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

Bungaroo Creek Water Reserve

Drinking water source protection plan

West Pilbara water supply scheme

Looking after all our water needs

Water resource protection series
Report WRP 135
November 2012

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Department of Water
168 St Georges Terrace
Perth Western Australia 6000
Telephone +61 8 6364 7600
Facsimile +61 8 6364 7601
National relay service 13 36 77
www.water.wa.gov.au

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For more information about this report, contact
Water Source Protection Planning on +61 8 6364 7600 or drinkingwater@water.wa.gov.au.

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Preface

How do we protect public drinking water source areas?

The *Australian drinking water guidelines* (ADWG) (NHMRC & NRMMC 2004a) 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 Organisation.

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

A preventive risk-based approach means that we look at all the different risks to water quality to determine what risks can reasonably be avoided and what risks need to be minimised or managed. 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 catchment. 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 (e.g. chlorination to inactivate pathogens), maintenance of pipes and testing of water quality. Another community benefit of catchment protection is its complementary nature to 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 the catchment's water quality now and for the future.

In Western Australia, the Department of Water protects public drinking water source areas (PDWSAs) by putting the ADWG into practice, writing plans, policies and guidelines, and providing input into land-use planning.

The *Metropolitan Water Supply Sewerage and Drainage Act 1909* and the *Country Areas Water Supply Act 1947* provide us with useful 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. We work cooperatively with other agencies in the implementation of this legislation.

This drinking water protection plan has been developed to achieve elements two and three of the 12 elements recommended for the protection of drinking water in the ADWG. It shows where the PDWSA is located, its characteristics, existing and potential water quality contamination risks, and includes recommendations to deal

with water quality risks. Our regional offices will work with the community, other government agencies and landowners to put these recommendations into practice.

An important step in maximising the protection of water quality in PDWSAs is to accurately define boundaries, priority areas and protection zones to help guide land use planning and to identify where legislation applies. There are three different priority areas. Priority 1 (P1) areas are defined and managed to ensure there is no degradation of the quality of the drinking water source using the principle of risk avoidance. Priority 2 (P2) areas are defined and managed to maintain or improve the quality of the drinking water source using the principle of risk minimisation. Priority 3 (P3) areas are defined and managed to maintain the quality of the drinking water source for as long as possible using the principle of risk management. Protection zones surround drinking water extraction points, so that the most vulnerable areas are protected from contamination.

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

The following table outlines the stages involved in the preparation of this drinking water source protection plan:

	Stages in development of a plan	**Comment**
1	Conduct stakeholder consultation. (September 2011–March 2012)	Preliminary information gathering and advice sought from key stakeholders to finalise the draft document for public comment.
2	Consult draft drinking water source protection plan. (June–July 2012)	Draft protection plan released for a four-week public comment period.
3	Publish approved drinking water source protection plan. (August–November 2012)	Final protection plan published, after considering submissions. Includes recommendations on how to protect water quality. Proclamation of this public drinking water source area can now be progressed.

Summary

Bungaroo Creek is a new groundwater source, planned to supply bulk water into the West Pilbara Water Supply Scheme in accordance with the Deed of Agreement between Rio Tinto and the State of Western Australia. The West Pilbara Water Supply Scheme supplies water to the towns of Karratha, Dampier, Roebourne, Cape Lambert and Point Samson.

The new Bungaroo source utilises a borefield located approximately 35 km southeast of Pannawonica (230 km southwest of Karratha), within the Pilbara region of Western Australia. The borefield is owned and operated by Rio Tinto Iron Ore (through Hamersley Iron, which is a licensed water service provider under the *Water Services Licensing Act 1995*).

Bungaroo borefield consists of nine production bores drilled within the Bungaroo Creek Palaeochannel. The aquifer is considered to be semi-confined within the immediate area of the borefield and unconfined further upstream within the Bungaroo Creek catchment.

This plan proposes the establishment of a water reserve to protect the Bungaroo Creek borefield and the Bungaroo and Jimmawurrada Creek catchment areas that recharge the aquifer during creek flows. The water reserve should be managed for Priority 1 source protection, with 500 m wellhead protection zones established around all production bores, to help protect the source of water used for abstraction and potable supply.

