



Yule River Water Reserve

drinking water source protection review



Port Hedland Regional Water Supply

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Port Hedland Regional Water Supply

Department of Water and Environmental Regulation

Water resource protection series

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Cover photograph: Aerial photo of Yule River Water Reserve area, using Landgate data

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Summary

This drinking water source protection review considers changes that have occurred in and around the Yule River Water Reserve since completion of the *Yule River Water Reserve water source protection plan* (WRC 2000). It should be read in conjunction with the 2000 plan. Both of these documents are available on our website or by contacting us (see details on the inside cover of this report).

The Yule River Water Reserve is located in the Port Hedland region, which is the coastal gateway and service hub to some of the world's richest resource deposits of iron ore.

Since the 2000 plan, a groundwater model for the lower Yule River has been completed. Based on this modelling and new information, this review proposes a change to the existing Yule River Water Reserve boundary. This proposed change has been consulted. It will not introduce new land use restrictions in the area because mining and pastoral leases are compatible with conditions in the Yule River Water Reserve.

Water Corporation supplies water to the Port Hedland region via the Port Hedland Regional Water Supply, using the Yule River Water Reserve and the De Grey River Water Reserve. The De Grey River Water Reserve is subject to a separate drinking water source protection report, available at www.dwer.wa.gov.au (DWER 2018).

The Yule bore field is approximately 45 km west of Port Hedland. Water from this reserve is abstracted from a shallow alluvial aquifer beneath the Yule River. The aquifer is semi-confined (in the areas where clay lenses occur) which makes it vulnerable to contamination from surface based land uses. The entire water reserve has been assigned a priority 1 (P1) area to protect its water quality. The proposed water reserve overlies government and Water Corporation land.

We prepared this document in consultation with key stakeholders – pastoral lease holders, the Water Corporation and the Town of Port Hedland.

This review is consistent with the *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011) and State planning policy no. 2.7: *Public drinking water source policy* (WAPC 2003).

Table 1 shows important information about the Yule River Water Reserve.

Table 1 Key information about the Yule Water Reserve

Yule River Water Reserve	
Status of this report	This report is based on information from the 2014–15 financial year. Public drinking water source area boundaries, priority areas, bore locations, wellhead protection zones and other data may be subject to change. For up-to-date information, please email drinkingwater@dwer.wa.gov.au .
Local government authority	Town of Port Hedland
Locations supplied	Port Hedland Regional Water Supply (Port Hedland, South Hedland, Wedgefield, Finucane Island and Nelson Point)
Water service provider	Water Corporation
Aquifer type	<p>Shallow – during floods the watertable can meet ground surface.</p> <p>Semi-confined where silty clay is present below the watertable.</p> <p>Both these aquifers are vulnerable to contamination from surface-based activities.</p>
Licence from DWER to take water	GWL65501, issued to Water Corporation under the <i>Rights in Water and Irrigation Act 1914</i>
Number of bores	10 production bores with three more planned
Bore names and GPS coordinates	<p>1/96 E 635065 N 7720855 zone 50</p> <p>2/96 E 633462 N 7720968 zone 50</p> <p>3/96 E 634975 N 7721954 zone 50</p> <p>5/96 E. 629746 N 7726997 zone 50</p> <p>7/96 E 627602 N 7726300 zone 50</p> <p>11/96 E 625818 N 7728091 zone 50</p> <p>12/96 E 624392 N 7728815 zone 50</p> <p>13/96 E 623339 N 7728459 zone 50</p> <p>15/96 E 631197 N 7726279 zone 50</p> <p>16/96 E 621922 N 7729185 zone 50</p> <p>(Bore data from Water Corporation)</p>

Yule River Water Reserve	
Dates of drinking water source protection reports	<p>2000 – <i>Yule River Water Reserve water source protection plan</i> (Water and Rivers Commission)</p> <p>2018 – <i>Yule River Water Reserve drinking water source protection review</i> (this document)</p>
Consultation	<p>Mail out and consultation with key stakeholders: Water Corporation, pastoral lease holders, Port Hedland Council.</p> <p>No changes are proposed in this review that would restrict existing, approved land uses.</p>
Proclamation status/history	<p>Proclaimed in 1970 under the <i>Country Areas Water Supply Act 1947</i>.</p> <p>Updated and proclaimed in 2001, following publication of the <i>Yule River Water Reserve water source protection plan</i> (2000), to reflect extension of the bore field.</p> <p>This review proposes a new water reserve boundary based on modelling and new information.</p>
Key reference documents	<p><i>Australian drinking water guidelines</i> (NHMRC & NRMMC 2011)</p> <p>State planning policy no. 2.7: <i>Public drinking water source policy</i> (WAPC 2003)</p> <p>Pilbara groundwater allocation plan (DoW 2012)</p>

1 Review of Yule River Water Reserve water source protection plan

1.1 Boundary, priority areas and protection zones

Since publication of the *Yule River Water Reserve water source protection plan* (WRC 2000) a number of investigations and publications about the Yule River Water Reserve have been completed.

The changes to the water reserve boundary proposed in this review (Figure A2) are based on a groundwater model of the lower Yule River aquifer developed by MWH engineering consultants (2010). The model used information from hydrogeological and geophysical investigations, including:

- aerial geophysics and LiDAR surveys
- drilling and pump tests
- streamflow
- groundwater data mostly from monitoring bores but also other bores in the vicinity
- surface water levels collected at the ecologically and culturally significant Li Lin Pool
- rainfall data and bore field abstraction volumes.

Recent work underpinning this water source protection review includes an assessment of the Lower De Grey and Yule aquifers and redefinition of the boundaries to better reflect the local hydrogeology (DoW 2012a, 2013a).

Confining layers are discontinuous across the Lower Yule aquifer within the proposed water reserve where clay lenses occur. The semi-confined aquifer is vulnerable to contamination from inappropriate land uses and was therefore assigned a priority 1 (P1) area.

The greatest source of the Yule aquifer's recharge is the flooding and streamflow of the Yule River and its tributaries (Figure A2). Recharge occurs directly by infiltration from the river. Rainfall associated with summer cyclones and autumn thunderstorms is highly episodic and variable between years.

The proposed water reserve occurs over non-intensively used land: Crown land (leases and reserves), land used for other government purposes such as roads and rest stops and Water Corporation managed land (figures A2 and A3). DWER will arrange proclamation of the proposed boundary change under the *Country Areas Water Supply Act 1947*. The whole water reserve remains a P1 area with a 500 m radius for wellhead protection zones around each production bore (Figure A4).

1.2 Update on water supply scheme

The *Pilbara regional water supply strategy: a long-term outlook of water demand and supply* (DoW 2013) discusses upgrades being made to the Port Hedland Regional Water Supply Scheme. This scheme, operated by the Water Corporation, supplies customers in:

- Port Hedland
- South Hedland
- Wedgefield
- Finucane Island
- Nelson Point.

The scheme is currently supplied with groundwater from two independent sources; the lower De Grey River and Yule River bore fields.

The Port Hedland region is the coastal gateway and service hub to some of the world's richest resource deposits of iron ore. It is targeted as an area for growth within the state and is an important component of Government's *Pilbara Cities* initiative (Department of Regional Development and Lands 2010 and Water Corporation 2012b).

Because of projected increases in water demand, there has been considerable investment in water assets and projects in the North West to support the *Pilbara Cities* initiative and in assessing Pilbara groundwater, especially the yield of critical public water supply aquifers. Some of the recent studies are discussed in Table 2. Water Corporation is considering an expansion to the Yule bore field, initially with three additional bores.

Groundwater abstraction in the Pilbara Region is managed under the proclaimed *Pilbara groundwater area* and a licence is required to take groundwater. The Water Corporation's groundwater allocation was increased in 2012 via licence no. 65501, which allows the Corporation to draw up to 10.5 GL of water per year from the Yule bore field to supply Port Hedland.

Abstracted water is stored by Water Corporation in bore field tanks then transferred to other bulk storage tanks in South Hedland, the port area and on Finucane Island. The water from the wellfield is treated by chlorination prior to supply to the public.

