Government of **Western Australia**
Department of **Water**

Ledge Point Water Reserve

Drinking water source protection review

Ledge Point town water supply

Securing Western Australia's water future

Water resource protection series
Report WRP 155
November 2016

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Cover photograph: Aerial photograph of the Ledge Point Water Reserve

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Contents

Tables

Summary

This drinking water source protection review considers changes that have occurred in and around the Ledge Point Water Reserve since completion of the *Ledge Point water source protection plan* (Water and Rivers Commission 2000). Both of these documents are available on the Department of Water website or by contacting us.

Ledge Point is a small fishing and holiday town located on the Western Australian coast about 120 km north of Perth, in the Shire of Gingin (Figure A1). Water is supplied to the town by the Water Corporation from two bores which draw water from the superficial aquifer (Tamala Limestone). The aquifer is unconfined and considered vulnerable to contamination from surface land uses and activities.

The main risks to water quality within the Ledge Point Water Reserve are hydrocarbons and pathogens from the mixed business area, and hydrocarbons and chemicals from the limestone quarry and accidents on the main road (Figure A2).

We prepared this document in consultation with key stakeholders, including the Water Corporation and the Shire of Gingin.

The main changes since the 2000 plan are:

- industrial land uses have been established in the mixed business area, which is within the wellhead protection zones (WHPZs) of the production bores
- an updated risk assessment identifies rubbish dumps, fuel and chemical storage and general industrial activities within the WHPZs as having high management priorities
- an updated hydrogeological assessment by the Department of Water indicates that the immediate recharge area for the bore field extends northwards into privately owned rural land.

This review consolidates the ongoing recommendations from the 2000 plan with the following new recommendations:

- ensure fuels and chemicals are properly stored and disposed of within the mixed business area to prevent groundwater contamination
- encourage business operators and landowners in the mixed business area to implement best management practices to protect groundwater
- consider locating any new production bores to the south of the existing bore field and extending the boundary of the water reserve accordingly
- consider amending the boundary of the water reserve when production bore 2/89 has been relocated, based on hydrogeological modelling of the recharge area and consultation with the Shire of Gingin and landowners.

This review is consistent with the *Australian drinking water guidelines* (ADWG) (NHMRC & NRMMC 2011) and State planning policy no. 2.7: *Public drinking water source policy.*

The following table shows important information about the Ledge Point Water Reserve.

Key information about the Ledge Point Water Reserve	
Local government authority	Shire of Gingin
Location supplied	Ledge Point
Water service provider	Water Corporation
Aquifer type	Unconfined (vulnerable to surface-based contamination)
Licensed abstraction	120 000 kL per year
Number of bores	2
Bore names and GPS coordinates	1/89 (E 345 903.8, N 6 557 987.6, zone 50) 2/89 (E 345 867.9, N 6 558 173.9, zone 50)
Date of bore completion	1/89 – 20 July 1989 2/89 – 26 July 1989
Dates of drinking water source protection reports	2000 – *Ledge Point Water Reserve water source protection plan* 2013 – *Ledge Point Water Reserve drinking water source protection review* (this document)
Consultation	1996 – stakeholder and landowner consultation as part of the water source protection plan 2014 – consultation with key stakeholders including the Shire of Gingin and the Water Corporation
Proclamation status	Proclaimed on 16 January 2001 under the *Country Areas Water Supply Act 1947*

1 Review of Ledge Point's drinking water source protection plan

1.1 Boundary, priority areas and protection zones

The Ledge Point Water Reserve was proclaimed in 2001 under the *Country Areas Water Supply Act 1947*. This public drinking water source area (PDWSA) includes 500 m wellhead protection zones (WHPZs) around each of the two production bores and most of the PDWSA is managed as a priority 1 (P1) area. The industrial (mixed business) area is managed as a priority 3 (P3) area (Figure A1).

An updated hydrogeological assessment of the Ledge Point Water Reserve was undertaken in 2014 by the Department of Water. The assessment concluded that because the superficial aquifer comprises sand and limestone (fractured rock), it is likely to have a highly variable fracture flow system. This leads to some uncertainty regarding groundwater flow rates and flow paths.

The assessment showed that the recharge area for the bore field extends north-east, beyond the existing boundary of the water reserve and into Lot 520. This lot is privately owned, rural land that is currently undeveloped and covered by native vegetation.

The Department of Water recommends that the recharge area for existing and proposed production bores be defined by hydrogeological modelling. Modelling could be conducted when this review is next updated, or when planning is undertaken to relocate production bore 2/89. The boundary of the water reserve should then be reviewed based on the outcome of the hydrogeological modelling and consultation with the Shire of Gingin and landowner/s.

If you require more information about how we protect drinking water sources, please read Appendix E.

1.2 Update on water supply scheme

The Department of Water renewed Water Corporation's groundwater allocation licence no. 64870 in 2011. The licence allows the Water Corporation to draw up to 120 000 kL of water from the superficial aquifer (unconfined) each year to supply Ledge Point's drinking water from two production bores. This licence expires in 2015, when the Water Corporation may apply for a licence renewal.

The Ledge Point bore field consists of the two original production bores (1/89 and 2/89, see figures C1 and C2) which draw water from the unconfined superficial aquifer at a depth of between 33 m and 40 m. Water from the production bores is treated to reduce naturally occurring hardness, then pumped to an elevated tank. The water then undergoes chlorination to disinfect the water and ensure microbiological quality for consumers, before being distributed via gravity to the town scheme.

It should be recognised that although treatment and disinfection are essential barriers against contamination, PDWSA management is the first step in protecting water quality and ensuring a safe drinking water supply. This approach is endorsed by the *Australian drinking water guidelines* (ADWG) (NHMRC & NRMMC 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 a more reliable, safer and lower-cost drinking water to consumers than either approach could achieve individually.

For more information on why it is so important to protect our drinking water source areas, read Appendix D.