The major water quality risks to the water reserve include mining exploration activities, requiring access and operation within close proximity to the borefield, future mining activities upstream of that borefield, and pastoral activities in close proximity to the borefield.

This plan recommends careful management of mining operations and the prevention of stock entering the borefield area to reduce the water-quality contamination risk these activities pose to the Bungaroo Creek source and West Pilbara Water Supply Scheme.

This plan is consistent with the Australian drinking water guidelines (ADWG) (NHMRC & NRMMC 2004a) and State planning policy no. 2.7: *Public drinking water source policy* and was prepared in consultation with key stakeholders, including Rio Tinto Iron Ore.

A summary of information relevant to the Bungaroo Creek Water Reserve is given below.

Local government authority	The Shire of Ashburton
Locations supplied	Karratha, Dampier, Roebourne, Wickham, Point Samson, Cape Lambert.
Aquifer type	Unconfined to semi-confined
Volume of water abstracted	10 Gigalitres per year
Number of bores	Nine production bores
Bore name and GPS coordinates	WB10BUN002 (E 432 178, N 758 3086)WB10BUN003 (E 433 304, N 758 1872)WB10BUN004 (E 426 391, N 758 7798)WB10BUN005 (E 434 369, N 758 1314)WB10BUN007 (E 432 540, N 758 3637)WB10BUN008 (E 427 074, N 758 6972)WB10BUN009 (E 430 427, N 758 5548) WB09BUN002 (E 435 424, 758 1470)WB09BUN003 (E 431 616, N 758 4428)
Legislative protection	Proclamation of the water reserve will need to be progressed under the *Country Areas Water Supply Act 1947* when this plan is finalised.
Water allocation	A section 5C licence to take water with an allocation limit of 10 GL has been granted by the Department of Water in accordance with the *Rights in Water and Irrigation Act 1914*.
Size of the Bungaroo Creek Water Reserve	126119 ha
Size of the collective wellhead protection zones	689 ha
Size of the wellhead protection zone stock prevention area	870 ha

1 Overview of the Bungaroo Creek drinking water source

1.1 The drinking water supply system

The Bungaroo borefield is located approximately 35 kilometres southeast of Pannawonica (230 km southeast of Karratha), within the Pilbara region of Western Australia (refer to Figure A1). Bungaroo borefield is situated within the Bungaroo Creek Water Reserve and consists of nine production bores, screened between depths of 18.7 metres and 115.6 m, in the alluvium, tertiary pisolite and fractured rock within the Bungaroo valley floor.

The borefield within the Bungaroo Creek Water Reserve will supply water to the West Pilbara Water Supply Scheme (WPWSS) which utilises both ground and surface water sources supplying water to the towns of Karratha, Dampier, Roebourne, Cape Lambert and Point Samson. The scheme's current supply is sourced from the Harding Dam (surface water) and the Millstream Water Reserve (groundwater) during periods of peak demand.

Rio Tinto Iron Ore will operate the Bungaroo borefield supplying 10 gigalitres a year to the West Pilbara Water Supply Scheme operated by the Water Corporation.

Operation of the Bungaroo water supply involves raw water from the borefield being pumped into a collector main (pipe) and transferred into a collector tank under an automated process which utilises flow-controlled instrumentation. Raw water which enters the collector tank will be treated by a chlorine-dosing facility for disinfection and fluoride for health purposes.

The chlorinated water will then be pumped from the collector tank by a transfer pump station to existing infrastructure at the Millstream Water Reserve. Water from both the Millstream reserve and the Bungaroo borefield can be combined and stored into the existing Summit tanks for reticulated supply.

It should be recognised that although treatment and disinfection are essential barriers against contamination, catchment 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,* 2004 (ADWG) (NHMRC & NRMMC 2004a) and reflects a 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, please read the preface at the front of this plan.

1.2 Water management

1.2.1 Licence to take water

Water resource use and conservation in Western Australia is administered by the Department of Water, in accordance with the *Rights in Water and Irrigation Act 1914*. Under this Act, the right to use and control water is vested with the Crown. This means that a licence is required for drilling bores and abstracting groundwater (pumping water from a bore, spring or soak) within proclaimed groundwater areas throughout the state. An exemption may apply, such as for abstracting water for domestic purposes only.

