteristics. This data shows the quality of water in the PDWSA. An assessment of the drinking water quality once treated is also made against the ADWG. This assessment is made by an intergovernmental committee called the Advisory Committee for the Purity of Water, chaired by the Department of Health.

A water quality summary for the Broome Water Reserve for the period July 2007 to July 2012 is presented in Appendix B. For more information on water quality, see the Water Corporation's most recent drinking water quality annual report at [www.watercorporation.com.au](http://www.watercorporation.com.au) What we do > Water quality > Water quality publications > Click on the most recent *Water quality annual report*.

### 2.1 Microbiological risks

Pathogens are types of microorganisms that are capable of causing illness. These include bacteria, protozoa and viruses. In drinking water supplies, pathogens are commonly found in the faeces of humans and domestic animals (such as dogs and cattle).

Pathogens can enter drinking water supplies from faecal contamination in the water reserve. In groundwater sources, this occurs indirectly—faecal material can infiltrate

through the soil and into the groundwater. For example, contamination can occur from septic tanks or grazing animals.

A number of pathogens are commonly known to contaminate water supplies worldwide. These include bacteria (e.g. *Salmonella*, *Escherichia coli* and cholera), protozoa (e.g. *Cryptosporidium*, *Giardia*) and viruses. Monitoring for the presence of *E. coli* in water supplies provides an indication of the level of recent faecal contamination.

Pathogen contamination of a drinking water source is influenced by many factors including the existence of pathogen carriers (e.g. humans and domestic animals), the transfer to and movement of the pathogen in the water source and its ability to survive in the water. The percentage of humans in the world that carry pathogens varies. For example, it is estimated that between 0.6 to 4.3 per cent of people are infected with *Cryptosporidium* worldwide, and 7.4 per cent with *Giardia* (Geldreich 1996).

The survival and movement of pathogens in groundwater is influenced by the characteristics of the pathogen (such as its size and the length of time it normally takes to decay) and the groundwater properties (including flow rate, porosity, amount of carbon in the soil, temperature and pH). Inactivation rate (the time it normally takes a pathogen to decay) is one of the most important factors governing how far pathogens may migrate. Typical half-lives of pathogens range from a few hours to a few weeks. For example, some reported migration distances of bacteria in groundwater are:

- 600 m in a sandy aquifer
- 1000–1600 m in channelled limestone
- 250–408 m in glacial silt-sand aquifers (Robertson & Edbery 1997).

Unlike chemicals, which dissipate and dilute when they enter a water source, pathogens can multiply under the right conditions, increasing the likelihood of contamination. Therefore it is important to understand both the surface water and groundwater systems to be able to protect the drinking water source from pathogens.

When people consume drinking water contaminated with pathogens the consequences vary considerably, ranging from mild illness (such as stomach upset or diarrhoea) to hospitalisation and sometimes even death. During 2000, seven people died in Walkerton, Canada, because the town's water supply was contaminated by a pathogenic strain of *E. coli* and *Campylobacter* (NHMRC & NRMCC 2011).

Given the wide variety of pathogens, the differences in how they act in the environment and the potential consequences of consuming contaminated water, the most effective way to protect public health and reduce water treatment costs is to avoid the introduction of pathogens into a water source.

## 2.2 Physical risks

Turbidity is the result of soil or organic particles becoming suspended in water (cloudiness). Increased turbidity can result in cloudy or muddy-looking water, which is not aesthetically appealing to consumers. Turbidity can also reduce the effectiveness of treatment processes (such as disinfection). This is because pathogens can adsorb onto soil particles and may be shielded from the effects of disinfection. Chemicals can also attach to suspended soil particles.

Some physical properties of water such as pH (a measure of acidity or alkalinity) can contribute to the corrosion and encrustation of pipes. Other properties such as iron and dissolved organic matter can affect the colour and smell of water. Although not necessarily harmful to human health, coloured or 'hard' water will not be as appealing to consumers. Salinity can affect the taste of drinking water.

## 2.3 Chemical risks

Chemicals can occur in drinking water as a result of natural leaching from mineral deposits or from different land uses (NHMRC & NRMCC 2011). A number of these chemicals (organic and inorganic) are potentially toxic to humans.

Pesticides include agricultural chemicals such as insecticides, herbicides, nematicides (used to control worms), rodenticides and miticides (used to control mites). Contamination of a drinking water source by pesticides (and other chemicals) may occur as a result of accidental spills, incorrect use or leakage from storage areas. In these cases, the relevant authorities should be notified promptly and the spill cleaned up to prevent contamination of the drinking water source.

Hydrocarbons (e.g. fuels and oils) are potentially toxic to humans, and harmful chemical by-products may be formed when they are combined with chlorine during the water-treatment process. Hydrocarbons can occur in water supplies as a result of spills and leakage from vehicles.

Drinking water sources can also be contaminated by nutrients (such as nitrogen) from fertiliser, septic systems, and faecal matter from domestic or feral animals that washes through or over soil and into a water source. Nitrate and nitrite (forms of nitrogen) can be toxic to humans at high levels, with infants younger than three months being most susceptible (NHMRC & NRMCC 2011).

Other chemicals and heavy metals can be associated with land uses such as industry and landfill. These may enter drinking water sources and could be harmful to human health.

## 2.4 Other groundwater bores

The Broome Water Reserve is located within the Broome Groundwater Area. Under the provisions of sections 26D and 5C of the *Rights in Water and Irrigation Act 1914*,

a licence is required to construct a bore or abstract water within a proclaimed groundwater area (unless exempt under the Rights in Water and Irrigation Act Exemption and Repeal [Section 26C] Order 2007).

The Water Corporation operates the public water supply bores in the Broome Water Reserve. However, if other bores (e.g. for irrigation or private water supply) are drilled near to the public drinking water bores, contamination of the drinking water source may occur. A poorly constructed bore may introduce contaminants from surface leakage down the outside of the bore casing into an otherwise uncontaminated aquifer. Other bores may also impact on the operational performance of the public water supply bores.

It is therefore important to ensure that all bores in the Broome Water Reserve are appropriately located and constructed to prevent contamination of the water source, and not interfere with the normal operations of the public water supply bores. These matters will be considered when the department assesses water licence applications under the *Rights in Water and Irrigation Act 1914*. Additionally, all bores should be constructed in accordance with *Minimum construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2012).

## 3 Land-use assessment

### 3.1 Existing land uses and activities

The Broome Water Reserve is generally vegetated with pindan woodland; Figure A3 shows non-intensive land use within the reserve. Specific land uses are discussed below, with Table 1 presenting land uses, risks they pose to water quality and management options.

#### 3.1.1 Pastoral stations

A large part of the extended Broome Water Reserve is on the former Waterbank Station (a Crown allotment now managed by the Department of Planning). In the past, this station was used for occasional grazing. The structure plan developed for this land reflects the need to protect the recharge area from water quality contamination risks.

Pastoral lease Roebuck Plains Station also partly occupies the proposed Broome Water Reserve (see Figure A5).

#### 3.1.2 Diesel storage at bore sites

The Water Corporation bores are equipped with shaft drive pumps powered by diesel electric motors. Diesel fuel at each bore is stored in 5000 L above-ground storage tanks with smaller day tanks. Larger quantities of diesel are also stored at the pump station.

To minimise the potential for diesel contamination, the Water Corporation has established bunds around all fuel storage facilities. Diesel storage at the pump station is well bunded. In recent years the Water Corporation has replaced all diesel storage facilities with double-skin tanks. There has also been a progressive upgrade of bore infrastructure to fully sealed stainless-steel headworks and new concrete pump bases.

Prevention of diesel contamination in the wellfield is important because any contamination in this area could move quickly to the bores.