1.3 Update on the mixed business (industrial) area

The *Ledge Point Water Reserve water source protection plan* (2000) accepted that the Shire of Gingin had approved an unsewered industrial development within the WHPZs of the Ledge Point Water Reserve. The plan noted that the potential risks to groundwater quality were dependent upon the types of industry that would be established. The Water Corporation indicated that the closest production bore (2/89) would need to be relocated if contamination was detected.

The area was rezoned *mixed business* under the *Shire of Gingin Local Planning Scheme no.9* (Department of Planning 2012). The scheme sets a special control area over the entire Ledge Point Water Reserve – including the mixed business area – to ensure that land use and development considers the drinking water source. However, the water reserve is not identified in the Shire of Gingin's draft *Local planning strategy* (2010).

The industrial area is now developed, with only two vacant lots remaining (figures A2 and C4). The risks to groundwater from the current activities in the industrial area are described in section 1.7.3. The Water Corporation should ensure that the frequency of water quality monitoring is appropriate for the current risks to drinking water quality and the potentially short groundwater travel time to production bore 2/89.

If production bore 2/89 needs to be relocated in the future, the new bore should be placed in one of the following locations, depending upon water availability:

- north of the existing bore field, with the water reserve extended over private land on part of Lot 520 or
- south of the existing bore field, with the water reserve extended over Crown land.

1.4 Aboriginal native title claims

Native title is the recognition in Australian law that some Aboriginal people continue to hold native title rights to lands and water arising from their traditional laws and customs.

There is one native title claim within the Ledge Point Water Reserve; Yued (WAD6192/98).

The Department of Water is committed to working with Aboriginal people in its planning and management activities. The department recognises that native title is an important framework for water management.

1.5 Enforcing by-laws, surveying the area and maintenance

This review recommends that the Water Corporation continue by-law enforcement under the existing delegation arrangement. This also includes:

- erecting and maintaining signs in accordance with *S111 Source protection signage* (Water Corporation 2013)
- maintaining security and fencing surrounding the bore compounds and treatment compounds
- ongoing regular surveillance and inspections.

1.6 Other Department of Water work

The *Gingin groundwater allocation plan: for public comment* (Department of Water 2013) was released in August 2013. The allocation plan presents updated allocation limits and licensing rules designed to maintain the reliability of current groundwater entitlements. The limits and rules reduce the risks to the groundwater-dependent environment from abstraction. The Department of Water is currently developing the final allocation plan.

1.7 Update on water quality risks

As part of this review, we have conducted a new assessment of water quality contamination risks to the Ledge Point drinking water source, in accordance with the ADWG. Table 1 shows a summary of this risk assessment.

The bore field, drinking water treatment plant and the majority of the Ledge Point Water Reserve are located on Crown reserve (Figure A1). A relatively small area of privately owned land within a mixed business area is located within the WHPZs.

1.7.1 Limesand quarry

There is one limesand quarry within the Ledge Point Water Reserve (Figure A2). The quarry is located on Crown reserve vested with the Shire of Gingin, approximately 1 km up-gradient of the production bores.

The operator should implement best management practices to minimise the risks of groundwater contamination within the Ledge Point Water Reserve. These risks include fuel and lubricant leaks from heavy machinery and vehicles and fuel spills from fuel storage facilities and refuelling equipment.

1.7.2 Roads and tracks

The bore field is located near the main road into Ledge Point, with production bore 1/89 less than 60 m from the road (figures A1 and C3). The road has been built-up and appears to drain towards the production bores.

Accidents and spills of fuels, oils and chemicals pose a risk to drinking water quality. The short distance between the road and the production bores means that any spills will need to be contained and cleaned up promptly to prevent contaminants from reaching the bores.

There are several access tracks along the boundary of the water reserve and near the production bores, but there appears to be little off-road vehicle use within the broader water reserve. Unauthorised off-road vehicle use near the production bores poses a risk of hydrocarbon contamination from fuel or oil spills, leaks and accidents.

1.7.3 Mixed business area

Current activities in the P3 mixed business area include residential housing, storage units and warehouses, boat building, boat services and repairs, bulk garden supplies, laundry services, factories or workshops, offices and general light industrial activities.

A visual inspection of the mixed business area identified numerous risks to groundwater quality from hydrocarbon and chemical contamination. On-site dumps containing tyres, industrial materials, fuel drums, paint drums and chemical drums were observed. Fuel and chemical storage was observed on bare ground without measures to prevent or contain spills or leaks. Vehicles, motors, trucks, engines and other mechanical equipment were also observed in varying conditions of disrepair on bare ground. There are also risks of nutrient and pathogen leaching from septic tanks and from bulk mulch, compost and manure stockpiles if stored on bare ground.

Many of these risks can be managed by ensuring operators adopt best management practices to protect groundwater from contamination. This includes storing and disposing of hazardous substances appropriately (see our water quality protection note no. 65: *Toxic and hazardous substances - storage and use)*.

Street drainage from the mixed business area appears to be directed towards the bore field. Stormwater is infiltrated within the WHPZs via stormwater pits, posing a risk of hydrocarbon, chemical and heavy metal contamination of the groundwater. Modifying or upgrading the street drainage system to reduce this risk should be considered during future road works or retrofitting.

1.7.4 Other groundwater bores in the area

Bores drilled near a public drinking water supply bore (such as for irrigation or private purposes) can cause contamination of the drinking water source. For example, a poorly constructed bore may introduce contaminants from surface leakage down the outside of the bore casing into an otherwise uncontaminated aquifer.

It is therefore important to ensure that any bores are appropriately located and constructed to prevent contamination of the public drinking water source. This will be

assessed through Department of Water's water licensing process where applicable under the *Rights in Water and Irrigation Act 1914.* All bores should be constructed in accordance with *Minimum construction requirements for water bores in Australia* (National Uniform Drillers Licensing Committee 2012).

1.8 Water quality information

The Water Corporation has provided updated water quality information for the Ledge Point Water Reserve. This is shown in Appendix B.