It should be recognised that although treatment and disinfection are essential barriers against contamination, public drinking water source area (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 & 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 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 catchments, read Appendix E.

1.3 Aboriginal sites of significance and native title claims

Aboriginal sites of significance are important places with special cultural connections to Aboriginal people. They are important because they link Aboriginal cultural tradition to place, land and people over time. These sites are integral to the lives of Aboriginal people, and are found in urban, rural and remote areas. They are most common near rivers, lakes, swamps, hills and coast. The *Aboriginal Heritage Act 1972* aims to protect all Aboriginal places and objects that are culturally important to Aboriginal people. It is against the law to disturb a site or to remove artefacts. This, however, is at the discretion of the Minister.

There are a number of recorded sites of significance and heritage places within the Yule River Water Reserve. Our *Ecological water requirements of the Yule River aquifer* (Brambridge 2010) discusses the Aboriginal groups for whom the Yule River's pools hold significance, and their use for activities such as fishing and swimming.

There are 16 Aboriginal sites of significance recorded within the proposed Yule River Water Reserve (see Figure A5). It is important to note that not all Aboriginal sites of significance and heritage have been recorded and are on the register of Aboriginal sites. As such, it is important that traditional custodians are always consulted in regards to their country.

Native Title is the recognition in Australian law that some Aboriginal people continue to hold native title rights and interests in lands and waters.

The Yule River Water Reserve lies within the Kariyarra People claim area (WC1999/003, see Figure A5).

DWER is committed to working with Aboriginal people in its planning and management activities. DWER recognises that native title is an important framework for water management.

1.4 Enforcing by-laws, surveying the area and maintenance

This review recommends that the Water Corporation continue by-law enforcement under the existing delegation arrangement (see section 2.2, recommendation no. 6). This includes:

- erecting and maintaining signage
- maintaining security and fencing surrounding production bores
- ongoing regular surveillance and inspections.

1.5 Other Department of Water and Environmental Regulation work

Since publication of the *Yule River Water Reserve water source protection plan* (WRC 2000), several investigations and publications about the water resources in the area have become available. Some of the Pilbara studies produced during this prolific period have already been referred to previously, others are listed in Table 2.

Table 2 Summary of publications and investigations relating to local water resources

Author, date	Report	Details
Ruprecht J and Ivanescu (for WRC) 2000	<i>Surface hydrology of the Pilbara region</i>	Provided a regional review of the groundwater and surface water resources.
Johnson and Wright (for WRC) 2001	<i>Central Pilbara groundwater study</i>	
MWH Australia 2010	<i>Development of a subregional scale numerical groundwater model of the lower Yule catchment</i>	Investigation co-funded by DoW, Government of Western Australia, Perth; and the Australian Government's <i>Water for the Future</i> program (Department of Water 2011 discusses the investigations). Groundwater model development to predict groundwater conditions, the future effect of bore pumping rate.
Economic Consulting Services 2007	<i>Prospective demand for water in the west Pilbara of WA</i>	Commissioned by DoW to develop estimates of current and future water usage in the Pilbara, for use in regional water planning processes and the various uses of water by the mining industry.
Fugro 2009	<i>De Grey and Yule: Falcon airborne gravity gradiometer and magnetic geophysical survey</i>	Geophysical studies contracted by the department.
DoW 2011	<i>Hydrogeological investigations of Pilbara groundwater resources</i>	Discussed the parameters measured and used for assessing the hydrogeology of the Yule aquifer.

Author, date	Report	Details
Haig 2009	<i>The Pilbara coast water study</i>	Prepared for DoW. Discussed the need to set sustainable yields for the Yule and De Grey Rivers' bore fields. Reviewed pre-2009 investigations, includes discussion of Sinclair Knight Merz's 2011 study of hydraulic conductivity from pumping tests; and investigations by WorleyParsons (2003 and 2005) for the Water Corporation. Discusses risk management.
Antao 2013	Monitoring program to support the Pilbara groundwater allocation plan	Discusses the various users of the aquifer and the responsibility of the department and licensees to ensure that the resources are managed so that groundwater productivity, water quality and dependent values are maintained into the future.
DoW 2010b	<i>Pilbara regional water plan 2010–2030</i>	Sets the strategic direction for the management and sustainable development of the region's water resources. Commitments to residential and industrial growth in Port Hedland require an increasing water supply through developing new water sources and expanding existing water sources.
DoW 2013b	<i>Western Australian water in mining guideline</i>	Potential effects of mining on water resources and best practice guidance were discussed in these reports prepared for DoW. Mining projects in the Pilbara can have a significant effect on groundwater and surface water, particularly where mining occurs below the watertable or there is a risk of salinisation.

1.6 Update on water quality risks

As part of this review, DWER has conducted a new assessment of water quality contamination risks to the Yule River Water Reserve, in accordance with the ADWG. Table 3 includes risks that are still considered significant.

Refer to Appendix D for information about typical contamination risks in PDWSAs, and Appendix F to gain a greater understanding about the risk assessment process we use.

The main contamination risks to the Yule River Water Reserve are from activities in close proximity to the bore field: recreation, infrastructure, mining activities and stock grazing. These are outlined in more detail below.

1.6.1 Land tenure

The proposed water reserve is over Government or Water Corporation land (Figure A3). The bore field is on Crown Reserve 33015, vested with DWER for the purpose of water supply. Mundabullangana and Indee Stations are two pastoral Crown leases that overlap much of the water reserve. A stock route (Crown reserve 9701) crosses the north of the water reserve.

The present non-intensive pastoral land use is considered to be compatible in P1 areas. It is recommended that all drinking water extraction bores be protected from stock access, in fenced compounds.

1.6.2 Flooding

There is active interaction between surface water and groundwater in the Pilbara region, especially on the coastal plain where there is significant recharge from rivers into the groundwater systems. This interaction occurs as recharge to the alluvial groundwater systems underlying most of the coastal plain. The area is prone to cyclones and flood inundation which necessitates infrastructure repairs (figures C2, C3 and C6). Flooding could lead to more rapid and further distribution of contaminants in the water reserve, via surface runoff and alluvial groundwater flow.

1.6.3 Infrastructure

The Yule River alluvial aquifer has the potential to be contaminated with hydrocarbons and chemicals from several sources including spillage of contaminants along the Great Northern Highway, gas transmission pipelines and power lines that traverse the water reserve close to the production bores. Other infrastructure within the water reserve includes roads and tracks and water supply infrastructure.

1.6.4 Recreation

Recreation activities within the water reserve are well publicised, including picnicking, fishing and camping (Figures C3 to C6). Cooking on open fires can increase the risk of fire within the water reserve.

Recreation websites promote the Yule River location as being free and dog-friendly, with many camp sites suitable for overnight stays, including some with drop toilets. A Main Roads picnicking area (Figure C5) includes drum rubbish bins and dump site facilities for the disposal of sewage. The Yule River flows through many semi-permanent pools of water on the way to the coast – some are popular swimming spots. During the dry season, camping occurs in the dry river bed as well.

Water quality risks from recreation include:

- pathogens from body contact with the water

- toilets and pet faeces
- nutrients from onsite wastewater treatment systems and rubbish
- hydrocarbons from vehicles.

Main Roads manages the Northwest Coastal Highway. There are tracks leading from the highway to riverine picnic spots.

All recreational activities within this water reserve should be guided by the *Operational policy 13: Recreation within public drinking water source areas on Crown land* (DoW 2012b).

1.6.5 Mining

The proposed water reserve overlies more than 20 mining tenements and mines (see Figure A6). The area is a significant source of iron ore. Gold, construction material (gravel and clay), gems and semi-precious stones have also been mined. The Department of Mines, Industry Regulation and Safety is the custodian of mining information and up-to-date information can be found on their website.

Mining operations abstract groundwater for mine dewatering, dust suppression, wash-down of equipment and mineral processing. The dewatering discharge is often used in mineral processing or released at controlled points into downstream riverine drainages (WAPC 2011, WRC 2001).