Management of contamination risks at the power plant is also important, given the site overlies the wellfield's recharge area. From a water quality contamination risk perspective, electrification of the wellfield should be considered.

#### 3.1.3 Road transport

Broome's main access roads are adjacent but outside of the water reserve's proposed boundaries.

Spillage of contaminants from accidents during road transport and leaching of contaminants from stormwater are potential sources of contamination. New regional roads should avoid the water reserve. For existing roads, design measures should be used to direct stormwater away from production bores.

### 3.1.4 Emergencies

The escape of chemicals during unforeseen incidents and the use of chemicals during emergency responses can cause groundwater contamination.

The local emergency response team needs to be familiar with the location and purpose of the Broome Water Reserve and how best to manage water quality contamination risks during emergencies.

### 3.1.5 Pistol club and rifle range

A pistol club and rifle range is located within the water reserve immediately east of the existing wellfield (between the wellfield and the 12 Mile rural subdivision, north of the Broome Highway). The pistol club is in the groundwater capture area for the wellfield. Pollution risks associated with pistol clubs include effluent from onsite wastewater treatment systems, hydrocarbons leaking from vehicles, and lead leaching from spent projectiles in areas with unfavourable soil and groundwater chemistry.

The risks posed by this facility should continue to be addressed through best management practices.

### 3.1.6 Aboriginal cultural values and sites of significance

Aboriginal people have significant and ongoing cultural connections and responsibilities for country throughout the Broome area and the Dampier Peninsula.

There are also specific sites of significance that Aboriginal people value as important and significant to their cultural heritage. These sites link Aboriginal culture and tradition to place, land and people over time. These areas may form an integral part of Aboriginal identity and the heritage of Western Australia. In Western Australia, sites are formally recognised and protected under the *Aboriginal Heritage Act 1972*.

There are several registered Aboriginal sites located along the coastal strip outside the proposed Broome Water Reserve. While no registered sites are shown within the existing water reserve or its proposed extension, there may be unsurveyed or unregistered sites within the reserve. The Water Corporation should refer to the Government's 'Cultural Heritage Due Diligence Guidelines' to make an assessment about whether surveys should be undertaken before any new drilling or ground disturbance within the Broome Water Reserve. Registered and non-registered site information is held by the Department of Indigenous Affairs.



Surveys commissioned by agencies such as the Water Corporation should be in accordance with the rates and provisions of the Government Standard Heritage Agreement.

The State has entered into a State Activities Funding Agreement with the Kimberley Land Council (KLC), which includes the Government Standard Heritage Agreement for surveys with groups represented by the KLC. This does not include the Yawaru Registered Native Title Body Corporate.

### 3.1.7 Native title

Native title is the recognition of unique ties, in the form of traditional rights and interests, some Aboriginal groups are able to demonstrate as having to land. Native title may exist where traditional connection to land and waters has been maintained by a defined group since sovereignty.

The Broome water reserve is bisected by the Rubibi Community native title determination area [WAD 6006/98], the Goolarabooloo Jabirr-Jabirr Peoples (WAD6002/98), the Jabirr Jabirr People (WAD124/10) and the Goolarabooloo Families claim (WAD2/11).

The Rubibi native title holders are represented by Yawuru Registered Native Title Body Corporate (RNTBC), which should be contacted if surveys are required within the relevant southern portion of the water reserve.

Goolarabooloo-Jabirr Jabirr native title claimants are represented by the KLC, which should be contacted if surveys are required within the relevant northern portion of the water reserve.

The Department of Water will ensure these matters are considered in the ongoing management of the Broome Water Reserve. Current maps of native title areas can be obtained from the National Native Title Tribunal.

## 3.2 Proposed land uses and activities

Several proposed land uses were outlined in the Department of Regional Development and Lands' 2011 *Dampier Peninsula Planning Strategy draft*, and originally in the *Waterbank structure plan* (Department of Land Administration 2000). The *Waterbank structure plan* was developed by the Waterbank Coordinating Committee, (chaired by the then Department of Land Administration) and was adopted by Cabinet. That committee was established to identify the various land use and development options for the area.

Protection of the public water supply source was given significant consideration during development of the *Waterbank structure plan*, which identifies most of the land up-gradient from the wellfield as the water supply recharge area. The plan

recognises traditional Aboriginal rights of access and generally excludes development in the area.

### 3.2.1 Airport

The *Waterbank structure plan* (Department of Land Administration, 2000) identified a replacement site for the Broome Airport through an exhaustive consultative process that included consideration of future water source protection requirements. The site was also confirmed as part of the Yawuru global agreement, and is partially within the portion of the existing water reserve south of Broome Road that was identified as a Priority 3 area in the 2001 source protection plan. The area south of Broome Road is now proposed to be removed from the Broome Water Reserve to recognise these decisions.

Table 1 Land use and potential water quality risks in water reserve

Land use/activity	Hazard	Management priority	Compatibility of land use/activity	Best management practice guidance*
Diesel storage at bore sites	<ul style="list-style-type: none"> <li>• <b>Hydrocarbons</b> from spills from storage tanks and, vehicles and machinery</li> </ul>	Medium to high	Fuel storage is normally incompatible in P1 areas. This is an existing land use activity that is required to provide fuel for bore pumps but added precautions need to be taken such as using double-lined storage tanks and future provision of electricity to power the bores.	For storage of chemicals in tanks, see the following Water quality protection notes (WQPNs): <ul style="list-style-type: none"> <li>– elevated chemical storage (no. 56)</li> <li>– ground level (no.61)</li> <li>– mobile fuel storage (no. 60)</li> <li>– temporary elevated (no. 58)</li> <li>– underground (no. 62).</li> </ul>
Road transport along Broome – Derby Road on southern boundary of water reserve, and along Broome – Cape Leveque Road on western boundary of reserve	<ul style="list-style-type: none"> <li>• <b>Hydrocarbons and chemicals</b> from fuel and chemical spills from vehicles and machinery</li> <li>• <b>Pesticides</b> from weed spraying along edges of roads</li> <li>• <b>Nutrients</b> from spillage or leaks</li> </ul>	Low  Low  Low	Roads are located outside the proposed water reserve boundary. (Hazards are only applicable if spills enter the water reserve.)	WQPNs: <ul style="list-style-type: none"> <li>– infrastructure corridors (no. 83)</li> <li>– roads (no. 44)</li> <li>– spills (no.10).</li> </ul>
Diversified pastoral and range land uses	<ul style="list-style-type: none"> <li>• <b>Pathogen contamination</b> from domestic animal excreta and carcasses</li> <li>• <b>Nutrients</b> from excreta originating from domestic animals</li> <li>• <b>Fuel and chemical spills</b> from vehicles and machinery</li> <li>• <b>Over abstraction</b></li> </ul>	Low  Low  Low  Low	Non-intensive pastoral activities are compatible with conditions in a P1 area. Most industrial land uses are incompatible in P1 areas – see WQPNs <ul style="list-style-type: none"> <li>–Land use compatibility (no. 25)</li> <li>–Light industry (no. 93)</li> <li>– General and heavy industry (no. 20).</li> </ul>	WQPNs: <ul style="list-style-type: none"> <li>– pastoral activities within rangelands (no. 35).</li> <li>– onsite wastewater treatment systems (no. 70).</li> </ul> Allocation licensing and land-use planning processes.



## 4 Catchment protection strategy

### 4.1 Protection objectives

The objective of this plan is to protect Broome Water Reserve. This will be achieved by ensuring the water quality is protected and public health is not placed at risk.

The measures and management practices recommended in this plan are aimed at avoiding, minimising, or managing the risk of groundwater contamination, depending on the vulnerability of the source to contamination, the strategic nature of the resource and existing land uses in the area.