Hardness and total filterable solids by summation (TFSS) have exceeded the ADWG's aesthetic values over the review period. Naturally occurring hardness is characteristic of the superficial aquifer in the area.

Microbial contaminants were detected in 1.5 per cent of samples during the review period. This indicates that while pathogen contamination may be possible, there are no existing pathogen issues in the water reserve.

Table 1 Summary of potential water quality risks, land use compatibility and best management practices

Land use/activity	**Hazard**	**Management priority**	**Comments**	**Best management practice guidance[1]**
Roads and tracks	Hydrocarbons and chemicals	Medium	Existing sealed roads are acceptable. There appears to be minimal off-road vehicle use in the water reserve. Erect signage along the boundary of the water reserve and at the start of actively used off-road vehicle tracks.	WQPN no. 44: *Roads near sensitive water resources*
Limesand quarry	Hydrocarbons	Medium	The quarry is located on Crown reserve.	WQPG no. 1: *Water quality management in mining and mineral processing: An overview* WQPN no. 15: *Extractive activities near sensitive water resources*

Land use/activity	Hazard	Management priority	Comments	Best management practice guidance[1]
Mixed business area - septic tanks - industrial activities and vehicles - fuel and chemical storage - on-site rubbish dumps - soil, compost or manure stockpiles	Pathogens, nutrients, hydrocarbons and chemicals	High	Risks could be managed by applying some simple best management practices. By-laws apply to industrial waste and waste disposal under the *Country Areas Water Supply Act 1947*. Encourage landowners and business operators to adopt best management practices to protect groundwater. Decommission production bore 2/89 if it becomes contaminated, and locate a replacement bore away from the mixed business area.	WQPN no. 65: *Toxic and hazardous substances - storage and use* WQPN no. 51: *Industrial wastewater management and disposal* WQPN no. 93: *Light industry near sensitive waters* WQPN no. 28: *Mechanical servicing and workshops* WQPN no. 90: *Organic material - storage and recycling* WQPN no. 56: *Tanks for elevated chemical storage* WQPN no. 61: *Tanks for ground level chemical storage* Australian Standard 3780: *The storage and handling of corrosive substances*

[1]Water quality protection notes (WQPNs) and water quality protection guidelines (WQPGs) are available http://drinkingwater.water.wa.gov.au

2 Implementation of Ledge Point's drinking water source protection plan

2.1 Status of previous recommendations

Table 2 outlines recommendations from the 2000 plan and their current status.

Table 2 Implementation status for the Ledge Point Water Reserve

No.	Recommendation	Comments
1	Gazette the water reserve.	Gazetted in 2001 under the *Country Areas Water Supply Act 1947.*
2	Incorporate the water reserve into land planning strategies.	*Shire of Gingin local planning scheme no. 9* (Department of Planning 2012) identifies the location of the Ledge Point Water Reserve through a special control area. Shire of Gingin's draft *Local planning strategy* needs to incorporate the Ledge Point Water Reserve (section 2.2, recommendation 1).
3	Refer development proposals which are likely to impact on water quality within the water reserve to the Department of Water (formerly Water and Rivers Commission).	Development proposals within the water reserve are referred to the Swan Avon Region office of the Department of Water. This is continued as a new recommendation in this review (section 2.2, recommendation 2).
4	Erect signs along the boundary of the water reserve.	Water Corporation signs are displayed on the bore compounds and drinking water treatment plant. Additional signs advising on the location of the Ledge Point Water Reserve should be erected near the mixed business area and along the boundary of the water reserve, especially at the start of actively used off-road vehicle tracks (section 2.2, recommendation no. 4).

No.	Recommendation	Comments
5	Emergency response: • Develop response plan. • Inform Westplan-HAZMAT (formerly WAHMEMS) personnel of special requirements for the Guilderton Water Reserve.	The Water Corporation has spill response procedures in place. This is continued as a new recommendation in this review (section 2.2, recommendation no. 3).
6	Establish a surveillance program to identify incompatible land uses or potential contamination threats within the water reserve.	The Water Corporation undertakes surveillance within the water reserve. This is continued as a recommendation of this review (section 2.2, recommendation no. 5).
7	Establish a monitoring program to detect any contamination to production bore 2/89 from the mixed business area.	The Water Corporation undertakes ongoing water quality monitoring for the bore field to ensure that any contaminants are identified. The Water Corporation determined that an additional monitoring bore was not required between the mixed business area and production bore 2/89. This review recommends that monitoring be continued (section 2.2, recommendation no. 5).
8	Future extension of the bore field should allow a 300 m up-gradient separation from the existing industrial subdivision and a 300 m buffer zone east of Old Ledge Point Road.	Extension of the bore field has not been necessary. An amended version is continued as a recommendation in this review (section 2.2, recommendation no. 8).
9	Review of the plan and recommendations.	Undertaken through the preparation of this review document.

2.2 Consolidated recommendations

Based on the findings of this review, the following recommendations will now be applied to the Ledge Point Water Reserve. The bracketed stakeholders are those expected to have a responsibility for, or an interest in, the implementation of that recommendation.

1. Incorporate the Ledge Point Water Reserve into the Shire of Gingin's draft *Local planning strategy*. (Shire of Gingin)
2. Refer development proposals within the Ledge Point Water Reserve that are inconsistent with the Department of Water's WQPN no.25: *Land use compatibility in public drinking water source areas* or recommendations in this review to the Department of Water regional office for advice. (Department of Planning, Shire of Gingin, proponents of proposals)
3. Ensure incidents covered by Westplan–HAZMAT in the Ledge Point Water Reserve are addressed by ensuring that:
    - the Shire of Gingin's LEMC is aware of the location and purpose of the Ledge Point Water Reserve
    - the locality plan for the Ledge Point Water Reserve is provided to the Department of Fire and Emergency Services headquarters for the HAZMAT emergency advisory team
    - the Water Corporation acts in an advisory role during incidents in the Ledge Point Water Reserve
    - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Ledge Point Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality. (Water Corporation)
4. Erect signs along the boundary of the Ledge Point Water Reserve including an emergency contact telephone number, in accordance with the Water Corporation's *S111 Source protection signage* (2013). Consider erecting additional signs at the entrance to the mixed business area to increase awareness of the need to protect groundwater in that area. (Water Corporation)
5. Water Corporation should continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. The water quality monitoring program should consider the existing risks from the mixed business area. (Water Corporation)
6. Ensure fuels and chemicals are properly stored and disposed of within the mixed business area to prevent groundwater contamination. (Department of Water and Shire of Gingin)
7. Encourage business operators and landowners in the mixed business area to implement best management practices for industrial activities to protect groundwater. (Department of Water and Shire of Gingin)