Key areas for water management in the mining industry include preventing potential contamination of local water resources, and addressing concerns about potential long-term impacts of mine voids, which may include the development of hyper-saline lakes. Contamination risks at mine sites include:

- pathogens associated with human waste
- chemical contamination such as hydrocarbons and chemicals associated with:
 - vehicle and mobile plant refuelling
 - mining equipment and infrastructure leaks or repairs
 - mine void acidification
 - herbicides from weed spraying along edges of infrastructure such as roads and train line
 - chemical storage
 - wash down of mine equipment
 - landfill
 - exploration activities.

All mining activities within the water reserve are compatible with conditions and are guided by best practice management.

1.6.6 Bores and groundwater contamination

Bores drilled near a drinking water production bore (which may be used 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 DWER'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).

The De Grey and Yule alluvial aquifers are close to the coast (Figure A2) and hence could be influenced by seawater intrusion (especially Yule, which has a less reliable recharge). The position of the seawater interfaces remain relatively stable but can move inland into the aquifers if groundwater flow declines due to over-abstraction or failed recharge. Ongoing monitoring of water quality is required to manage potential movement of the seawater interface. The effects on water quality along the sides of the aquifer are considered a short- to medium-term issue that will need monitoring and management.

Table 3 Summary of potential water quality risks, land use compatibility and best management practices

Land use/activity	Hazard ²	Management priority	Comments	Best management practice guidance ¹
Recreation (camping, picnicking, fishing and swimming in river and pools)	Pathogens, nutrients, hydrocarbons herbicides and pesticides Increased risk of fires Other risks to riverine vegetation buffer	Medium	May attract feral animals such as pigs. Main Roads clears rubbish bins at picnicking area. Fenced bore compounds. Sign and locked gate to bore field.	Operational policy no. 13: <i>Recreation within public drinking water source areas on Crown land</i> (DoW 2012b)
Mining	Hydrocarbons, chemicals and pathogens	Medium	Mining occurs mostly in the west of the water reserve. Mining in the water reserve is considered compatible with conditions. HAZMAT emergency response is in place. Discoloured liquids flowing from	<i>Western Australian water in mining guideline</i> (DoW 2013b) Water quality protection guidelines 1-11: <i>Water quality management in mining and mineral processing</i> Water quality protection notes (WQPNS): <ul style="list-style-type: none"> • WQPN 5: <i>Toxic and hazardous substances: storage and use</i> • WQPN 15: <i>Extractive industries near sensitive water resources</i> • WQPN 25: <i>Land use compatibility in public PDWSAs</i> • WQPN 26: <i>Liners for containing pollutants using synthetic membranes</i> • WQPN 28: <i>Mechanical servicing and workshops</i>

Land use/activity	Hazard ²	Management priority	Comments	Best management practice guidance ¹
			<p>deposited material have been reported.</p> <p>Ongoing Water Corporation surveillance and water quality monitoring (see Appendix B for water quality data).</p>	<ul style="list-style-type: none"> • WQPN 68: <i>Mechanical equipment wash down</i> • WQPN 84: <i>Rehabilitation of disturbed land in PDWSAs</i> • Several WQPNs supply guidance for chemical storage, see WQPN 56, 58, 60, 61, 62 or 64, depending on the storage type. <p>State wide policy no. 1: <i>Policy and guidelines for construction and silica sand mining in PDWSA</i></p>
Pastoral station and stock route	<p>Pathogens and nutrients from livestock waste</p> <p>Hydrocarbons and chemicals</p>	Medium/Low	<p>Non-intensive pastoral activities are compatible with conditions in a P1 area.</p> <p>Cattle have access to the river.</p> <p>Production bore locations should be fenced.</p>	<p>WQPN 25: <i>Land use compatibility in PDWSAs</i></p> <p>WQPN 35: <i>Pastoral activities within rangelands</i></p> <p>WQPN 96: <i>Pest animal management in PDWSA</i></p> <p>Public sector circular (PSC) no. 88: <i>Use of herbicides in water catchment areas</i> (Department of Health 2007)</p> <p><i>A guide to the use of pesticides in Western Australia – Providing information on legislation, policies and best practice</i> (Department of Health 2013)</p>

¹Water quality protection notes (WQPNs) are available www.dwer.wa.gov.au or see *Further reading*.

²Information on the hazards associated with each land use activity is detailed further within Appendix D.

1.7 Water quality information

The Water Corporation has provided updated water quality information for the Yule River Water Reserve water supply. This is shown in Appendix B.

Some samples indicated arsenic levels approaching the ADWG health guideline value. Several positive *Escherichia coli* counts were recorded. However, it should be noted that Water Corporation treats the raw water to meet acceptable drinking water quality before it is delivered to consumer's homes.

2 Implementation of Yule River Water Reserve's drinking water source protection plan

2.1 Status of previous recommendations

Table 4 outlines recommendations from the drinking water plan published in 2000, and their current status.

Table 4 Implementation status for Yule River Water Reserve

No.	Recommendation	Comments
1	Gazettal of water reserve.	Gazetted in 2000 and updated in 2001 under the <i>Country Areas Water Supply Act 1947</i> .
2	Investigate amendment of the boundary of the Turner River Water Reserve in consultation with key stakeholders.	This option is not being pursued and the Turner River Water Reserve has been abolished.
3	Incorporate water reserve boundary and its protection into land planning strategies.	The existing water reserve has not been incorporated as a special control area in the Shire of Port Hedland's local planning scheme. This is carried forward as a new recommendation in this review (Section 2.2).
4	Referral of development proposals: <ul style="list-style-type: none"> • WRC (now DWER) to provide the Shire of Port Hedland with guidelines for referral of development proposals. • Referral of development proposals. 	Guidelines have been provided through DWER water quality protection notes. This is carried forward as a new recommendation in this review (Section 2.2).
5	Erection of signs: <ul style="list-style-type: none"> • development of guidelines for signage • determine number and location of signs required • erect signs. 	There is a sign advising the location of the Yule River Water Reserve. This is carried forward as a new recommendation in this review (Section 2.2).

No.	Recommendation	Comments
6	Emergency response: <ul style="list-style-type: none"> • develop response plan • inform WAHMEMS personnel of special requirements for the Yule River Water Reserve. 	Emergency response protocols have since changed to Westplan-HAZMAT and the local emergency management committee (LEMC). This is carried forward as a new recommendation in this review (Section 2.2).
7	Surveillance program: <ul style="list-style-type: none"> • develop guidelines for the surveillance of water reserves • implement a surveillance program. 	Water Corporation undertakes surveillance within the water reserve. This is carried forward as a new recommendation in this review (Section 2.2).
8	Investigate contamination risks to aquifers recharged from river flows	See studies listed in Table 2. Risks that were identified are discussed in this review.
9	Fencing of re-equipped bores and regular maintenance of existing fenced bore compounds.	Ongoing (Water Corporation). This is carried forward as a new recommendation in this review (Section 2.2).
10	Maintenance of bores to prevent leaks causing semi-permanent pools.	Ongoing (Water Corporation). This is carried forward as a new recommendation in this review (Section 2.2).
11	Review of the plan and recommendations.	Undertaken through the preparation of this review document. This is carried forward as a new recommendation in this review (Section 2.2).