A 'catchment to consumer' preventive risk-based and multiple-barrier approach is used to protect drinking water quality in Western Australia, consistent with the *National water quality management strategy: Australian drinking water guidelines 6, 2004* (ADWG) (NHMRC & NRMCC 2004a).

The protection of the Broome Water Reserve is in accordance with government legislation and policy and involves three elements:

- Proclamation of the water reserve under the *Country Areas Water Supply Act 1947*. Proclamation ensures the location of the water source is available to statutory land-use planning decision-makers, developers and the general public.
- Priority areas are assigned to the land within the water reserve to guide land-use planning and development to protect water quality.
- Wellhead protection zones are determined around existing and proposed production bores within the water reserve to protect areas where contamination could quickly find its way into the water supply system. Specific by-laws can apply to these zones to protect water quality.

### 4.2 Proclaimed area

The Broome Water Reserve was proclaimed in 1986 and amended in 2002 following the completion of the Broome Water Reserve Water Source Protection Plan (2001). During the development of this DWSPP, the reserve's boundary was reviewed using additional data and groundwater modelling. As a result, this plan recommends the proclaimed boundary be extended to the north-east to better protect the capture zones of the bores and the full recharge area of the wellfield (see Figure A2). It also recommends the removal of the existing priority 3 area south of Broome Road.

The final alignment of the water reserve along its western boundary (Broome–Cape Leveque Road) will be subject to consultation with the Department of Transport with the intention of following the eastern road reserve boundary of Broome–Cape Leveque Road.

## 4.3 Priority areas

The protection of PDWSAs relies on legislation and policy available for water resource management and land-use planning. The Department of Water's policy for the protection of PDWSAs includes three risk-based priority areas:

- Priority 1 (P1) areas have the fundamental water quality objective of risk avoidance.
- Priority 2 (P2) areas have the fundamental water quality objective of risk minimisation.
- Priority 3 (P3) areas have the fundamental water quality objective of risk management.

The determination of priority areas is based on the strategic importance of the land and water source, the local planning-scheme zoning, the form of land tenure and existing approved land uses or activities. For further detail, please refer to the Department of Water's Water quality protection note (WQPN) no. 25: *Land use compatibility in public drinking water source areas*.

The proposed priority areas for the Broome Water Reserve have been determined in accordance with current Department of Water policy. These areas are described below and displayed in Figure A3. The department's WQPN no. 25 outlines activities that are 'acceptable', 'compatible with conditions' or 'incompatible' within the different priority areas. For an explanation of the background and support for protection of PDWSAs, please refer to WQPN no. 36: *Protecting public drinking water source areas*.

It is proposed that all of the land within the Broome Water Reserve be identified as P1 for the following reasons:

- Water from this source constitutes a strategic supply to the Broome town water supply scheme, so it should be assigned a high level of protection.
- Existing land uses within the water reserve are considered compatible with P1 source-protection objectives.

## 4.4 Protection zones

In addition to P1, P2 and P3 areas, protection zones are defined to protect drinking water sources from contamination in the immediate vicinity of water extraction facilities. Specific conditions may apply within these zones such as restrictions on the storage of chemicals.

Wellhead protection zones (WHPZs) are generally circular (unless information is available to determine a different shape or size), with a 500 m radius around each production bore in a P1 area and a 300 m radius around each production bore in P2 and P3 areas. WHPZs will not extend outside the boundary of the Broome Water Reserve.

In the proposed Broome Water Reserve all bores are located in P1 areas and consequently all WHPZs will have a 500 m radius (see Figure A4).

## 4.5 Land-use planning

It is recognised under the Western Australian Planning Commission's (WAPC) *State planning strategy* (1997) that appropriate protection mechanisms in statutory land-use planning processes are necessary to secure the long-term protection of drinking water sources. As outlined in the WAPC's Statement of planning policy no. 2.7: *Public drinking water source policy* (2003) it is appropriate that the Broome Water Reserve, its priority areas and protection zones be recognised in the *Broome Shire local planning scheme*. Any development proposals within this water reserve that are inconsistent with advice in the Department of Water's WQPN no. 25 or the recommendations in this plan, should be referred to the Department of Water for advice on water quality protection.

For further information on the integration of land-use planning and water source protection, please refer to the WQPN no. 36.

## 4.6 Best management practices

Often, there are opportunities to reduce water contamination risks by carefully considering design and management practices. To help protect water sources, the Department of Water will continue to encourage the adoption of best management practices for all land uses in the Broome Water Reserve.

Guidelines on best management practices for many land uses are available in the form of industry codes of practice, environmental guidelines and WQPNs. They outline the recommended practices to ensure the protection of water quality and can help managers reduce any detrimental effects from their operations. These documents have been developed in consultation with stakeholders such as industry groups, agricultural producers, state government agencies and technical advisers. Relevant examples can be downloaded from the department's website, see *Water quality protection note index* at <http://www.water.wa.gov.au/PublicationStore/first/95393.pdf> >.

Other simpler measures, such as signs or a brochure, can also help protect water quality by raising the public's awareness of their drinking water supply. Signs will be erected and a brochure will be produced once this plan is finalised. This brochure will be made available to the community and will inform people in simple terms about the Broome drinking water source and the need to protect it.

## 4.7 Surveillance and by-law enforcement

The amended Broome Water Reserve will be protected under the *Country Areas Water Supply Act 1947* (WA). Proclamation of this water reserve allows by-laws under this Act to be applied to protect water quality.

The Department of Water considers the use of surveillance and enforcement measures in public drinking water source areas to be an important mechanism to help protect water quality. Signs will be erected on the boundaries of this water reserve to inform the public about activities that are prohibited or regulated. This plan recommends that surveillance and by-law enforcement for the Broome Water Reserve be delegated to the Water Corporation.

## 4.8 Emergency response

The escape of contaminants during unforeseen incidents and the use of chemicals during emergency responses can result in water contamination. The Broome local emergency management committee (LEMC), through the Broome emergency management district, should be familiar with the location and purpose of the Broome Water Reserve. A locality plan should be provided to the fire and rescue services headquarters for the hazardous materials (HAZMAT) emergency advisory team. The Water Corporation should have an advisory role to the HAZMAT team for any incidents in the Broome Water Reserve.

Personnel who deal with WESTPLAN–HAZMAT (Western Australian plan for hazardous materials) incidents within the area should have access to a map of the Broome Water Reserve. These personnel should have an understanding of the potential impacts of contamination of this water resource.

## 4.9 Implementation of this plan

Table 1 identifies the potential water quality risks associated with existing land uses in the proposed Broome Water Reserve. Further information and the recommended protection strategies to deal with those risks are outlined in Appendix C.