The Bungaroo Creek Water Reserve is located within the Pilbara Groundwater Area and the Ashburton subarea which are proclaimed under the *Rights in Water and Irrigation Act 1914*. An allocation licence for an annual entitlement of 10 GL to Hamersley Iron Pty Ltd has been granted by the Department of Water to take water from the Bungaroo Creek aquifer under section 5C of the RIWI Act (GWL171733(2)).

1.2.2 Water planning

The *Pilbara regional water plan 2010–2030* (Department of Water 2010), published in May 2010, sets the overall strategic direction for water resource management in the Pilbara. It has a planning view to 2030 and identifies priority actions for implementation during the next five years. One of those priority actions is that drinking water source protection plans (DWSPPs) are prepared for all sources across the Pilbara.

DWSPPs have been prepared for all licensed Water Corporation sources currently harnessed in the Pilbara region, in addition to the Hamersley Iron system that supplies drinking water to Tom Price supplied by the Southern Fortescue and Marandoo Water Reserves. Existing DWSPPs are due for review five years after completion.

The Department of Water has developed a guide (refer to section 1.5.2), to facilitate good water management practices in mining operations across the Pilbara, aiming to achieve the best possible water, environmental and economic management outcomes.

These guidelines are needed because the amount of mining below the watertable has significantly increased in the Pilbara, and is expected to continue to do so. To avoid long-term impacts, it is important that water security, together with environmental and cultural values, are recognised and managed.

Part of the guidelines' aim is to ensure mine operators consider fit-for-purpose water use, so the chosen water source will be appropriate for the different purposes and needs within the mining operations and surrounding areas. For example, as far as practical, the best quality water with the greatest source protection should be used for drinking water supplies, including mine-site drinking water supply.

The plan also recommends that mining operations within public drinking water source areas (PDWSAs) recognise the potential impacts of their operations on drinking water sources and develop strategies to protect the water quality (Department of Water 2009).

1.2.3 Future water needs

Demand for water for the West Pilbara Water Supply Scheme is predicted to grow, due to an increase in mining activity in the area. The Bungaroo Creek borefield is thought to contain sufficient supply to meet this increased demand in the interim.

1.3 Characteristics of the catchment

1.3.1 Physical environment

Bungaroo Creek is part of a broad, low-gradient valley, approximately 44km long and 0.5–4 km wide, prone to flooding after seasonal, tropical storms and cyclones. Cutting through the Buckland Hills, the valley is bounded to the north and south by steep scarps, mostly formed of the resistant Dales Gorge member of the Brockman iron formation (Rio Tinto Iron Ore, 2011).

The valley is approximately 0.5 km wide at the upstream end and 4 km wide where it confluences with Jimmawurrada Creek about 30 km downstream. The valley floor gradually slopes from approximately 300 m at Australian Height Datum (AHD) upstream to 180 m AHD, at production bore WB10BUN004, downstream over a distance of 30 km (refer to figure A4). It contains numerous braided, dry creek beds that are prone to flooding during the wet season (Rio Tinto Iron Ore, 2011).

The Bungaroo Creek joins the Jimmawurrada Creek in the lower part of the catchment area. The Jimmawurrada Creek catchment has an area of about 400 square kilometres. The upstream valley is narrower than Bungaroo Creek, but the flood plain is wider in lower Bungaroo upstream of the Bungaroo-Jimmawurrada Creek confluence (Rio Tinto Iron Ore, 2011).

1.3.2 Climate

The Pilbara coast climate is arid-tropical with a low and variable annual rainfall. The mean annual rainfall recorded at the nearest gauging station, ‘Yalleen Station’ (BOM - 005029) is 400 mm, with daily rainfall totals ranging from 19 mm in 1997 to 300 mm in 2009 (Bureau of Meteorology 2011).