2.2 Consolidated recommendations

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

1. Proclaim the amended Yule River Water Reserve boundary under the *Country Areas Water Supply Act 1947*. (DWER)
2. Incorporate the findings of this review and the location of the Yule River Water Reserve (including its priority areas and protection zones) in the Port Hedland local planning scheme in accordance with the WAPC's State planning policy no. 2.7: *Public drinking water source policy*. (Town of Port Hedland)
3. Refer development proposals within the Yule River Water Reserve that are inconsistent with DWER's WQPN no.25: *Land use compatibility in public drinking water source areas*, or recommendations in this review, to DWER's regional office for advice. (Department of Planning, Lands and Heritage, Town of Port Hedland, proponents of proposals)
4. Ensure incidents covered by Westplan–HAZMAT in the Yule River Water Reserve are addressed by ensuring that:
 - the Pilbara Emergency Management District LEMC is aware of the location and purpose of the Yule River Water Reserve.
 - the locality plan for the Yule River 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 Yule River Water Reserve.
 - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Yule River Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality. (Water Corporation).
5. Erect and maintain signs along the boundary of the Yule River Water Reserve including an emergency contact telephone number. (Water Corporation)
6. Water Corporation should continue the current regime of water quality monitoring, maintenance of fencing, inspections and by-law enforcement. (Water Corporation)
7. Update this review within seven years. (DWER)