## 5 Recommendations

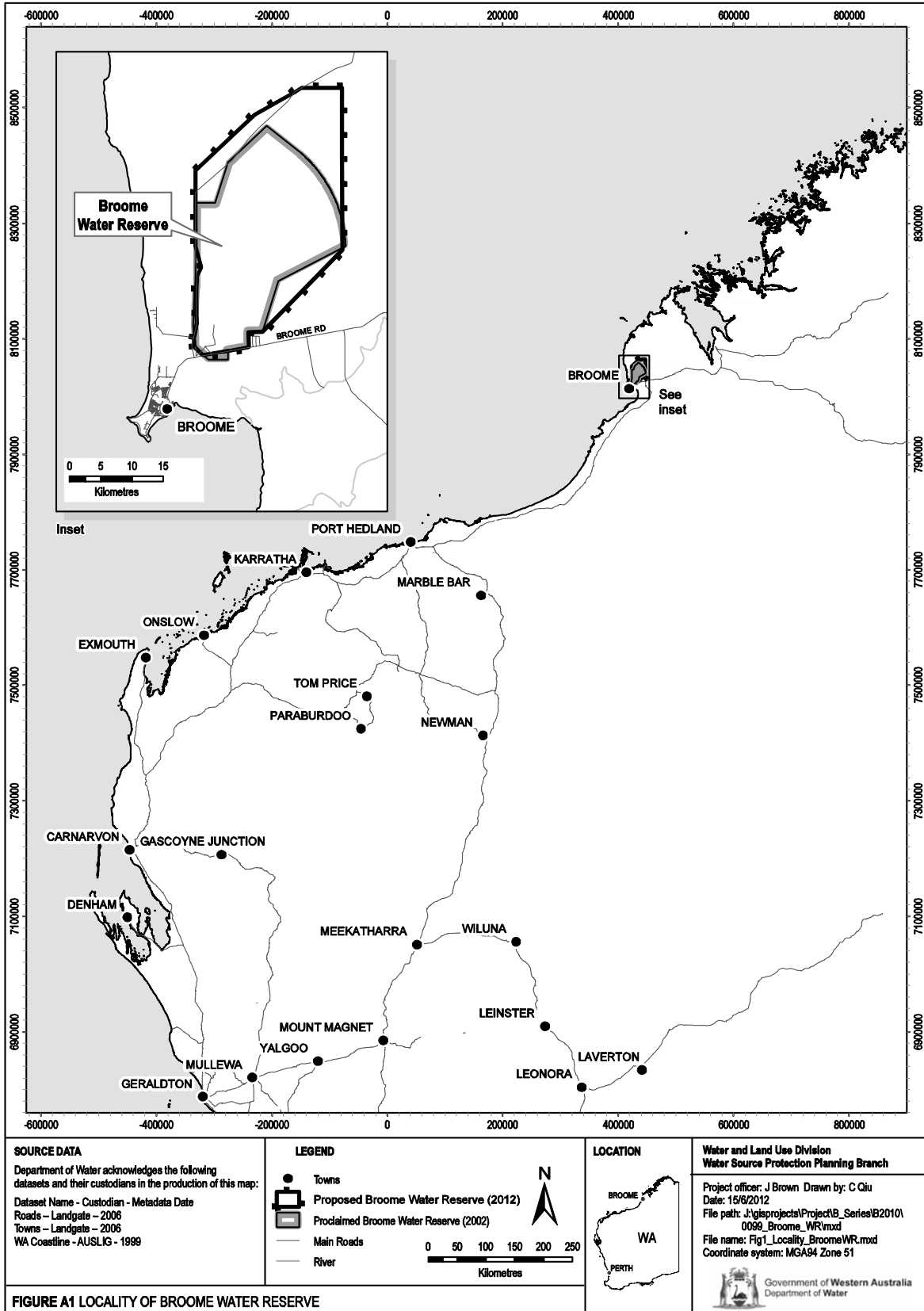
In order to protect the quality of water in the Broome Water Reserve the Department of Water recommends the following (the bracketed stakeholders are those expected to have a responsibility for, or interest in, the implementation of that recommendation):

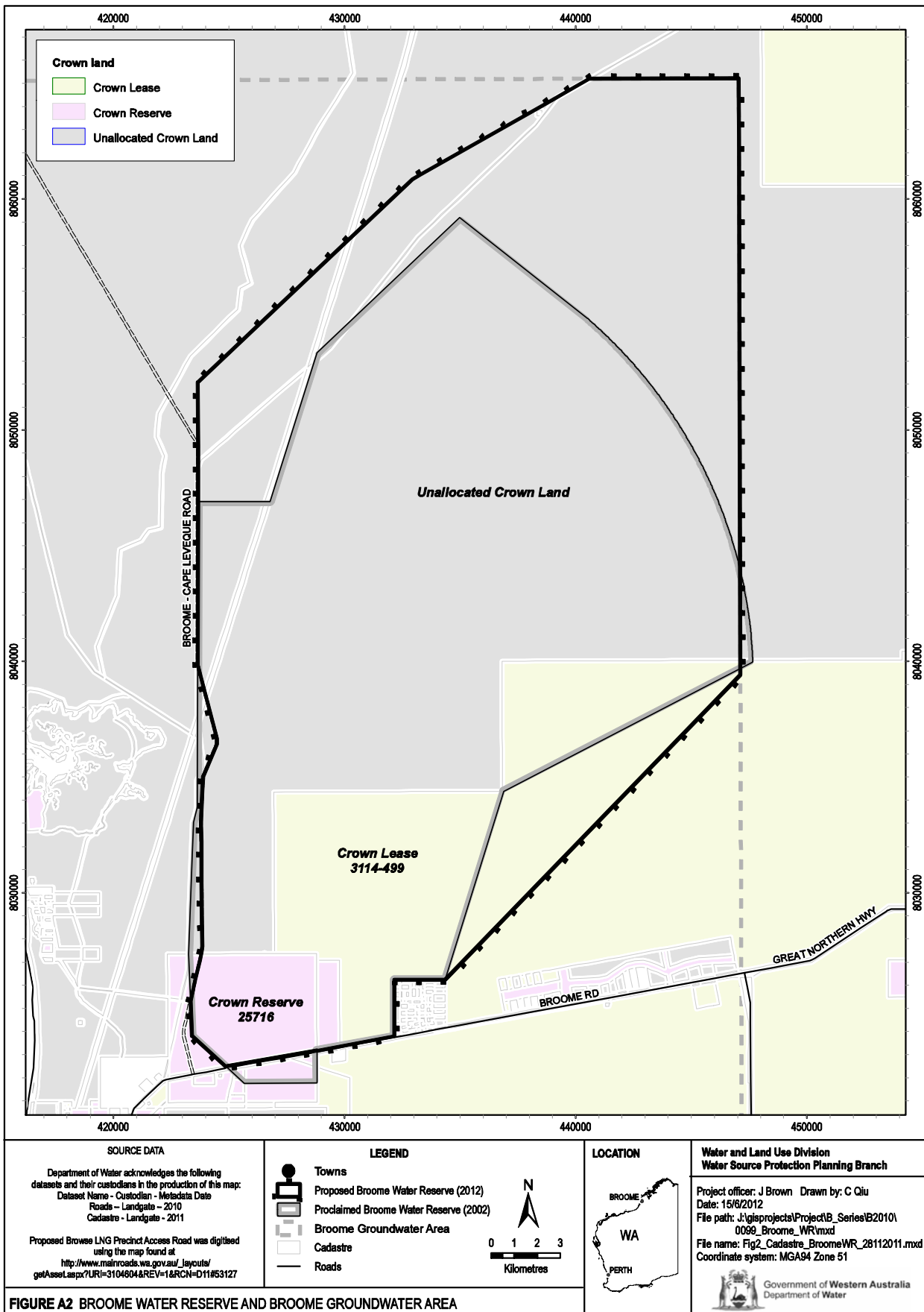
- 1 The boundary of the Broome Water Reserve should be amended as proposed in this plan and proclaimed under the *Country Area Water Supply Act 1947* (WA). The priority areas and protection zones recommended in this plan should be included in the proclamation map. (Department of Water)
- 2 An implementation strategy should be developed for this plan's recommendations (including the recommended protection strategies as detailed in Appendix C) showing responsible stakeholders and planned time frames. (Department of Water, applicable stakeholders)
- 3 The *Shire of Broome town planning scheme* should incorporate this plan and reflect the identified Broome Water Reserve boundary, priority 1 area and protection zones in accordance with the Western Australian Planning Commission's Statement of planning policy no. 2.7: *Public drinking water source policy*. (Shire of Broome)
- 4 All development proposals within the Broome Water Reserve that are inconsistent with the Department of Water's Water quality protection note no.25: *Land use compatibility in public drinking water source areas* or recommendations in this plan should be referred to the Department of Water for advice. (Department of Planning, Shire of Broome, proponents of proposals)
- 5 Incidents covered by WESTPLAN–HAZMAT (Western Australian plan for hazardous materials) in the Broome Water Reserve should be addressed by ensuring that:
  - the Broome local emergency management committee (LEMC) is aware of the location and purpose of the Broome Water Reserve
  - the locality plan for the Broome Water Reserve is provided to the Fire and Emergency Services Authority headquarters for the HAZMAT (hazardous materials) emergency advisory team
  - the Water Corporation acts in an advisory role during incidents in the Broome Water Reserve
  - personnel dealing with WESTPLAN–HAZMAT incidents in the area have ready access to a locality map of the Broome Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality (Department of Water and Water Corporation)
  - The Water Corporation and the Department of Water should work with the Department of Environment and Conservation where bushfire control is required within the Broome Water Reserve (Department of Water, Water Corporation and Department of Environment and Conservation).