The variability in rainfall is due to the episodic nature of the tropical cyclones, or cyclone-related events, which cross the area in the summer months between December and April, and provide most (80 per cent) of the total rainfall. Winter rainfall may also occur in May or June, due to the influence of larger cold fronts that dominate winter weather patterns in the southern half of the state. The driest months are September to November, and the wettest are January to March (Rio Tinto Iron Ore 2011).

Temperature data for Pannawonica, the nearest representative site, with data from 1972 to 2005, indicates January has generally been the hottest month, with a mean maximum of 41.0°C and a mean minimum of 27.7°C. July is the coldest month with a mean maximum of 26.7°C and a mean minimum of 12.6°C (Bureau of Meteorology 2011).

1.3.3 Hydrology and hydrogeology

The Robe River Catchment Area is approximately 7571 km^2 in area and contains the Bungaroo Creek Water Reserve which is approximately 1261.19 km^2 in area. Groundwater within the Bungaroo valley is recharged from direct rainfall and during inundation from creek flows.

Peak flood flows were estimated for rainfall events having an annual recurrence interval of up to 100 years, with which peak discharge rates of 6000 metres cubed per second have been estimated.

Groundwater recharge mainly occurs from local rainfall and stream flow, after heavy rainfall associated with cyclonic storm events in the wider catchment. Significant recharge events occur when the Bungaroo Creek floods. Evidence of such events was observed after cyclone Monty (25/2/04 – 1/3/04), Cyclone Clare (8–10/01/06) and, most recently, Cyclone Emma (26–28/1/06) and heavy rainfall in February 2009.

Streamflow events are the major and most significant groundwater recharge phenomenon. Considerable recharge to the groundwater system is likely to occur from Bungaroo Creek tributaries and drainage during average rainfall years.

Within the upper Bungaroo Creek Catchment Area, direct rainfall recharge to the shingle valley floor and creek bed is estimated to be about 55 per cent of the annual rainfall. In the lower catchment area, groundwater recharge decreases to approximately three per cent, where less permeable geology exists. The Bungaroo Creek source is therefore consider to be unconfined in the upper catchment to semi-confined in the lower catchment areas, due to the changes of permeability within the catchment area and connectivity between aquifers.

Resource evaluation drill holes across the valley also provide a pathway to connect the different aquifers, increasing connectivity across the different aquifers within the Bungaroo valley.

Groundwater in the Bungaroo valley occurs in the valley floor alluvium, tertiary pisolites and fractured basement rock. Drilling and field observations suggest the valley floor alluvium in upper Bungaroo is very thick and highly permeable, compared to the lower Bungaroo valley.

There are two major tributaries that drain into Bungaroo Creek. The width of these tributaries is quite considerable – about 200 m wide – and they reach a distance of 25 km upstream.

The general hydrogeology of the Jimmawurrada Creek catchment appears very similar to Bungaroo Creek. Drilling in the Jimmawurrada flood plain shows that the tertiary pisolite is eroded and replaced by more recent clay rich alluvium.

The bores constructed in quaternary and tertiary material in the Jimmawurrada flood plain were capable of producing only modest bore yields (15-20 L/s), unlike in the Bungaroo palaeochannel. Shallow groundwater table exists in much of the Jimmawurrada Creek area in the lower Bungaroo catchment area, with the water table generally between 2–3 m below ground level.

The Bungaroo borefield area is also considered to be in hydraulic connection with Jimmawurrada Creek sediments and is likely to receive considerable recharge from the Jimmawurrada Creek catchment. As a result, the water reserve includes the Jimmawurrada Creek catchment area.

Regional groundwater flow is generally from southeast to northwest, in direction. Water levels range from greater than 290 m AHD in upper Bungaroo Creek to approximately 130 m AHD at the Jimmawurrada Creek confluence (Rio Tinto Iron Ore 2011).

1.4 How is the drinking water protected?

The Bungaroo Creek Water Reserve has not yet been proclaimed under the *Country Areas Water Supply Act 1947* (WA).

Department of Water proposes to arrange proclamation of this water reserve for the purpose of protecting the public drinking water source from potential contamination, after this plan is published.