Appendices

Appendix A – Figures

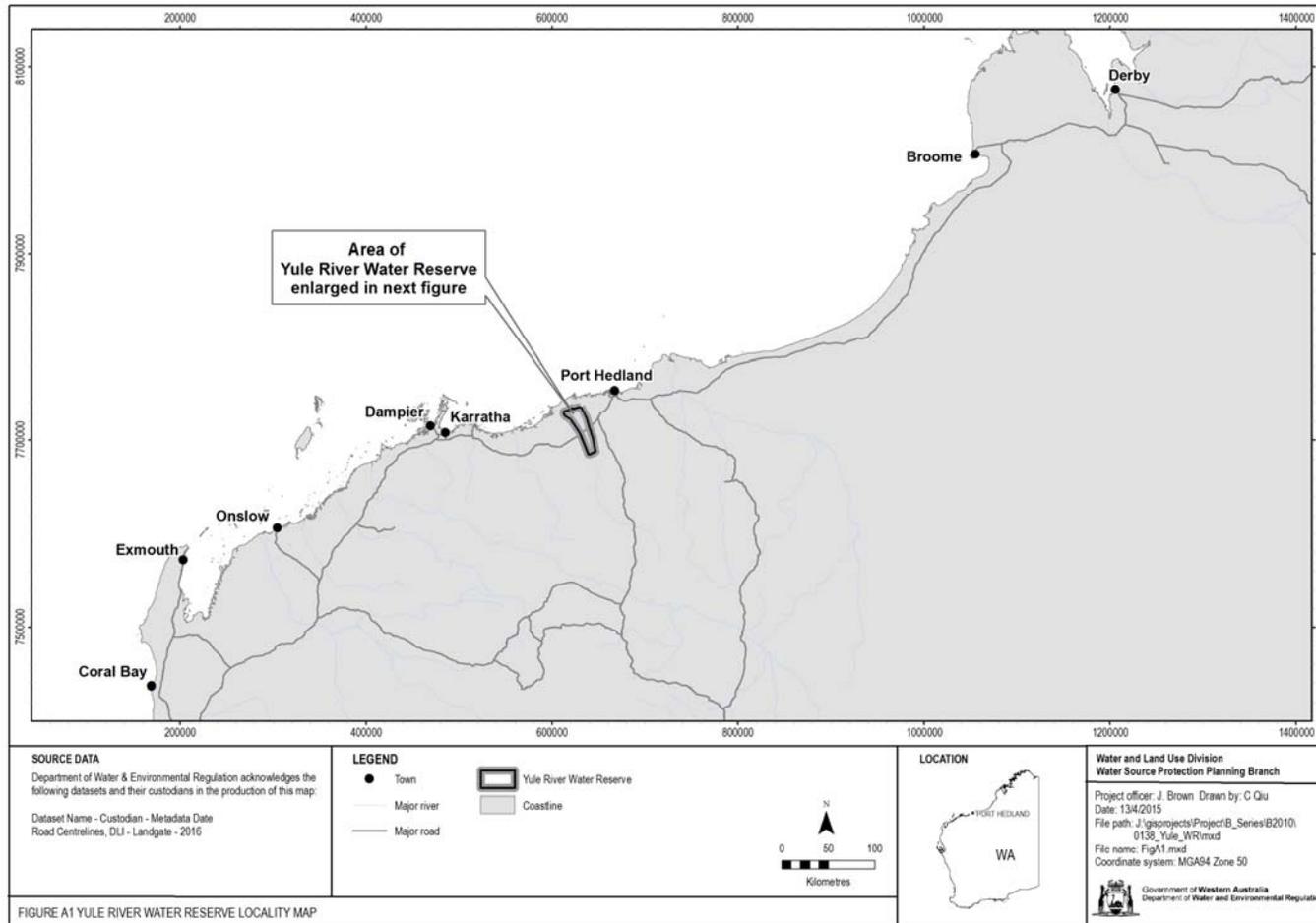


Figure A1 Yule River Water Reserve locality map

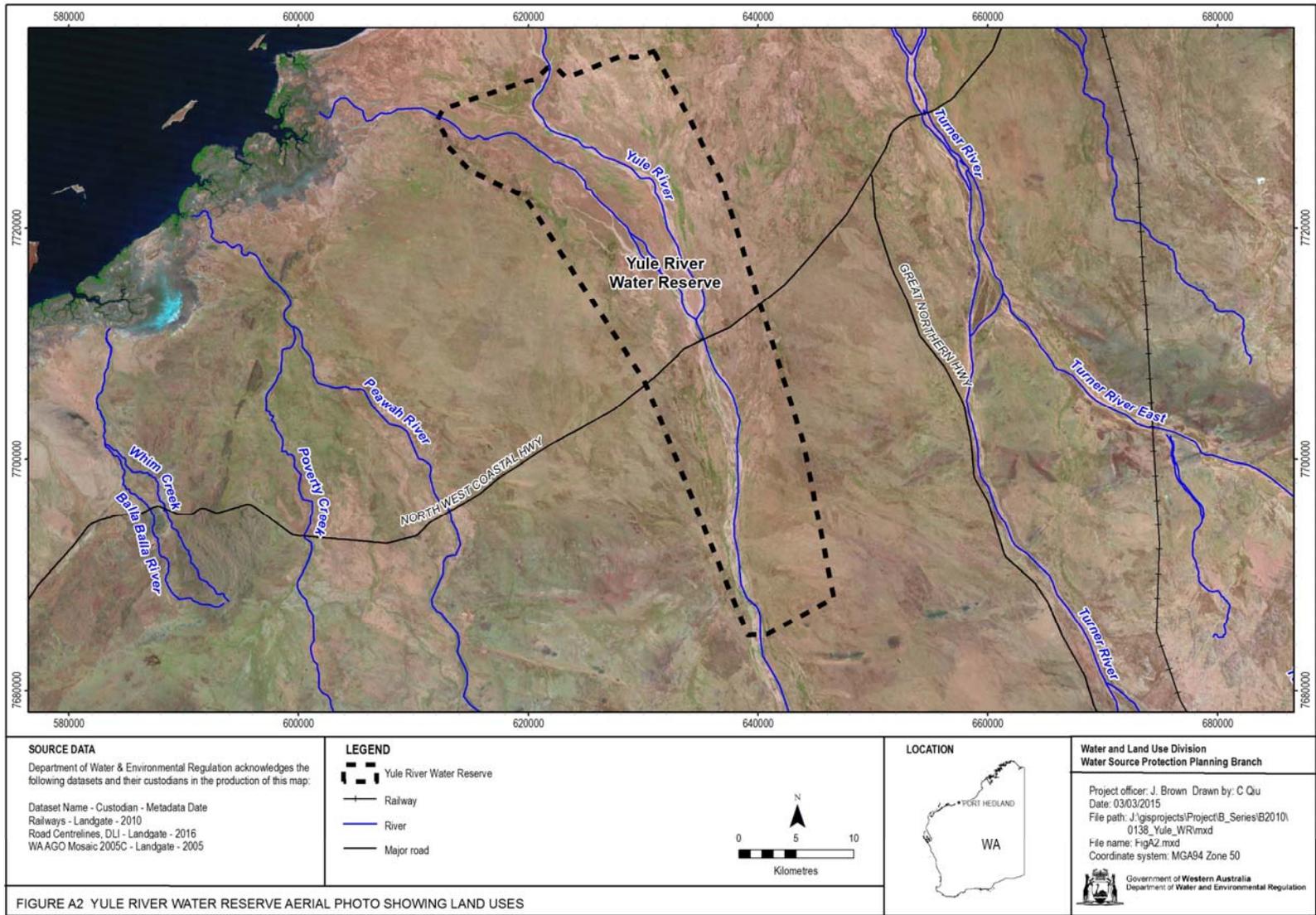


Figure A2 Existing Yule River Water Reserve aerial photo showing land uses

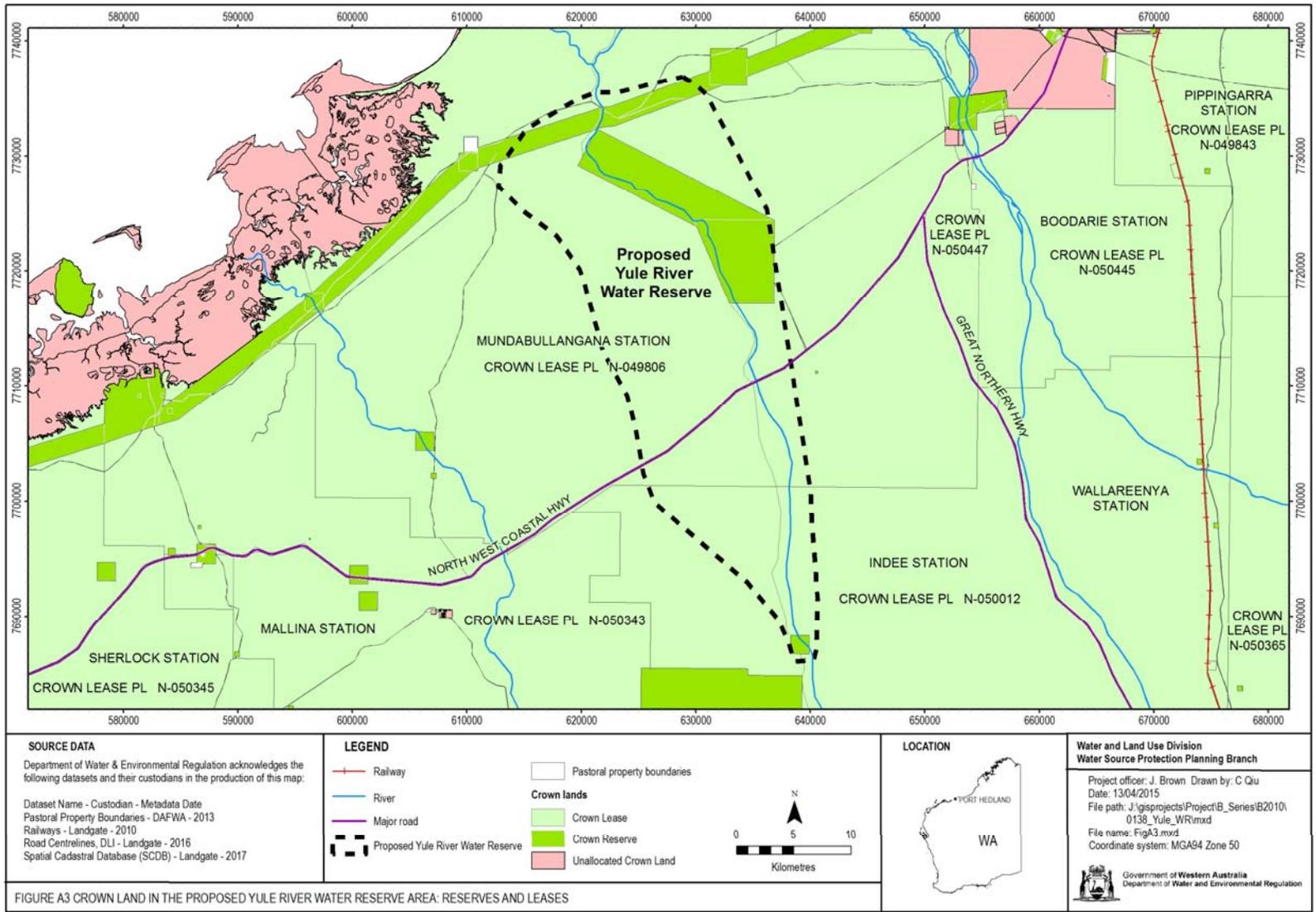


Figure A3 Crown reserves and leases in the proposed Yule River Water Reserve

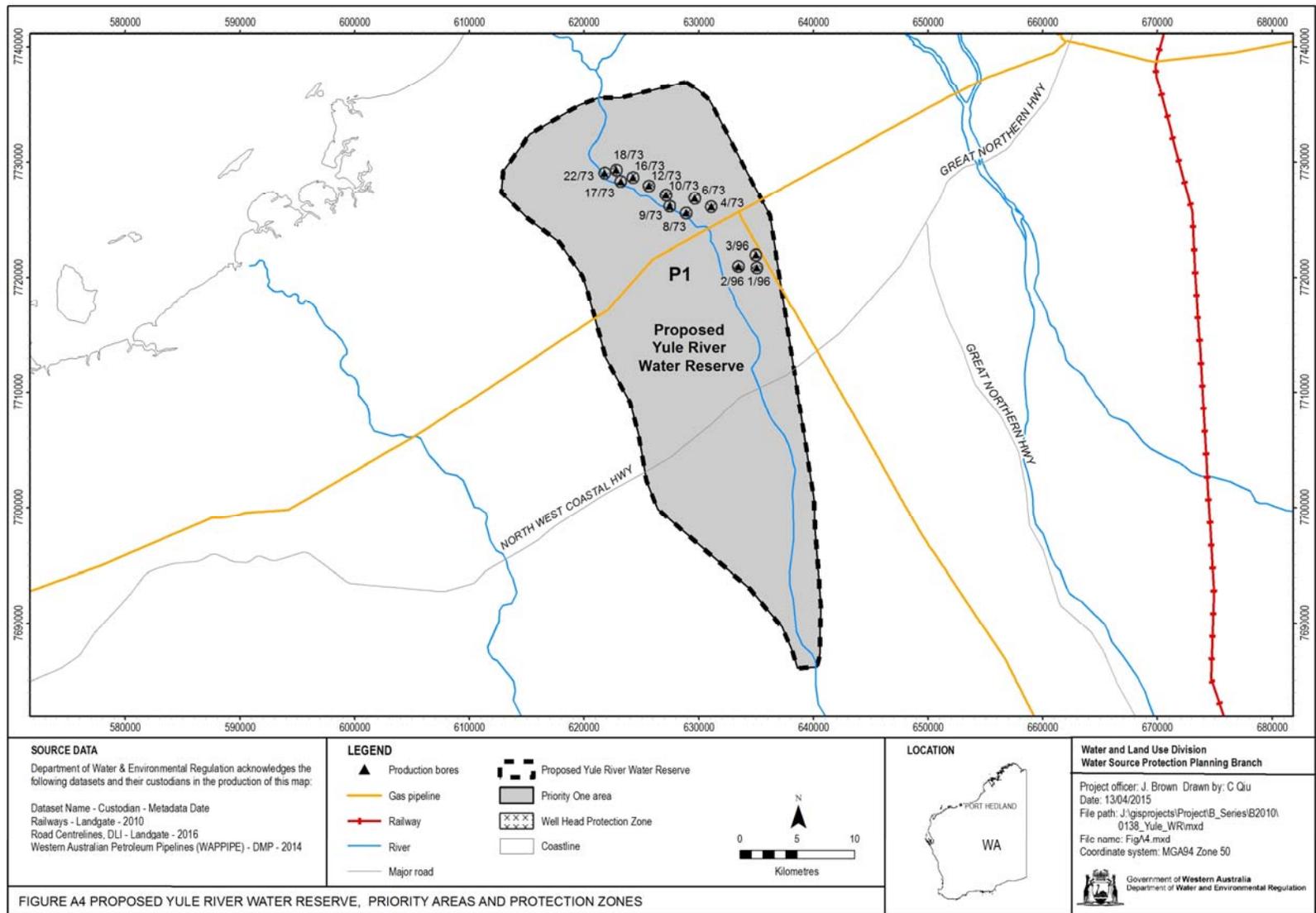


Figure A4 Proposed Yule River Water Reserve priority areas and protection zones

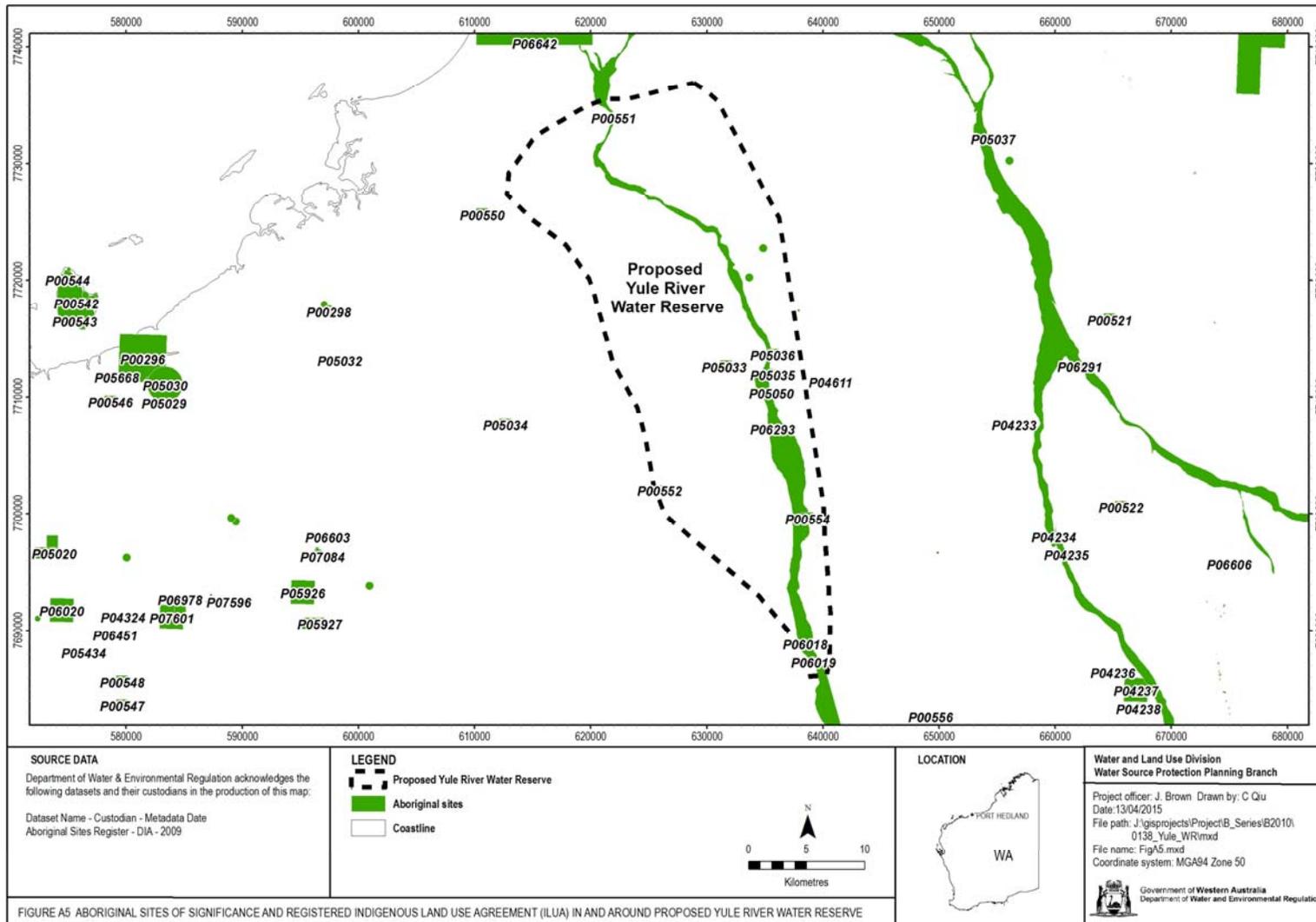