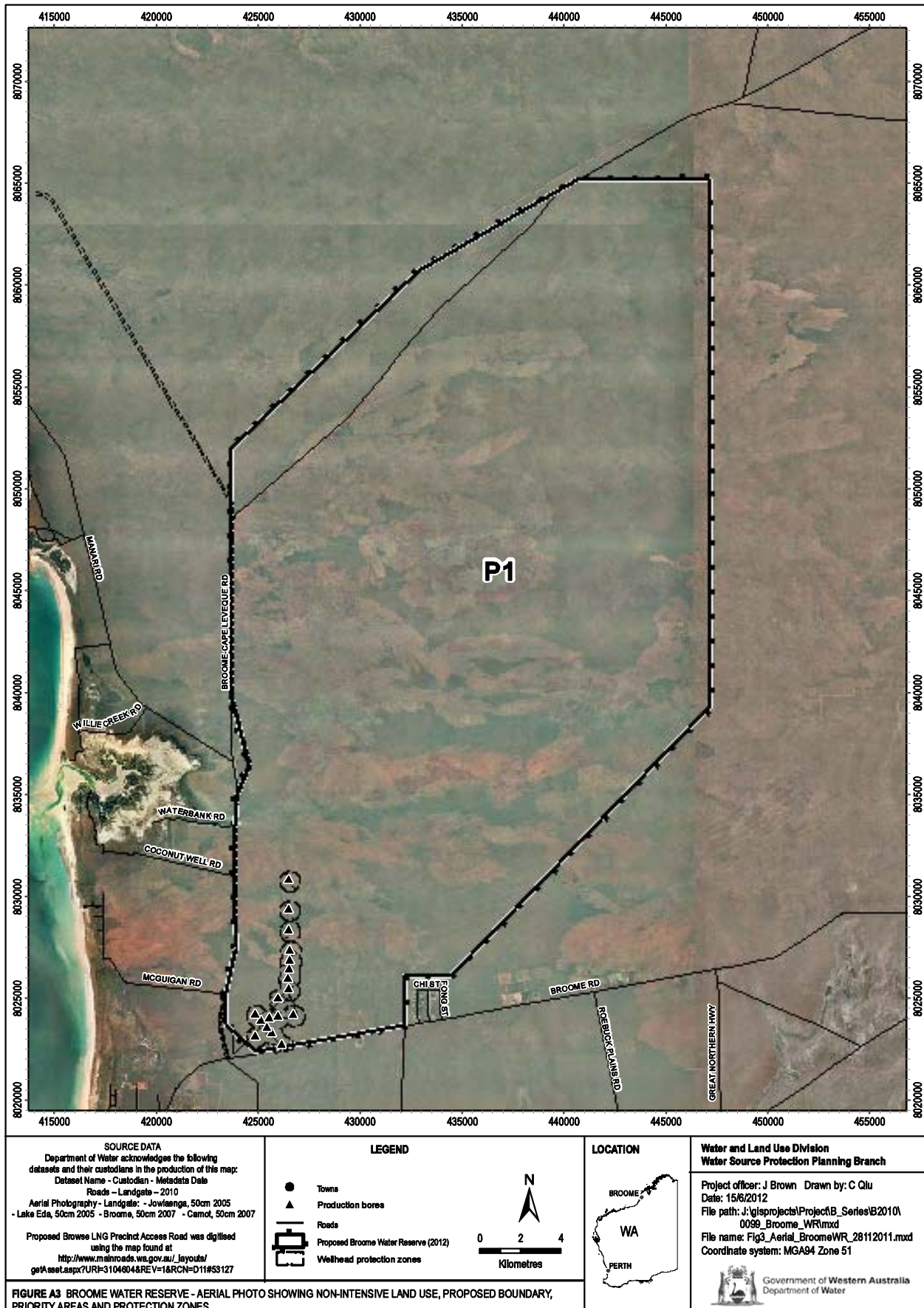
- 6 The Department of Water should delegate responsibility for monitoring and enforcement measures within the Broome Water Reserve to the Water Corporation. (Department of Water, Water Corporation)
- 7 Signs should be erected along the boundary of the Broome Water Reserve to define the location and promote awareness of the need to protect drinking water quality. Signs should include an emergency contact telephone number. (Water Corporation)
- 8 A review of this plan should be undertaken after five years. (Department of Water)