1.5 Other useful information

1.5.1 Other groundwater bores in the area

Rio Tinto Iron Ore operates other production bores in the Bungaroo Creek Water Reserve, as part of its exploration and mining operations. If bores (e.g. dewatering, fit for purpose supply) are drilled near a public drinking water supply bore, they can cause contamination of the drinking water source. For example, a poorly constructed private 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 any bores are appropriately located to avoid drawdown and constructed to prevent contamination of the public drinking water source. Where required, this will be assessed through the Department of Water's water licensing process 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 Minimum Bore Specifications Committee 2003).

All exploration drilling holes should be rehabilitated in accordance with the Department of Mines and Petroleum's draft 'Guidelines for environmentally responsible mineral exploration & prospecting in Western Australia' (Department of Mines 2012).

1.5.2 Pilbara water in mining guideline

This guideline sets out how to meet the Department of Water's regulatory requirements for mining projects. The guideline was developed to improve the information available on our regulatory processes with the outcome of improving how water is managed across the Pilbara mining industry (Department of Water 2009).

1.5.3 The Pilbara coast water study

The *Pilbara coast water* study is a source review of all groundwater, surface water and supplementary supply options in support of the region's coastal supply schemes.

The study highlights the most potential groundwater supply options for development in the near future (Haig 2009).

1.5.4 Report and recommendations of the Environmental Protection Authority for the Mesa J iron ore development — Pannawonicca

This report was published in 1991 and contains recommendations by the Environmental Protection Authority on the Mesa J iron ore mining development downstream of the borefield in the Bungaroo Creek Water Reserve. The recommendations for approval by the EPA were based on the outcomes of the consultative environmental review process undertaken by Rio Tinto Iron Ore (Environmental Protection Authority 1991).

1.5.5 Claim-wide participation agreement

The Kuruma Marthudunera people have a long-standing association with the Bungaroo Valley and Jimmawarruda Creek areas over which this DWSPP will apply. Rio Tinto recognises the importance of these areas to the Kuruma Marthudunera people's cultural heritage and contemporary life and has signed a participation agreement with the group.

Rio Tinto has agreed to develop heritage and environmental management plans for the Coastal Water Project and to provide updates to the Kuruma Marthudunera people during the design, implementation and operation of the Bungaroo bore field.

Rio Tinto has also undertaken to employ Kuruma Marthudunera people to monitor activities, provide site visits and involve the Kuruma Marthudunera people in discussions with state agencies and other experts.

1.5.6 Bungaroo coastal water supply feasibility study

This study by Rio Tinto Iron Ore includes results from numerical modelling used to estimate the sustainable yield from the lower Bungaroo valley, and assess the exploitable groundwater resources of the Bungaroo Creek aquifer. The modelling work was conducted as part of a broader 2010 feasibility study.

That feasibility study also included details on hydrological and hydrogeological data collected as part of the modelling, pump-testing and monitoring bore network results. The results also included water quality monitoring data collected from the source,

which was assessed against the criteria recommended within the *Australian drinking water guidelines* (ADWG) (refer to Appendix B).

Potential impacts from dewatering, affecting groundwater depth and supply to heritage sites such as 6 Mile Well, were also simulated. Mitigation measures, as a result, have been proposed in the report to manage the predicted impacts, which included consultation with the Kuruma Marthudunera People, the traditional land owners (Rio Tinto Iron Ore 2011).

2 Common contamination risks

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

Some contaminants in drinking water can affect human health. Other impurities can affect the water's aesthetic qualities, including its appearance, taste, smell and 'feel' but are not necessarily hazardous to human health. For example, cloudy water with a distinctive odour or strong taste may not be harmful to health, but clear, pleasant-tasting water may contain harmful, undetectable microorganisms (NHMRC & NRMMC 2004b). Contaminants can also interfere with water treatment processes, and damage water supply infrastructure (such as iron corroding pipes).

The ADWG outline criteria for acceptable drinking water quality to protect human health, manage aesthetics and maintain water supply infrastructure.

For more information about water quality in this drinking water source, see section 3.

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

2.1 Microbiological risks

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

Pathogens can enter drinking water supplies from faecal contamination in the water reserve. In groundwater sources, this occurs indirectly – faecal material can infiltrate through the soil and into the groundwater. For example, contamination can occur from septic tanks or grazing animals.