Figure A5 Aboriginal sites of significance and registered Indigenous land use agreements in and around proposed Yule River Water Reserve

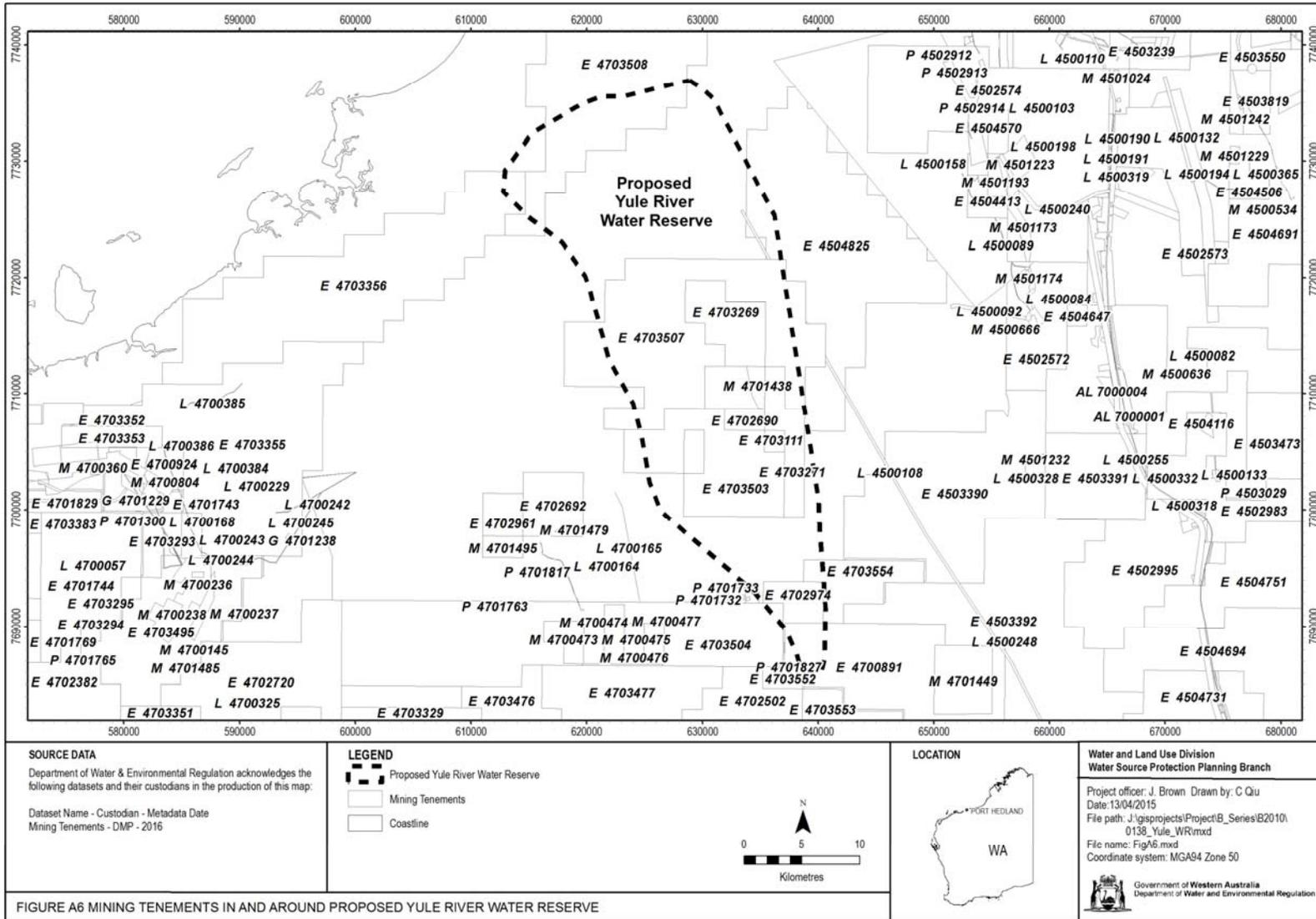


Figure A6 Mining tenements in and around proposed Yule River Water Reserve

Appendix B – Water quality data

The Water Corporation has monitored the raw (source) water quality from Yule in accordance with the requirements of the *Australian drinking water guidelines 2011* (ADWG) 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 Yule River 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 December 2008 to November 2013.