8. Any new production bores within the water reserve should be located at least 300 m up-gradient of the mixed business area. Consideration should be given to locating any new production bores south of the existing bore field if viable, and extending the boundary of the water reserve accordingly. (Water Corporation, Department of Water)
9. Review the boundary of the Ledge Point Water Reserve when this review is next updated or if planning is undertaken to relocate production bore 2/89. Any revisions to the boundary should be based on hydrogeological modelling of the recharge area for existing and future production bores and consultation with the Shire of Gingin and landowners. (Department of Water)
10. Update this review within seven years. (Department of Water)

Appendices

Appendix A — Figures

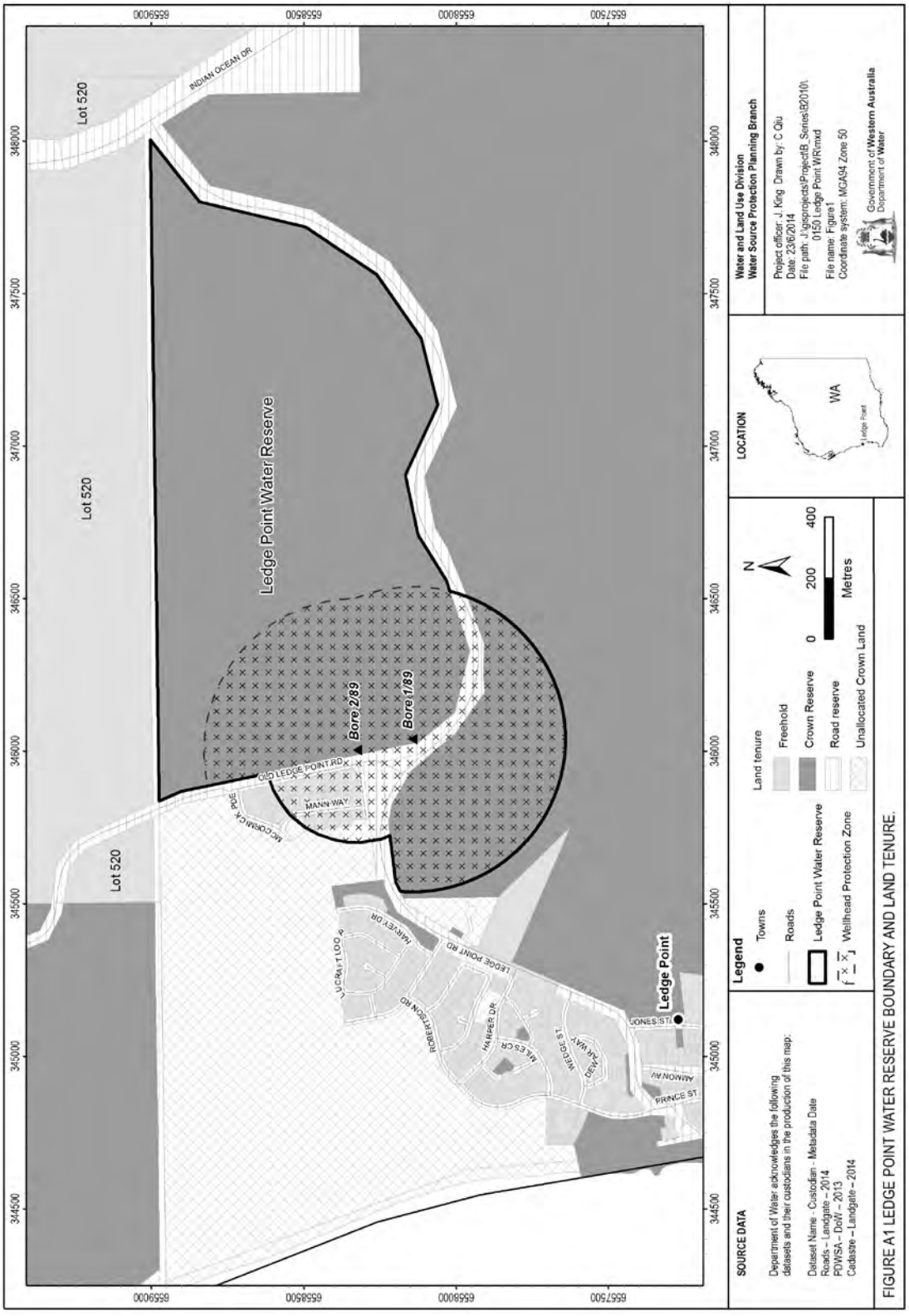

Figure A1 Ledge Point Water Reserve boundary and land tenure

Figure A2 Ledge Point Water Reserve aerial photograph showing land uses

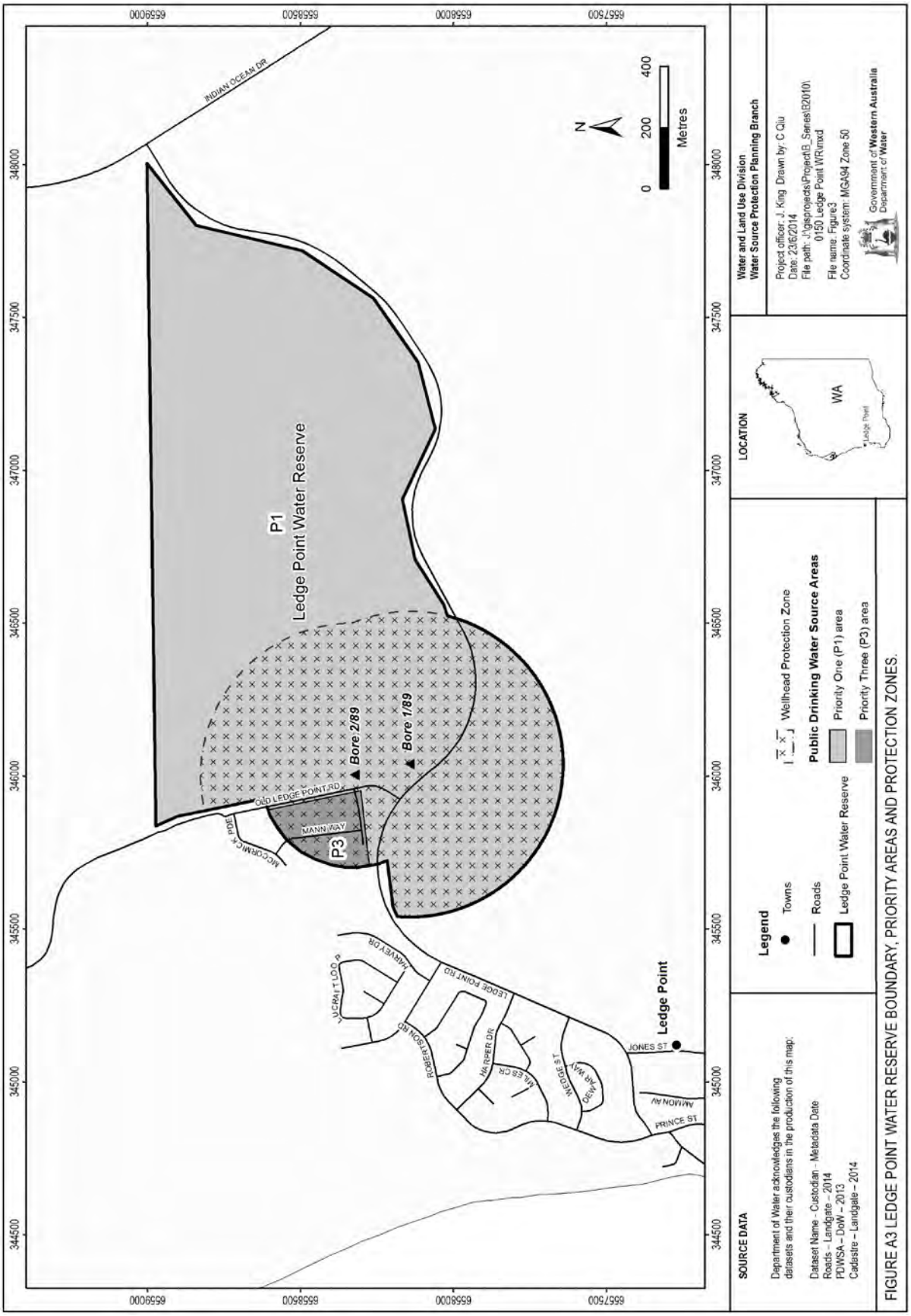

Figure A3 Ledge Point Water Reserve priority areas and protection zones (note, these remain the same as the 1999 plan)

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 Ledge Point in accordance with the requirements of the *Australian drinking water guidelines* (ADWG) (NHMRC & NRMMC 2011) and interpretations agreed to with the Department of Health. This data shows the quality of water in the catchment. The raw water is regularly monitored 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 Ledge Point bore field. 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 February 2009 to January 2014.