A number of pathogens are commonly known to contaminate water supplies worldwide. These include bacteria (e.g. salmonella, *Escherichia coli* and cholera), protozoa (e.g. *Cryptosporidium*, *Giardia*) and viruses. *E. coli* counts provide an indication of the level of faecal contamination.

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

The survival and movement of pathogens in groundwater is influenced by the characteristics of the pathogen (such as its size and the length of time it normally takes to decay) and the groundwater properties (including flow rate, porosity, amount of carbon in the soil, temperature, 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, maximum 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).

Therefore it is important to understand the groundwater system to be able to protect the drinking water source from pathogens.

When people consume drinking water contaminated with pathogens the effects 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 2004b). Where possible, avoiding the introduction of pathogens into a water source is the most effective way to protect public health.

2.2 Physical risks

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

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

2.3 Chemical risks

Chemicals can occur in drinking water as a result of natural leaching from mineral deposits or from different land uses (NHMRC & NRMMC 2004a). A number of these chemicals (organic and inorganic) are potentially toxic to humans.

Pesticides include agricultural chemicals such as insecticides, herbicides, nematicides (used to control worms), rodenticides and miticides (used to control mites). Contamination of a drinking water source by pesticides (and other chemicals) may occur as a result of accidental spills, incorrect use or leakage from storage

areas. In these cases, the relevant authorities should be notified promptly and the spill cleaned up to prevent contamination of the drinking water source.

Hydrocarbons (e.g. fuels, 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 applications, faulty septic systems, leach drains and from domestic and feral animal faecal matter 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 2004a).

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

3 Contamination risks in this drinking water source

3.1 Water quality

Rio Tinto Iron Ore has outlined a water quality monitoring regime as part of the operating strategy to be attached to the 5C allocation licence to take water issued by the department. Rio Tinto Iron Ore will monitor the quality of raw water from the Bungaroo Creek Water Reserve for microbiological, health-related and aesthetic (non-health-related) characteristics. An assessment of the drinking water quality once treated will also be made against the *Australian drinking water guidelines,* 2004 (ADWG) (NHMRC & NRMMC 2004a) by the Water Corporation. This assessment will also be undertaken by an intergovernmental committee called the Advisory Committee for the Purity of Water which is chaired by the Department of Health.

A summary of the raw-water quality for the borefield within the Bungaroo Creek Water Reserve for July 2012 is presented in Appendix B. For more information on the water quality for the towns of Karratha, Dampier, Roebourne, Cape Lambert and Point Samson for which the Bungaroo Creek borefield supplies, see the Water Corporation's most recent drinking water quality annual report at <www.watercorporation.com.au>.

3.2 Land uses and activities

The Bungaroo Creek Water Reserve is located over a mixture of unallocated and leased Crown land. Current land uses and activities and their risks to the drinking water source are described below. Table 1, at the end of this section, summarises this information in an easy-to-read format. Appendix C displays a more detailed risk assessment, and includes recommended protection strategies to address water quality risks.

3.2.1 Mining tenements

There are a number of mining tenements within the Bungaroo Creek Water Reserve (refer to Appendix F). Mining tenement AML 7000248 is currently being mined by Robe River Ltd under the *Iron Ore (Robe River) Agreement Act 1964*.

Proposed future mining by Rio Tinto Iron Ore, located upstream of the borefield has been hydrogeologically modelled to estimate the travel times for potential contamination to the borefield. The solute transport scenario predicted solute concentrations for ammonia nitrate and hydrocarbons over a 30-year time period. The results of the simulation estimated there was a low probability for contamination of the borefield in the upper Bungaroo aquifer from the future mine site (CyMod Systems 2010).

Existing and future mining proposals within the water reserve are compatible with conditions, and should be guided by the Water quality protection guidelines for

mining and mineral processing 1–11 and other relevant water quality protection notes published by the Department of Water (refer to Appendix C).