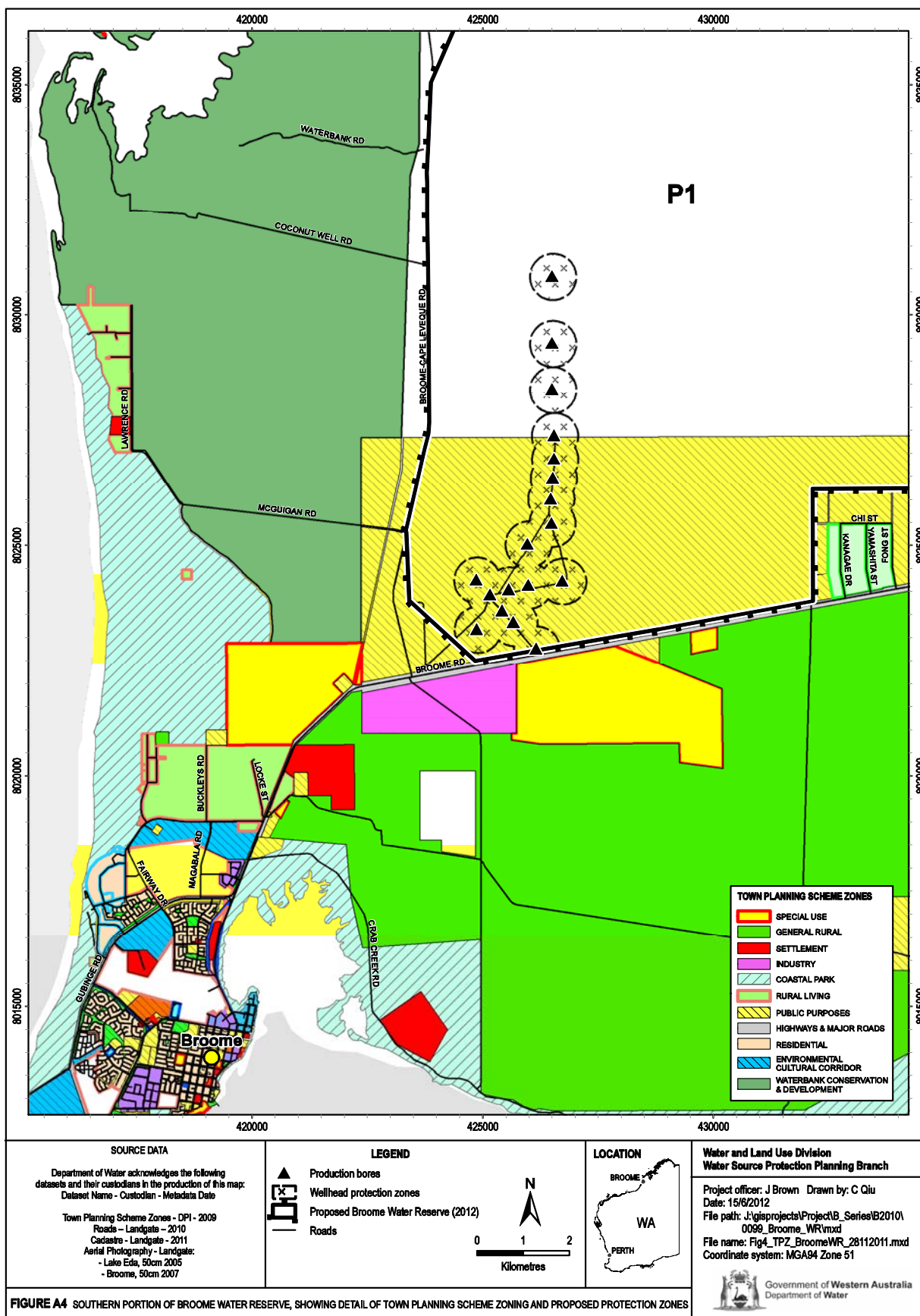
# Appendices

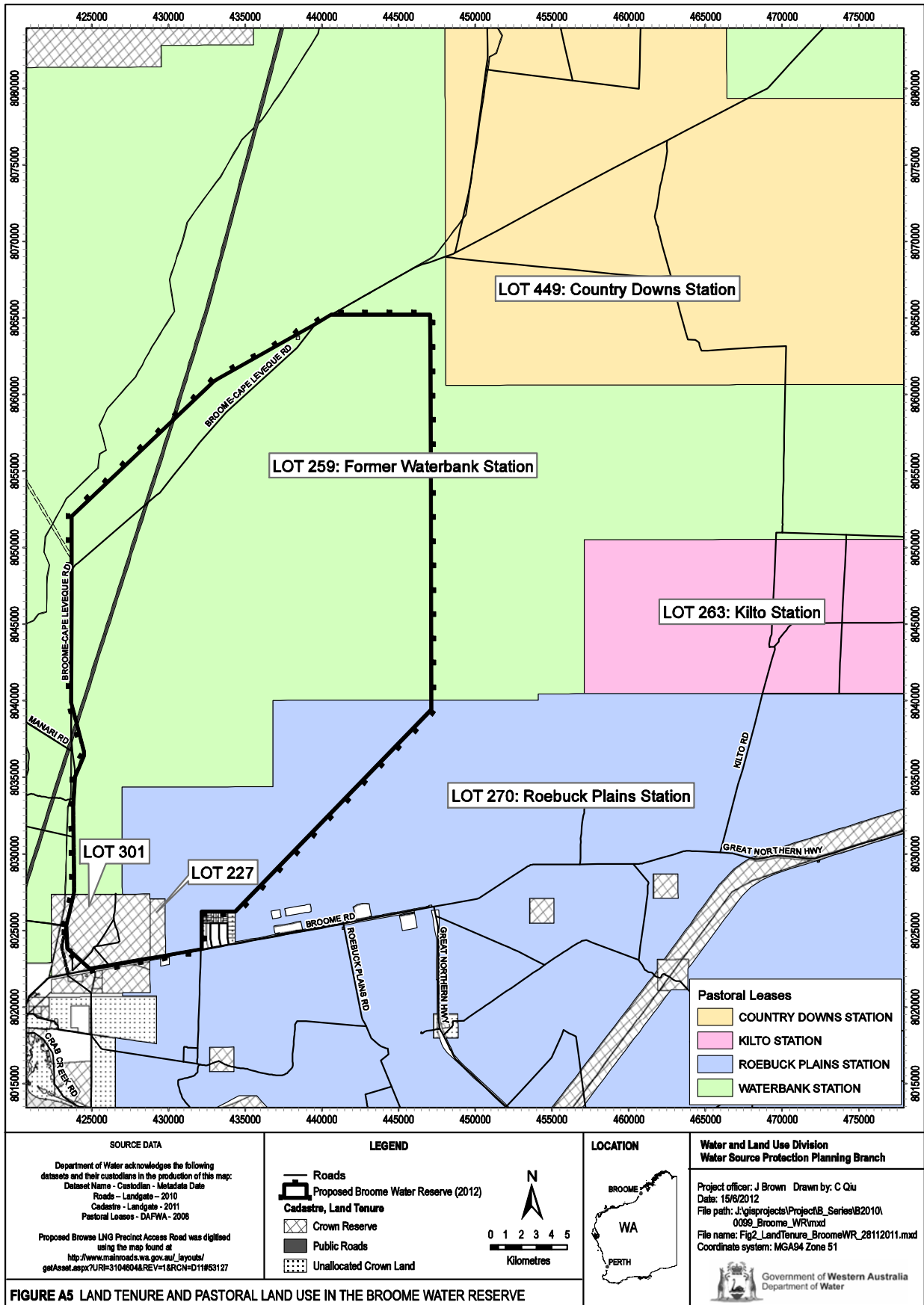
## Appendix A Figures











## Appendix B Water quality data

The information provided in this appendix has been supplied by the Water Corporation.

The Water Corporation has monitored the raw (source) water quality from Broome borefield in accordance with the requirements of the *Australian drinking water guidelines* (ADWG) (NHMRC & NRMCC 2011) and interpretations agreed to with the Department of Health. This data shows the quality of water in the public drinking water source area (PDWSA). The raw water is monitored regularly for:

- aesthetic characteristics (non-health-related)
- health-related characteristics including:
  - health-related chemicals
  - microbiological contaminants.

The following data represents the quality of raw water from Broome borefield. In the absence of specific guidelines for raw-water quality, the results have been compared with the ADWG values set for drinking water, which defines the quality requirements at the customer's tap. Any water quality parameters that have been detected are reported; those that on occasion have exceeded the ADWG are in bold and italics to give an indication of potential raw-water quality issues associated with this source. The values are taken from ongoing monitoring for the period July 2007 to July 2012.

It is important to appreciate that the raw-water data presented does not represent the quality of drinking water distributed to the public. Barriers such as storage and water treatment exist downstream of the raw water to ensure it meets the requirements of the ADWG.

For more information on the quality of drinking water supplied to the Northwest Region refer to the most recent Water Corporation drinking water quality annual report at <[www.watercorporation.com.au](http://www.watercorporation.com.au)> What we do > Water quality > Water quality publications > Most recent *Water quality annual report*.

### *Aesthetic characteristics*

The aesthetic quality analyses for raw water from Broome Borefield are summarised in the following table.



*Aesthetic detections for Broome borefield*

Parameter	Units	ADWG aesthetic guideline value*	Composite raw water sample point	
			Range	Median
Chloride	mg/L	250	95 – 120	115
Hardness as CaCO <sub>3</sub>	mg/L	200	50 – 65	60
Iron unfiltered	mg/L	0.3	<0.003 – <b>4.8</b>	0.03
pH	No unit	8.5	5.83 – 6.84	6.22
Sodium	mg/L	180	49 – 67	59.5
Total filterable solids by summation	mg/L	600	294 – 341	338.5
True colour	TCU	15	<1 – 2	<1
Zinc <sup>+</sup>	mg/L	3	0.02 – 0.04	0.03

\* An aesthetic guideline value is the concentration or measure of a water quality characteristic that is associated with good quality water.

<sup>+</sup> Parameter has been sampled two times or less in reporting period.