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 Ledge Point refer to the most recent Water Corporation drinking water quality annual report at www.watercorporation.com.au.

Aesthetic characteristics

The aesthetic quality analyses for raw water from Ledge Point bore field are summarised in the following table.

Aesthetic detections for Ledge Point

Parameter	**Units**	**ADWG aesthetic guideline value***	**Ledge Point bore field**	
			Range	**Median**
Chloride	250	mg/L	160–190	175
Copper	1	mg/L	0.01–0.012	0.011
Hardness as $CaCO_3$	200	mg/L	***240–260***	***260***
Iron unfiltered	0.3	mg/L	<0.003–0.025	0.006
pH measured in laboratory	8.5	NOUNIT	7.36–7.95	7.54
Silicon as SiO_2	80	mg/L	11–17	15
Sodium	180	mg/L	100–110	110
Sulfate	250	mg/L	36–39	37
Total filterable solids by summation (TFSS)	600	mg/L	***677–722***	***710***
Turbidity	5	NTU	<0.1–0.5	<0.1
Zinc	3	mg/L	<0.02–0.02	<0.02

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

Health-related chemicals

Raw water from Ledge Point 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 Ledge Point

Parameter	Units	ADWG health guideline value*	Ledge Point	
			Range	Median
Arsenic	mg/L	0.007	0.002–0.004	0.002
Barium	mg/L	0.7	0.04–0.04	0.04
Boron	mg/L	4	0.08–0.08	0.08
Chromium	mg/L	0.05	0.0006–0.0008	0.0007
Copper	mg/L	2	0.01–0.012	0.011
Fluoride laboratory measurement	mg/L	1.5	0.1–0.15	0.15
Nitrite plus nitrate as N	mg/L	11.29†	3.8–4.5	4.1
Radon-222	Bq/L	100	1.79–1.79	1.79
Sulfate	mg/L	500	36–39	37

* 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.

Microbiological contaminants

Microbiological testing of raw-water samples from Ledge Point bore field 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 reviewed period, positive *E. coli* counts were recorded in 1.5 per cent of samples.