3.2.2 Pastoral lease

In addition to the mining tenements, the Bungaroo Creek Water Reserve also lies substantially within the Yalleen pastoral lease. The lease is held by Yalleen Pastoral Company Pty Ltd, owned by Robe River Mining Pty Ltd and subleased to Williambury Station (WA) Pty Ltd.

The prevention of stock entering wellhead protection zones and appropriate location of stockyards and watering points for water quality protection, will help to reduce the level of risk of pathogen contamination (see section 5, recommendation 8).

3.2.3 Aboriginal sites of significance and native title claims

Aboriginal sites of significance are those areas that Aboriginal people value as important and significant to their cultural heritage. The sites are significant because they link Aboriginal culture and tradition to place, land and people over time. These areas form an integral part of Aboriginal identity and the heritage of Western Australia. The *Aboriginal Heritage Act 1972* protects all Aboriginal sites in the state.

There are 116 Aboriginal sites of significance on the Aboriginal Sites System Register within the Bungaroo Creek Water Reserve (refer to figure A6). The names of each site and identification number where possible are listed within Appendix E.

The Kuruma Marthudunera People as the traditional land owners have the Kuruma Marthudunera (combined) registered native title claim (WAD6090/98) within the Bungaroo Creek Water Reserve.

Proclamation of the Bungaroo Creek Water Reserve under the *Country Areas Water Supply Act 1947* will not restrict access to heritage sites or sites of significance such as Old Yalleen or Six Mile Well.

The Department of Water is committed to working with the Kuruma Marthudunera people during the planning, management and implementation of activities within this public drinking water source area. The department recognises the Kuruma Marthudunera People's connection to the land as the traditional land owners and native title that provides an important framework for the management of water resources within the State.

The importance of the Kuruma Marthudunera People's connection to land is also recognised through the Claim Wide Participation Agreement with Hamersley Iron Pty Limited; Robe River Limited; Robe River Mining Co Pty Ltd on its own behalf as a Venturer and as Manager for and on behalf of the Robe River Iron Associates; Kuruma Marthudunera People.

3.3 Possible future contamination risks

The main future contamination risk to the Bungaroo Creek Water Reserve is the expansion of mining activities and continued stock grazing in close proximity to the borefield. As a result, the risks to the Bungaroo Creek Water Reserve are:

- pathogens associated with cattle faeces, mine campsites, landfill and exploration located upstream of the surface and groundwater flow
- nutrients associated with cattle faeces, mine camp landfill and explosives used for ore extraction
- hydrocarbons and chemicals associated with vehicle and mobile plant refuelling, tanker transport, chemical bulk storage, mine equipment and infrastructure leaks, wash down of mine equipment and exploration activities.

Numerical modelling, as part of the feasibility study (refer to section 1.5.3), simulated contaminant transport for ammonia nitrate and hydrocarbons from the proposed Rio Tinto Iron Ore future mine site, located upstream of the borefield. The results of the simulation indicated a low probability that contaminants would affect water quality within the lower Bungaroo aquifer from ammonia nitrate and hydrocarbons associated with the future mine site (CyMod Systems 2010).

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

Land use/activity	Hazard	Management priority	Compatibility of land use/activity	Best management practice guidance[1]
Pastoral activity	Pathogens from cattle faecal matter	High–medium	Pastoral leases are compatible with conditions in P1 areas.	WQPN no. 35: *Pastoral activities within rangelands.*
Ore extraction	Spills of hydrocarbons, other chemicals and nutrients.	High–medium	Mining is compatible with conditions in P1 areas.	Water quality protection guidelines (WQPG) 1–11: *Mining and mineral processing*.
Mining operations	Pathogens from faecal matter, hydrocarbons, other chemicals and nutrients.	High–low	Mining is compatible with conditions in P1 areas.	WQPG 1–11: *Mining and mineral processing*.
Access roads	Hydrocarbons and chemicals	Medium	Mining is compatible with conditions in P1 areas.	WQPN no. 44: *Roads near sensitive water resources.*
Mining leases	Pathogens from faecal matter, hydrocarbons, other chemicals and nutrients.	High–low	Mining is compatible with conditions in P1 areas.	WQPG 1–11: *Mining and mineral processing*.
Recreation	Pathogens from faecal contamination	Medium	Existing recreation activities are compatible with the priority 1 area.	Statewide policy no. 13: *Policy and guidelines for recreation within public drinking water source areas on Crown land.*

[1] Full details of guidance notes, further information is provided in the references list. Information on the hazards associated with land use activity is detailed further within Appendix C.