*Health-related chemicals*

Raw water from Broome borefield is analysed for chemicals that are harmful to human health, including inorganics, heavy metals, industrial hydrocarbons and pesticides. Health-related parameters that have been detected in the source are summarised in the following table.

*Health-related detections for Broome borefield*

Parameter	Units	ADWG health guideline value*	Composite raw water sample point	
			Range	Median
Annual radiation dose <sup>†</sup>	mSv	1	0.167 – 0.167	0.167
Barium <sup>†</sup>	mg/L	0.07	0.160 – 0.170	0.165
Boron <sup>†</sup>	mg/L	4	0.12 – 0.12	0.12
Copper <sup>†</sup>	mg/L	2	0.045 – 0.075	0.06
Manganese unfiltered	mg/L	0.5	<0.002 – 0.032	0.002
Nitrite plus nitrate as N	mg/L	11.29	4.2 – 5.7	4.9
Radon-222 <sup>†</sup>	Bq/L	100	1.12 – 1.12	1.12
Sulfate	mg/L	500	5.0 – 9.5	7.25

\* A health guideline value is the concentration or measure of a water quality characteristic that, based on present knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & ARMCANZ 2011).

† A guideline value of 11.29 mg/L (as nitrogen) has been set to protect bottle-fed infants less than three months of age. Up to 22.58 mg/L (as nitrogen) can be safely consumed by adults and children over three months of age.

† Parameter has been sampled two times or less in reporting period.

*Microbiological contaminants*

Microbiological testing of raw-water samples from Broome borefield is currently conducted on a monthly basis. *Escherichia coli* counts are used as an indicator of the degree of recent faecal contamination of the raw water from warm-blooded animals.

A detection of *E. coli* in raw water abstracted from any bore may indicate contamination of faecal material through ingress into the bore, or recharge through to the aquifer (depending on aquifer type).

During the review period, positive *E. coli* counts were recorded in 18.2 per cent of samples. Sampling showed a maximum count of 11 MPN/100mL and a median of <1 MPN/100mL.

## Appendix C Land use, potential water quality risks and recommended protection strategies

This table was prepared from data in Section 3 of this plan.

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	Management priority			
<b>Diesel storage</b> at bore sites	<ul style="list-style-type: none"> <li>• <b>Hydrocarbons</b> from spills from storage tanks, vehicles and machinery.</li> </ul>	Medium to high		<ul style="list-style-type: none"> <li>• bunds and double-lined storage tanks</li> <li>• spill response procedures.</li> </ul>	Consider electric pumps for bore sites in future.
<b>Pistol club and rifle range</b>	<ul style="list-style-type: none"> <li>• <b>Hydrocarbons and chemicals</b> from fuel and chemical spills/leakages from vehicles and machinery; and projectiles.</li> <li>• <b>Pathogens</b> from animals and on-site wastewater disposal systems.</li> </ul>	Low  Low	This is an existing, approved land use.		Best management practices should be considered for on-site wastewater disposal systems.

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	Management priority			
Road transport along Broome–Derby Road and along Cape Leveque Road	<ul style="list-style-type: none"> <li>• <b>Hydrocarbons and chemicals</b> from fuel and chemical spills from vehicles and machinery</li> <li>• <b>Pesticides</b> from weed spraying along edges of roads</li> <li>• <b>Nutrients</b> from accidents or leaks.</li> </ul>	<p>Low</p> <p>Low</p> <p>Low</p>	Broome–Derby Road and the Cape Leveque Road are located adjacent but outside of the proposed water reserve boundary.	<ul style="list-style-type: none"> <li>• water quality monitoring</li> <li>• HAZMAT emergency response</li> <li>• signage.</li> </ul>	<p>Install signs on the roads identifying the boundary of the Broome Water Reserve.</p> <p>Ensure adequate gates and signage to prevent access to Water Corporation land in the P1 area.</p> <p>Ensure road water sumps and runoff control measures are adequate and divert water away from the water reserve.</p> <p>Ensure contingency plans are in place for any spills resulting from accidents.</p> <p>Use pesticides for verge and road weed treatment in accordance with Statewide policy no. 2: <i>Pesticide use in public drinking water supply areas</i> (WRC 2000) and Public sector circular no. 88: <i>Herbicide use in water catchment areas</i> (Department of Health 2007).</p>

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	Management priority			
<b>Pastoral and range land</b>	<ul style="list-style-type: none"> <li>• <b>Pathogen</b> contamination from domestic animal excreta and carcasses</li> <li>• <b>Nutrients</b> from excreta originating from domestic animals</li> <li>• <b>Fuel and chemical spills</b> from vehicles and machinery.</li> </ul>	<p>Low</p> <p>Low</p> <p>Low</p>	<p>Minor pastoral activity (cattle) occurs in the south-eastern part of the proposed water reserve.</p> <p>Non-intensive pastoral activities are compatible with conditions in P1 areas in PDWSAs.</p>	<ul style="list-style-type: none"> <li>• water quality monitoring</li> <li>• land-use planning controls</li> <li>• water treatment (e.g. chlorination)</li> <li>• signage.</li> </ul>	<p>Maintain water quality monitoring program.</p> <p>Ensure stock is fenced well away from production bores.</p> <p>Maintain adequate stock watering points for grazing animals away from production bores.</p> <p>All bores to be constructed in accordance with <i>Minimum construction requirements for water bores in Australia</i> (National Uniform Drillers Licensing Committee 2012).</p>



## List of shortened forms

<b>ADWG</b>	<i>Australian drinking water guidelines</i>
<b>AHD</b>	Australian height datum
<b>ANZECC</b>	Australian and New Zealand Environment Conservation Council
<b>ARMCANZ</b>	Agriculture and Resource Management Council of Australia and New Zealand
<b>BGA</b>	Broome Groundwater Area
<b>DWSP</b>	drinking water source protection plan
<b>EC</b>	electrical conductivity
<b>GL</b>	gigalitre
<b>ha</b>	hectare
<b>HAZMAT</b>	hazardous materials
<b>kL</b>	kilolitre
<b>KLC</b>	Kimberley Land Council
<b>km</b>	kilometre
<b>km<sup>2</sup></b>	square kilometre
<b>LEMC</b>	local emergency management committee
<b>m</b>	metres
<b>m<sup>3</sup></b>	cubic metres
<b>mg/L</b>	milligram per litre
<b>mL</b>	millilitre
<b>ML</b>	megalitre
<b>mm</b>	millimetre
<b>MPN</b>	most probable number
<b>NHMRC</b>	National Health and Medical Research Council
<b>NRMMC</b>	Natural Resource Management Ministerial Council
<b>NTU</b>	nephelometric turbidity units

<b>P1</b>	priority 1
<b>P2</b>	priority 2
<b>P3</b>	priority 3
<b>PSC 88</b>	public sector circular number 88
<b>PDWSA</b>	public drinking water source area
<b>TCU</b>	true colour units
<b>TDS</b>	total dissolved solids
<b>TFSS</b>	total filterable solids by summation
<b>TPS</b>	town planning scheme
<b>WAPC</b>	Western Australian Planning Commission
<b>WAWA</b>	(Former) Water Authority of Western Australia
<b>WHPZ</b>	wellhead protection zone
<b>WESTPLAN- HAZMAT</b>	Western Australian plan for hazardous materials
<b>WQPN</b>	water quality protection note