Appendix C — Photographs

Figure C1 Production bore 1/89, photograph by J. King, Department of Water

Figure C2 Production bore 2/89, photograph by J. King, Department of Water

Figure C3 View of the main road from production bore 1/89, photograph by J. King, Department of Water

Figure C4 View of the mixed business area from production bore 2/89, photograph by J. King, Department of Water

Appendix D — Typical contamination risks in groundwater sources

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 runoff 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, resulting in illness, hospitalisation or even death. 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 & NRMMC 2011). Contaminants can also interfere with water treatment processes, and damage water supply infrastructure (such as iron corroding pipes).

The ADWG (NHMRC & NRMMC 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.

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 (for example *Salmonella*, *Escherichia coli* and cholera), protozoa (such as *Cryptosporidium* and *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 (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 & NRMMC 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.

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.

Chemical risks

Chemicals can occur in drinking water as a result of natural leaching from mineral deposits or from different land uses (NHMRC & NRMMC 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 (such as 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 & NRMMC 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.

Appendix E — How do we protect public drinking water source areas?

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

The catchment to consumer framework applies across the entire drinking water supply system – from the water source to the taps in your home. It ensures a holistic assessment of water quality risks and solutions to ensure the delivery of a reliable and safe drinking water to supply your home.

A preventive, risk-based approach means that we look at all the different risks to water quality. We determine what risks can reasonably be avoided and what risks need to be minimised or managed to protect public health. This approach means that the inherent risks to water quality are as low as possible. A multiple-barrier approach means that we use different barriers against contamination at different stages of a drinking water supply system.

The first and most important barrier is protecting the public drinking water source area (PDWSA) (the area from which water is captured to supply drinking water). If we get this barrier right, it has a flow-on effect that can result in a lower cost, safer drinking water supply. Other barriers against contamination include storage of water to help reduce contaminant levels, disinfecting the water (for example chlorination to inactivate pathogens), maintenance of pipes and testing of water quality. Another community benefit from PDWSA protection is that it complements the state's conservation initiatives.

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. We should not forget that ultimately it's about protecting your health by protecting water quality now and for the future.

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.

This drinking water protection report achieves elements 2 and 3 of the 12 elements in the ADWG recommended for protecting drinking water. It shows the PDWSA's location, its characteristics, existing and potential water quality contamination risks, and makes recommendations to deal with those risks.

The *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* provide us with important tools to protect water quality in proclaimed PDWSAs. These Acts allow us to assess and manage the water quality contamination risks from different land uses and activities. The department works

cooperatively with other agencies and the community to implement this legislation and develop drinking water source protection reports. For example, the Western Australian Planning Commission has developed a number of state planning policies to help guide development in public drinking water source areas.

An important step in maximising the protection of water quality in PDWSAs is to define their boundaries, priority areas and protection zones to help guide land-use planning and to identify where legislation applies. There are three different priority areas. The objective of priority 1 (P1) areas is risk avoidance – ensuring there is no degradation of the water quality (for example over Crown land). The objective of priority 2 (P2) areas is risk minimisation – maintaining or improving water quality (for example over rural-zoned land). The objective of priority 3 (P3) areas is risk management – maintaining the water quality for as long as possible (for example, urban- or commercial-zoned land). Protection zones surround drinking water abstraction bores and surface water reservoirs so that the most vulnerable areas are protected from contamination.

With 129 proclaimed PDWSAs across Western Australia, the department prioritises the update of drinking water source protection reports (such as this document). Our aim is to update each report every seven years. In some locations, more frequent updates may be required to address changing water quality risks and land uses. These updates allow us to make changes to the PDWSA boundary, priority areas and protection zones if required. They also allow solutions to new water quality risks to be considered.

There are three different types of drinking water source protection report – each providing for different needs. The following table shows the differences between the types of reports.

There is a fourth type of report – Land use and water management strategy – that performs the same functions as a drinking water source protection report. However, these strategies are prepared by the Western Australian Planning Commission (with input from the Department of Water) and are strategic documents that integrate land use planning with water management. There are currently land use and water management strategies for Gnangara, Jandakot and Middle Helena.

If you would like more information about the ADWG and how we protect drinking water in Western Australia, visit <http://drinkingwater.water.wa.gov.au> or refer to our Water quality protection note (WQPN) no. 36: *Protecting public drinking water source areas*. You can also contact the Department of Water's Water source protection planning branch on +61 8 6364 7600 or email drinkingwater@water.wa.gov.au.

Drinking water source protection reports produced by Department of Water

Drinking water source protection report	**Scope and outcome**	**Consultation**	**Time to prepare**	**Implementation table**	**Proclamation**
Drinking water source protection assessment (DWSPA)	Desktop assessment of readily available information.	Targeted	Up to 3 months	No	Proclamation to protect water quality and guide land use planning can occur as a result of any type of drinking water source protection report.
Drinking water source protection plan (DWSPP)	Full investigation of risks to water quality building on information in the DWSPA.	Public	6–12 months	Prepared from recommendations in the DWSPA and/or information from public consultation.	
Drinking water source protection review (DWSPR)	Review change in land and water factors and implementation of previous recommendations. Sometimes prepared to consider specific issues in a PDWSA.	Key stakeholders	Up to 3 months	Prepared from recommendations in the DWSPA or DWSPP.	

Appendix F — Understanding risks to drinking water quality

The existing integrated land use planning and public drinking water source area (PDWSA) protection program is based on the findings of three parliamentary committee reports in 1994, 2000 and 2010 (see *Further reading*). Since 1995, this integrated program has resulted in the development of four Western Australian Planning Commission state planning policies. These planning policies recognise the importance of PDWSAs for the protection of water quality and public health.

This integrated program relies upon a preventive and risk-based assessment process in each PDWSA through the development of drinking water source protection reports. It is important to understand how risks are assessed to appreciate the impact of development within PDWSAs.

Risk-based assessments normally focus on the acceptability of risks after mitigation (residual risks). For drinking water sources, a preventive risk base assessment that considers both the maximum and residual risks is required. This means that in some cases, the maximum risks from land uses will still be considered unacceptable, even after mitigation has reduced the risk. This is a more conservative approach needed to protect the health of consumers.