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 North West Region refer to the most recent Water Corporation drinking water quality annual report at www.watercorporation.com.au.

Aesthetic characteristics

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

Aesthetic detections for Yule River bore field

Parameter	Units	ADWG aesthetic guideline value*	Yule River raw water	
			Range	Median
Chloride	mg/L	250	41–80	62.5
Colour - True	TCU	15	<1–1	<1
Hardness as CaCO ₃	mg/L	200	120–160	135
Iron unfiltered	mg/L	0.3	<0.003–0.008	<0.003
Silicon as SiO ₂	mg/L	80	50–60	52.5
Sodium	mg/L	180	43–52	51
Sulfate	mg/L	250	9–15	12.5
Total filterable solids	mg/L	600	368–455	418
Turbidity	NTU	5	<0.1–0.2	<0.1
pH (lab)	pH units	6.5–8.5	7.64–8.03	7.84

* 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 Yule 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 Yule River bore field

Parameter	Units	ADWG health guideline value*	Yule River raw water	
			Range	Median
Nitrite plus Nitrate as N	mg/L	11.29	0.83–1	0.92
Sulfate	mg/L	500	9–15	12.5
Arsenic	mg/L	0.007	0.003– 0.007	0.005
Barium	mg/L	0.7	0.12–0.28	0.19
Boron	mg/L	4	0/06–0.12	0.09
Molybdenum	mg/L	0.05	<0.0005–0.001	<0.0005
Selenium	mg/L	0.01	<0.003–0.003	<0.003
Uranium	mg/L	0.02	0.002–0.005	0.003
Chromium	mg/L	0.05	0.0008–0.0016	0.0012
Fluoride (lab)	mg/L	1.5	0.25–0.4	0.35

* 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 (NHRMC & ARMCANZ, 2011).

† The 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 Yule River 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 review period, positive *E. coli* counts were recorded in 19 per cent of samples.

Appendix C – Photographs

All photographs were taken by N. Mantle (DoW)



Figure C1 View of the Yule River (from the bridge on the highway, looking north)



Figure C2 Riverine vegetation and pool



Figure C3 Vehicle tracks, riverine vegetation



Figure C4 Camping, open fires



Figure C5 Rest area just off North West Coastal Highway



Figure C6 Rest site

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 & NRMCC 2011). Contaminants can also interfere with water treatment processes, and damage water supply infrastructure.

The *Australian drinking water guidelines* (ADWG; NHMRC & NRMCC 2011) outline 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 and include bacteria, protozoa and viruses. When people consume drinking water that is contaminated with pathogens, the consequences vary considerably, ranging from mild illness (such as stomach upset or diarrhoea) to hospitalisation and in some cases even death. For example, seven people died and about 2500 became ill in Walkerton, Canada, during 2000, because the town's water supply was contaminated by a pathogenic strain of *E. coli* and *Campylobacter* (NHMRC & NRMCC 2011).

The types of pathogens that are likely to cause harm to people are commonly found in the faeces of humans and domestic animals (such as dogs and cattle). These pathogens can enter drinking water supplies from faecal contamination in the catchment area, either directly or indirectly.

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 inactivation rate) 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.

Given the wide variety of pathogens, their behaviour 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. 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 and chemicals can attach onto soil particles and become more difficult to remove during disinfection and treatment processes.

Other physical properties of water can affect water supply infrastructure, or the aesthetics of the drinking water. For example, pH can contribute to the corrosion and encrustation of pipes; iron and dissolved organic matter can affect the colour and smell of water; and salinity levels can affect its taste. Although not necessarily harmful to human health, water with properties like this will be less appealing to customers.

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 used to control:

- weeds (herbicides)
- pests (insecticides, rodenticides)
- worms (nematicides)
- mites (miticides).

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. Harmful chemical by-products may be formed when hydrocarbons are combined with chlorine during the water treatment process. Hydrocarbons can occur in water supplies as a result of spills and leaks from vehicles and machinery.

Drinking water sources can also be contaminated by nutrients such as nitrogen and phosphorus. Nutrients can be introduced into a catchment via the application of fertiliser, from septic systems, and from animal faecal matter that washes through soil and into the groundwater. Nitrate and nitrite are two forms of nitrogen that 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 groundwater and could be harmful to human health if consumed.

Appendix E – 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 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, DWER 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 (WAPC) 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.

DWER's Water quality protection note no. 25: *Land use compatibility in PDWSAs* outlines appropriate development and activities within each of the priority areas (P1, P2 and P3).

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 also 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 WAPC (with input from DWER) 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 www.dwer.wa.gov.au or contact the Water source protection planning team on +61 8 6364 7600 or email drinkingwater@dwer.wa.gov.au.

Drinking water source protection reports produced by DWER

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.	Preliminary	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 changes in land and water factors and implementation of previous recommendations. Sometimes prepared to consider specific issues in a PDWSA.	Key stakeholders	3–6 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 (SPPs), recognising the importance of PDWSAs for the protection of water quality and public health:

- SPP no. 2.2: *Gnangara groundwater protection*
- SPP no. 2.3: *Jandakot groundwater protection*
- SPP no. 2.7: *Public drinking water source policy*
- SPP no. 2.9: *Water resources*.

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 based 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).

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

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. Furthermore, no previous detection of contamination is not proof that the risk is acceptable.

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
DoW	Department of Water
DWER	Department of Water and Environmental Regulation
HAZMAT	hazardous materials
kL	kilolitre
LEMC	local emergency management committee
mg/L	milligram per litre
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NTU	nephelometric turbidity units
PSC 88	Public sector circular number 88
PDWSA	public drinking water source area
TFSS	total filterable solids by summation
WAHMEMS	Western Australian hazardous materials emergency management scheme (old name for Westplan–HAZMAT)
WAPC	Western Australian Planning Commission
Westplan–HAZMAT	Western Australian plan for hazardous materials
WHPZ	wellhead protection zone
WQPN	water quality protection note
WRC	Water and Rivers Commission

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 & NRMCC 2011).
Allocation	Is the volume of water that a licensee is permitted to abstract, usually specified in kilolitres per annum (kL/a).
Anisotropic	Having different properties in different directions. For example, an aquifer with variations in hydraulic conductivity horizontally and vertically, or different grain sizes in all directions.
Aquifer	An aquifer is a geological formation or group of formations able to receive, store and transmit significant quantities of water.
Australian drinking water guidelines	The <i>National water quality management strategy: Australian drinking water guidelines 6, 2011</i> (NHMRC & NRMCC 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 <i>wellfield</i>).
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.
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.

Effluent	Effluent is treated or untreated liquid, solid or gaseous waste discharged by a process such as through a septic tank and leach drain system.
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.
Hydrology	The science dealing with water on the land, including such things as its properties, laws and geographical distribution.
Interbedded	Layers between, or alternating with, other layers of differing geological character.
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 <i>Escherichia coli</i>), protozoa (such as <i>Cryptosporidium</i> and <i>Giardia</i>) 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.

Pollution	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.
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 <i>Metropolitan Water Supply, Sewerage, and Drainage Act 1909</i> or the <i>Country Areas Water Supply Act 1947</i> .
Public sector circular number 88	A state government circular produced by the Department of Health providing guidance on appropriate herbicide use within water catchment areas.
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.
Runoff	Water that flows over the surface from a catchment area, including streams.
Treatment	Application of techniques such as settlement, filtration and chlorination to render water suitable for specific purposes, including drinking and discharge to the environment.
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.
Wastewater	Water that has been used for some purpose and would normally be treated and discarded. Wastewater usually contains significant quantities of pollutant.
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 <i>Country Areas Water Supply Act 1947</i> or the <i>Metropolitan Water Supply, Sewerage, and Drainage Act 1909</i> for the purposes of protecting a drinking water supply.
Watertable	The upper saturated level of the unconfined groundwater is referred to as the watertable.
Wellfield	A wellfield is a group of bores located in the same area used to monitor or withdraw groundwater.
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 (WAHMENS)	This is now known as Westplan–HAZMAT.