# Glossary

<b>Abstract/abstraction</b>	The pumping of groundwater from an aquifer, or the removal of water from a waterway or water body.
<b>Adsorb</b>	Adsorb means to accumulate on the surface of something. For example, microorganisms can adsorb onto soil particles.
<b>Australian drinking water guidelines</b>	The <i>National water quality management strategy: Australian drinking water guidelines 6, 2004</i> (NHMRC & NRMMC 2004a) (ADWG) outlines acceptable criteria for the quality of drinking water in Australia (see this plan's Bibliography).
<b>Aesthetic guideline value</b>	The concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer, e.g. appearance, taste and odour (NHMRC & NRMMC 2004a).
<b>Australian height datum</b>	Australian height datum is the height of land in metres above mean sea level. For example, the AHD is +0.026 m at Fremantle.
<b>Allocation</b>	The quantity of water that a licensee is permitted to abstract is their allocation, usually specified in kilolitres per annum (kL/a).
<b>Aquifer</b>	An aquifer is a geological formation or group of formations able to receive, store and transmit significant quantities of water.
<b>Bore</b>	A bore is a narrow, lined hole drilled into the ground to monitor or draw groundwater (also called a well).
<b>Bore field</b>	A group of bores to monitor or withdraw groundwater is referred to as a bore field (also see <i>wellfield</i> ).
<b>Catchment</b>	The physical area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
<b>Colony forming units</b>	Colony forming units are a measure of pathogen contamination in water.
<b>Confined aquifer</b>	An aquifer that is confined between non-porous rock formations (such as shale and siltstone) and therefore contains water under pressure.
<b>Department of Environment and Conservation</b>	The Department of Environment and Conservation was established on 1 July 2006, bringing together the Department of Environment and the Department of Conservation and Land Management.

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<b>Effluent</b>	Effluent is treated or untreated liquid, solid or gaseous waste discharged by a process such as through a septic tank and leach drain system.
<b>Electrical conductivity</b>	This estimates the volume of TDS or the total volume of dissolved ions in a solution (water) corrected to 25°C. Measurement units include millisiemens per metre and microsiemens per centimetre.
<b>Gigalitre</b>	A gigalitre is equivalent to 1 000 000 000 litres or one million kilolitres.
<b>Hectare</b>	A measurement of area, equivalent to 10 000 square metres.
<b>Health guideline value</b>	The concentration or measure of a water quality characteristic that, based on current knowledge, does not result in any significant risk to the health of the consumer over a lifetime of consumption (NHMRC & NRMCC 2004a).
<b>Hydrocarbons</b>	A class of compounds containing only hydrogen and carbon, such as methane, ethylene, acetylene and benzene. Fossil fuels such as oil, petroleum and natural gas all contain hydrocarbons.
<b>Hydrogeology</b>	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
<b>Leaching/ leachate</b>	The process by which materials such as organic matter and mineral salts are washed out of a layer of soil or dumped material by being dissolved or suspended in percolating rainwater. The material washed out is known as leachate. Leachate can pollute groundwater and waterways.
<b>mg/L</b>	A milligram per litre (0.001 grams per litre) is a measurement of a total dissolved solid in a solution.
<b>Most probable number</b>	Most probable number is a measure of microbiological contamination.
<b>Nephelometric turbidity units</b>	Nephelometric turbidity units are a measure of turbidity in water.
<b>Nutrient load</b>	The amount of nutrient reaching the waterway over a given timeframe (usually per year) from its catchment area.
<b>Nutrients</b>	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.

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<b>Pathogen</b>	A disease-producing organism that can cause sickness and sometimes death through the consumption of water, including bacteria (such as <i>Escherichia coli</i> ), protozoa (such as <i>Cryptosporidium</i> and <i>Giardia</i> ) and viruses.
<b>Pesticides</b>	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
<b>pH</b>	A logarithmic scale for expressing the acidity or alkalinity of a solution. A pH below seven indicates an acidic solution and above seven indicates an alkaline solution.
<b>Pollution</b>	Water pollution occurs when waste products or other substances (effluent, litter, refuse, sewage or contaminated runoff) change the physical, chemical or biological properties of the water, adversely affecting water quality, living species and beneficial uses.
<b>Production bore</b>	An excavation/ structure to access groundwater for the purpose of drinking water (as opposed to other purposes such as exploration, investigation or monitoring).
<b>Public sector circular number 88</b>	A state government circular produced by the Department of Health providing guidance on appropriate herbicide use within water catchment areas.
<b>Public drinking water source area</b>	Includes all underground water pollution control areas, catchment areas and water reserves constituted under the <i>Metropolitan Water Supply Sewerage and Drainage Act 1909</i> and the <i>Country Areas Water Supply Act 1947</i> .
<b>Recharge</b>	Recharge is the action of water infiltrating through the soil/ground to replenish an aquifer.
<b>Recharge area</b>	An area through which water from a groundwater catchment percolates to replenish (recharge) an aquifer. An unconfined aquifer is recharged by rainfall throughout its distribution. Confined aquifers are recharged in specific areas where water leaks from overlying aquifers, or where the aquifer rises to meet the surface.
<b>Runoff</b>	Water that flows over the surface from a catchment area, including streams.
<b>Scheme supply</b>	Water diverted from a source or sources by a water authority or private company and supplied via a distribution network to customers for urban and industrial use or for irrigation.
<b>Stormwater</b>	Rainwater that has run off the ground surface, roads, paved areas etc., and is usually carried away by drains.

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<b>True colour units</b>	True colour units are a measure of degree of colour in water.
<b>Total dissolved solids</b>	Total dissolved solids consist of inorganic salts and small amounts of organic matter that are dissolved in water. Clay particles, colloidal iron and manganese oxides, and silica fine enough to pass through a 0.45 micrometer filter membrane can also contribute to total dissolved solids. Total dissolved solids comprise sodium, potassium, calcium, magnesium, chloride, sulfate, bicarbonate, carbonate, silica, organic matter, fluoride, iron, manganese, nitrate (and nitrite) and phosphate (NHMRC & NRMCC 2004a).
<b>Total filterable solids by summation</b>	Total filterable solids by summation is a water quality test which is a total of the following ions: Na (sodium), K (potassium), Ca (calcium), Mg (magnesium), Cl equivalent (chloride), alkalinity equivalent, SO <sub>4</sub> equivalent (sulfate) or S (sulfur) in grams, Fe (iron), Mn (manganese), and SiO <sub>2</sub> (silicon oxide). It is used as a more accurate measure than total dissolved solids (TDS). The higher the value, the more solids that are present and generally the saltier the taste.
<b>Transmissivity</b>	The rate at which water is transferred (transmitted) through an aquifer - a measure of the capability of an aquifer to transmit.
<b>Treatment</b>	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes, including drinking and discharge to the environment.
<b>Turbidity</b>	The cloudiness or haziness of water caused by the presence of fine suspended matter.
<b>Unconfined aquifer</b>	An aquifer in which the upper surface of water is lower than the top of the aquifer itself. The upper surface of the groundwater within the aquifer is called the watertable.
<b>Wastewater</b>	Water that has been used for some purpose and would normally be treated and discarded. Wastewater usually contains significant quantities of pollutant.
<b>Water quality</b>	Water quality is the collective term for the physical, aesthetic, chemical and biological properties of water.
<b>Water reserve</b>	A water reserve is an area proclaimed under the <i>Country Areas Water Supply Act 1947</i> (WA) or the <i>Metropolitan Water Supply Sewerage and Drainage Act 1909</i> (WA) for the purposes of protecting a drinking water supply.

<b>Watertable</b>	The upper saturated level of the unconfined groundwater is referred to as the watertable.
<b>Wellfield</b>	A wellfield is a group of bores located in the same area used to monitor or withdraw groundwater.
<b>Wellhead</b>	The top of a well (or bore) used to draw groundwater is referred to as a wellhead.
<b>Wellhead protection zone</b>	A wellhead protection zone (WHPZ) is usually declared around wellheads in public drinking water source areas to protect the groundwater from immediate contamination threats in the nearby area.



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