Water quality risks are evaluated by considering the type and scale of a potential contamination event (consequence), together with the probability/frequency of that event occurring (likelihood). An understanding of this relationship will prevent the common misunderstanding that probability equals risk (see risk matrix below).

For example, just because a drinking water contamination incident has not occurred for many years (low likelihood) does not mean that the risk is low, because we also need to consider the consequence of that contamination when determining risk. Further, no previous detection of contamination is not proof that the risk is acceptable.

Risk matrix: Level of risk (from the Australian drinking water guidelines *2011)*

Likelihood	**Consequences**				
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
Almost certain	Moderate	High	Very high	Very high	Very high
Likely	Moderate	High	High	Very high	Very high
Possible	Low	Moderate	High	Very high	Very high
Unlikely	Low	Low	Moderate	High	Very high
Rare	Low	Low	Moderate	High	High

List of shortened forms

ADWG	*Australian drinking water guidelines*
ANZECC	Australian and New Zealand Environment Conservation Council
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
HAZMAT	hazardous materials
kL	kilolitre
km	kilometre
LEMC	local emergency management committee
m	metres
mg/L	milligram per litre
mL	millilitre
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
PDWSA	public drinking water source area
TCU	true colour units
TDS	total dissolved solids
TFSS	total filterable solids by summation
WAHMEMS	Western Australian hazardous materials emergency management scheme (old name for Westplan–HAZMAT)
Westplan–HAZMAT	Western Australian plan for hazardous materials
WHPZ	wellhead protection zone
WQPG	water quality protection guideline
WQPN	water quality protection note

Glossary

Abstraction	The pumping of groundwater from an aquifer, or the removal of water from a waterway or water body.
Adsorb	Adsorb means to accumulate on the surface of something.
Aesthetic guideline value	The concentration or measure of a water quality characteristic that is associated with acceptability of water to the consumer, for example appearance, taste and odour (NHMRC & NRMMC 2011).
Allocation	Is the volume of water that a licensee is permitted to abstract, usually specified in kilolitres per annum (kL/a).
Aquifer	An aquifer is a geological formation or group or formations able to receive, store and transmit significant quantities of water.
Australian drinking water guidelines	The *National water quality management strategy: Australian drinking water guidelines 6*, 2011 (NHMRC & NRMMC 2011) (ADWG) outlines acceptable criteria for the quality of drinking water in Australia (see this plan's References).
Bore	A bore is a narrow, lined hole drilled into the ground to monitor or draw groundwater (also called a well).
Bore field	A group of bores to monitor or withdraw groundwater is referred to as a bore field (also see *wellfield*).
Catchment	The area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
Confined aquifer	An aquifer that is confined between non-porous rock formations (such as shale and siltstone) and therefore contains water under pressure.
Contamination	A substance present at above background concentrations that presents, or has the potential to present, a risk of harm to human health, the environment, water resources or any environmental value.
Drinking water source protection report	A report on water quality hazards and risk levels within a public drinking water source area; includes recommendations to avoid, minimise, or manage those risks for the protection of the water supply in the provision of safe drinking water supply.

Fractured rock	An aquifer where groundwater is present in the fractures, joints, solution cavities, bedding planes and zones of weathering igneous, metamorphic and deformed sedimentary rocks. Fractures rock aquifers are highly susceptible to contamination from land-use activities when aquifers crop-out or sub-crop close to the land surface.
Health guideline value	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 & NRMMC 2011).
Hydrocarbons	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.
Hydrogeology	The study of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Leaching/ leachate	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.
mg/L	A milligram per litre (0.001 grams per litre) is a measurement of something (such as salinity) in a solution.
Nutrients	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.
Pathogen	A disease-producing organism that can cause sickness and sometimes death through the consumption of water, including bacteria (such as *Escherichia coli*), protozoa (such as *Cryptosporidium* and *Giardia*) and viruses.
Pesticides	Collective name for a variety of insecticides, fungicides, herbicides, algicides, fumigants and rodenticides used to kill organisms.
pH	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.
Porosity	The state of quality of a material to be porous – that is permeable by water.

Public drinking water source area	The area from which water is captured to supply drinking water. It includes all underground water pollution control areas, catchment areas and water reserves constituted under the *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* or the *Country Areas Water Supply Act 1947*.
Recharge	Recharge is the action of water infiltrating through the soil/ground to replenish an aquifer.
Recharge area	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.
Scheme supply	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.
Total dissolved solids	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 & NRMMC 2011).
Total filterable solids by summation	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_4 equivalent (sulfate) or S (sulfur) in grams, Fe (iron), Mn (manganese), and SiO_2 (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.
Treatment	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes, including drinking and discharge to the environment.
True colour units	True colour units are a measure of degree of colour in water.
Turbidity	The cloudiness or haziness of water caused by the presence of fine suspended matter.

Unconfined aquifer	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. This is also known as a superficial aquifer.
Water quality	Water quality is the collective term for the physical, aesthetic, chemical and biological properties of water.
Water reserve	A water reserve is an area proclaimed under the *Country Areas Water Supply Act 1947* or the *Metropolitan Water Supply, Sewerage, and Drainage Act 1909* for the purposes of protecting a drinking water supply.
Wellhead	The top of a well (or bore) used to draw groundwater is referred to as a wellhead.
Wellhead protection zone	A wellhead protection zone is usually declared around wellheads in public drinking water source areas to protect the groundwater from immediate contamination threats in the nearby area.
Western Australian hazardous materials emergency management scheme	This is now known as Westplan–HAZMAT.

References

Department of Planning 2012, *Shire of Gingin Local Planning Scheme no.9*, District Zoning Scheme, September 2012, Department of Planning, Perth.

Department of Water 2013, *Gingin groundwater allocation plan: for public comment,* Water resource allocation and planning series, Report no. 53, Government of Western Australia, Perth, available www.water.wa.gov.au > publications > find a publication.