References

- Antao, M 2013, *Monitoring program to support the Pilbara groundwater allocation plan*, prepared for Department of Water, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Braimbridge, M 2010, *Yule River: ecological values and issues*, Environmental water report no. 18, prepared for Department of Water, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Braimbridge, M & Loomes, R 2013 *Ecological water requirements of the Yule River aquifer*, Environmental water report series no. 24, prepared for Department of Water, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Department of Health 2007, *Use of herbicides in water catchment areas*, Public Service Circulars (PSC) no. 88, February 2007, Government of Western Australia, Perth, available www.health.wa.gov.au.
- 2011, *Mine sites, exploration camps and construction villages*, Government of Western Australia, Perth, available www.health.wa.gov.au.
- 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.health.wa.gov.au.
- Department of Regional Development and Lands 2010, *Pilbara Cities Vision*, available www.pdc.wa.gov.au.
- Department of Water 2010, *Pilbara regional water plan 2010–2030*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2011, *Hydrogeological investigations of Pilbara groundwater resources*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2012a, *Lower De Grey and Yule groundwater allocation limits report: background information and method used to set an allocation limit for the De Grey and Yule alluvial aquifers*, Water resource allocation and planning series no. 54, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2012b, Operational policy no.13: *Recreation within public drinking water source areas on Crown land*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2013a, *Pilbara groundwater allocation plan*, Water resource allocation and planning series no. 55, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2013b, *Western Australian water in mining guideline*, Water licensing delivery series no. 12, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2013c, *Pilbara regional water supply strategy*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.

- *Water quality protection notes (WQPNs)*, Government of Western Australia, Perth, available www.dwer.wa.gov.au:
- 2004, WQPN no. 25: *Land use compatibility in public drinking water source areas*
 - 2006, WQPN 5 *Toxic and hazardous substances: storage and use*
 - 2006, WQPN 35 *Pastoral activities within rangelands*
 - 2009, WQPN 84 *Rehabilitation of disturbed land in public drinking water source areas*
 - 2009, WQPN 96 *Pest animal management in public drinking water source areas*
 - 2013, WQPN 15 *Extractive industries near sensitive water resources*
 - 2013, WQPN 26 *Liners for containing pollutants using synthetic membranes*
 - 2013, WQPN 28 *Mechanical servicing and workshops*
 - 2013 WQPN 68 *Mechanical equipment wash down.*
- Department of Water and Environmental Regulation 2018, *De Grey River Water Reserve drinking water source protection review*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Economic Consulting Services 2007, *Prospective demand for water in the west Pilbara of WA*, report commissioned by the Department of Water, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Fugro 2009, *De Grey and Yule FALCONTM Airborne Gravity Gradiometer and Magnetic Geophysical Survey*, report produced for the Department of Water by Fugro Airborne Surveys, Perth, available www.dwer.wa.gov.au.
- Government of Western Australia 1914, *Rights in Water and Irrigation Act*, Reprinted under the *Reprints Act 1984* as at 1 February 2008, State Law Publisher, Perth, available www.slp.wa.gov.au.
- 1947, *Country Areas Water Supply Act*, reprinted under the *Reprints Act 1984* as at 4 May 2012, State Law Publisher, Perth available www.slp.wa.gov.au.
- 1972, *Aboriginal Heritage Act*, reprinted under the *Reprints Act 1984* as at 18 September 2010, State Law Publisher, Perth available www.slp.wa.gov.au.
- Haig, T 2009, *The Pilbara coast water study*, report prepared for the Department of Water, Hydrogeological record series, no. HG 34, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Johnson, SL and Wright, AH 2001, *Central Pilbara groundwater study*, report prepared for the (then) Water and Rivers Commission, Hydrogeological record series no. HG 8, Government of Western Australia, Perth, available www.dwer.wa.gov.au.

- 2003, *Mine void water resource issues in Western Australia*, report prepared for the (former) Water and Rivers Commission, Hydrogeological record series no. HG 9, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- MWH engineering consultants 2010, *Development of a subregional scale numerical groundwater model of the lower Yule catchment*, Department of Water the Australian Government, available www.dwer.wa.gov.au.
- 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.
- 2004, *Water made clear – A consumer guide to accompany the 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.dwer.wa.gov.au.
- Ruprecht, J and Ivanescu, I 2000, *Surface hydrology of the Pilbara region*, Government of Western Australia, Perth, unpublished report, Surface water hydrology series no. SWH 32, Government of Western Australia, Perth.
- State Emergency Management Committee 2005, Policy statement no. 7: *Western Australian emergency management arrangements*, Government of Western Australia, Perth.
- Sinclair Knight Merz 2010, *Framework for assessing potential local and cumulative effects of mining on groundwater resources*, Report 8: Framework testing – Pilbara and Hamersley regions, Western Australia, available <http://webarchive.nla.gov.au>.
- Water and Rivers Commission 1999, Statewide policy no. 1: *Policy and guidelines for construction and silica sand mining in public drinking water source areas*, available www.dwer.wa.gov.au.
- 2000a, *Yule River Water Reserve water source protection plan*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2000b, Water quality protection guidelines no. 1–11: *Water quality management in mining and mineral processing*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- Water Corporation, 2009, SG097 *Source protection operations manual*, unpublished corporate document, Water Corporation, Perth.
- 2012a *Port Hedland Regional Water Supply groundwater monitoring review*, unpublished internal report, Water Corporation, Perth.
- 2012b *Annual report 2012*, Water Corporation, Perth, available www.watercorporation.com.au.

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- 2013, *S111 Source protection signage*, unpublished corporate standard, Water Corporation, Perth.
- 2014, *Port Hedland Water monitoring summary 2013-2014*, unpublished corporate report, Water Corporation, Perth.
- Western Australian Planning Commission 2003, SPP no. 2.7: *Public drinking water source policy*, Government Gazette Western Australia, 10 June 2003, pp. 2077-82, Government of Western Australia, Perth, available www.planning.wa.gov.au.
- 2006, SPP no. 2.9: *Water resources*, Government Gazette Western Australia, 19 December 2006, pp. 5707-22 Government of Western Australia, Perth, available www.planning.wa.gov.au.
- 2011, *Port Hedland Regional Hotspots* Government of Western Australia, Perth, available www.planning.wa.gov.au.
- 2012, *Pilbara planning and infrastructure framework*, Government of Western Australia, Perth, available www.planning.wa.gov.au.
- World Health Organization 2004, *Guidelines for drinking-water quality – Volume 1 – Recommendations*, 3rd edn, World Health Organization, Geneva.

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 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, available www.dwer.wa.gov.au.
- *Water quality protection notes (WQPNs)*, Government of Western Australia, Perth, available www.dwer.wa.gov.au.
- 2009, WQPN 36: Protecting public drinking water source areas
 - 2006, WQPN 56: *Tanks for elevated chemical storage*
 - 2008, WQPN 61: *Tanks for ground level chemical storage*
 - 2013, WQPN 60: *Tanks for mobile fuel storage in public drinking water source areas*
 - 2009, WQPN 58: *Tanks for temporary elevated chemical storage*
 - 2013, WQPN 62: *Tanks for underground chemical storage*
 - 2013 WQPN 64: *Tanks - closure of underground chemical storage*
- Hrudey, SE & Hrudey, EJ 2004, *Safe drinking water – Lessons from recent outbreaks in affluent nations*, IWA Publishing, London.
- 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.
- Sinclair Knight Merz 2010, *Framework for assessing potential local and cumulative effects of mining on groundwater resources*, Report 8: Framework testing – Pilbara and Hamersley regions, Western Australia, available <http://webarchive.nla.gov.au>.
- Standing Committee on Public Administration, 2010, *Report no. 11: Recreation activities within public drinking water source areas*, Legislative Council, Perth, available www.parliament.wa.gov.au.
- Western Australian Planning Commission 1997, *State planning strategy*, Government of Western Australia, Perth.

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