——2000, *Water quality protection guidelines* (WQPG) *No. 1 Water quality management in mining and mineral processing: An overview*, Government of Western Australia, Perth, available www.water.wa.gov.au > publications > series browse > water quality protection guidelines.

——*Water quality protection notes* (WQPNs), Government of Western Australia, Perth, available www.water.wa.gov.au > publications > series browse > water quality protection notes.

- 2004, WQPN no. 25: *Land use compatibility in public drinking water source areas*
- 2006, WQPN no. 44: *Roads near sensitive water resources*
- 2006, WQPN no. 56: *Tanks for elevated chemical storage*
- 2006, WQPN no. 65: *Toxic and hazardous substances - storage and use*
- 2008, WQPN no. 61: *Tanks for ground level chemical storage*
- 2009, WQPN no. 36: *Protecting public drinking water source areas*
- 2009, WQPN no. 51: *Industrial wastewater management and disposal*
- 2009, WQPN no. 93: *Light industry near sensitive waters*
- 2011, WQPN no. 90: *Organic material - storage and recycling*
- 2013, WQPN no. 15: *Extractive activities near sensitive water resources*
- 2013, WQPN no. 28: *Mechanical servicing and workshops*.

Government of Western Australia 1909, *Metropolitan Water Supply, Sewerage, and Drainage Act*, reprinted under the *Reprints Act 1984* as at 27 April 2008, State Law Publisher, Perth.

——1914, *Rights in Water and Irrigation Act*, Reprinted under the *Reprints Act 1984* as at 1 February 2008, State Law Publisher, Perth.

——1947, *Country Areas Water Supply Act*, reprinted under the *Reprints Act 1984* as at 4 May 2012, State Law Publisher, Perth.

——1972, *Aboriginal Heritage Act*, reprinted under the *Reprints Act 1984* as at 18 September 2010, State Law Publisher, Perth.

National Health and Medical Research Council (NHMRC) & Natural Resource Management Ministerial Council (NRMMC) 2011, National Water Quality Management Strategy: *Australian drinking water guidelines*, Australian Government, Canberra.

National Uniform Drillers Licensing Committee 2012, *Minimum construction requirements for water bores in Australia,* 3rd edn, Australian Government National Water Commission, Braeside, Victoria, available www.water.wa.gov.au/PublicationStore/first/102386.pdf.

Robertson, JB & Edbery, SC 1997, *Natural protection of spring and well drinking water against surface microbial contamination. I. Hydrogeological parameters*, Critical Reviews in Microbiology, vol. 23(2), pp. 143 – 178.

Shire of Gingin 2010, draft *Local planning strategy*, Shire of Gingin, available at www.gingin.wa.gov.au/index.php/the-council-and-policies/town-planning/local-planning-strategy.

Standards Australia 3780 *The storage and handling of corrosive substances,* available infostore.saiglobal.com/store/Details.aspx?ProductID=1092991.

Water and Rivers Commission 2000, *Ledge Point Water Reserve water source protection plan*, Water and Rivers Commission, Water resource protection series No WRP 25, Government of Western Australia, Perth, available www.water.wa.gov.au > publications > series browse > water resource protection plan.

Water Corporation 2013, *S111 Source protection signage,* unpublished corporate standard, Water Corporation, Leederville.

Western Australian Planning Commission 2003, State planning policy no. 2.7: *Public drinking water source policy*, Government Gazette Western Australia, 10 June 2003, pp. 2077-82, Government of Western Australia, Perth.

Further reading

Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) & Australian and New Zealand Environment and Conservation Council (ANZECC) 1996, *Draft rural land uses and water quality – A community resource document*, ARMCANZ & ANZECC, Canberra.

Board M (MLA Member for Jandakot and Chairman of the Select Committee) 1994, *The Select Committee on Metropolitan Development and Groundwater Supplies – Report*, Legislative Assembly, Perth, Western Australia.

Department of Health 2007, *Use of herbicides in water catchment areas*, Circular no: PSC 88, February 2007, Government of Western Australia, Perth.

——2013, *A guide to the use of pesticides in Western Australia – Providing information on legislation, policies and best practice,* Government of Western Australia, Perth, available www.public.health.wa.gov.au/3/1139/2/pesticide_use.pm.

Department of Water & Department of Health 2008, *Risks from pathogenic micro-organisms in public drinking water source areas*, Government of Western Australia, Perth.

Department of Water 2011, *Living and working in public drinking water source areas,* Government of Western Australia, Perth,

——2012, Operational policy no.13: *Recreation within public drinking water source areas on Crown land*, Government of Western Australia, Perth.

Government of Western Australia 2007, *State water plan 2007*, Department of the Premier and Cabinet, Perth.

Hrudey, SE & Hrudey, EJ 2004, *Safe drinking water – Lessons from recent outbreaks in affluent nations,* IWA Publishing, London.

National Health and Medical Research Council (NHMRC) & Natural Resource Management Ministerial Council (NRMMC) 2004, W*ater made clear – A consumer guide to accompany the Australian drinking water guidelines 2004,* Australian Government, Canberra.

Sharp Hon C (MLC and Chairman of the Standing Committee) 2000, Report of the Standing Committee on Ecologically Sustainable Development in relation to the quality of Perth's water supply, Legislative Council, Perth, Western Australia.

Standing Committee on Public Administration, 2010, *Report 11: Recreation activities within public drinking water source areas,* Legislative Council, Perth, available www.parliament.wa.gov.au.

State Emergency Management Committee 2005, Policy statement no. 7: *Western Australian emergency management arrangements,* Government of Western Australia, Perth.

Water Corporation 2006, *SG097 Source protection operations manual*, Water Corporation, Perth.

Western Australian Planning Commission 1997, *State planning strategy*, Government of Western Australia, Perth.

——2006, State planning policy no. 2.9: *Water resources*, Government Gazette Western Australia, 19 December 2006, pp. 5707-22 Government of Western Australia, Perth.

World Health Organization 2004, *Guidelines for drinking-water quality – Volume 1 – Recommendations*, 3rd edn, World Health Organization, Geneva.

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