4 Protecting your drinking water source

The objective of this plan is to ensure that safe drinking water is available to consumers now and in the future. This objective needs to be achieved while recognising the rights of existing approved land uses to continue. The protection objectives for the Bungaroo Creek Water Reserve are to:

- Ensure drinking water source protection is built into mine planning and other land use development decisions and implemented during operation.
- Identify land uses that pose a contamination risk and manage those land uses to avoid or reduce water quality contamination risks.

4.1 Proclaiming the public drinking water source area

In order to protect the quality of the drinking water source, we are proposing to proclaim the Bungaroo Creek Water Reserve under the *Country Areas Water Supply Act 1947* (Refer to Figure A2 and Figure A5 in Appendix A).

Once the water reserve is proclaimed the local government authority is expected to incorporate the PDWSA into their planning schemes consistent with State planning policy no. 2.7: *Public drinking water source policy*. PDWSAs are commonly shown in planning schemes as special control areas. This provides guidance for state and local government planning decision makers and developers.

Proclamation of a PDWSA will not change the zoning of the land. All existing, approved land uses and activities in a proclaimed area can continue. However, best management practices should be employed in PDWSAs to protect the quality of the drinking water source. New developments or expansion of existing land uses or activities need to consider the recommendations in this plan.

For more guidance on appropriate land uses and activities in a PDWSA please refer to our WQPN no. 25: *Land use compatibility in public drinking water source areas*.

4.2 Defining priority areas

The protection of PDWSAs relies on statutory and non-statutory measures for water resource management and land-use planning. The Department of Water's policy for the protection of PDWSAs includes a system that defines three specific priority areas:

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

The determination of priority areas is based on the strategic importance of the land or water source including risks to water quality and quantity, the form of land tenure and existing approved land uses or activities. For further detail, please refer to our WQPN no. 25: *Land use compatibility in public drinking water source areas*.

The priority areas for the Bungaroo Creek Water Reserve have been determined in accordance with current Department of Water policy. These areas are described below and displayed in Figure A5. Our WQPN no.25: *Land use compatibility in public drinking water source areas* outlines activities that are 'acceptable', 'compatible with conditions' or 'incompatible' within the different priority areas. For an explanation of the background and support for protection of PDWSAs, please refer to WQPN no. 36: *Protecting public drinking water source areas*.

The Bungaroo Creek Water Reserve will to be managed as a P1 area. The designation of the P1 area is consistent with the Western Australian Planning Commission's *Statement of Planning Policy No. 2.7,* as the water reserve is located over crown lease and unallocated crown land (Refer to Figure A2 – A4). Designation of the P1 area is a result of the unconfined to semi - confined nature of the aquifer system and the need for an adequate management objective that provides appropriate protection measures to mitigate contamination risks specific to the Bungaroo Creek Water Reserve.

Existing mining operations by Robe River Iron Associations within the water reserve, are defined as a land use that is 'compatible with conditions' under the P1 management objective. The conditions of which, relate to;

- the report and recommendations of the EPA for the Mesa J mine, which identifies environmental impacts and their management, including Robe River Iron Associate's commitments, and
- the management objectives and operating rules to be attached to the 5C licence to take water, described within the *Water Resources Management Operating Strategy*.

4.3 Defining protection zones

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

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

The 9 production bores utilised within the Bungaroo Creek Water Reserve will be further protected by 500m WHPZ. The WHPZs have been designated around each production bore due to the unconfined – semi – confined nature of the aquifer.

4.4 Planning for future land uses

It is recognised under the Western Australian Planning Commission's (WAPC) *State planning strategy* (1997) that appropriate protection mechanisms in statutory land-use planning processes are necessary to secure the long-term protection of drinking water sources. As outlined in the WAPC's Statement of planning policy no.2.7: *Public drinking water source policy* (2003) it is appropriate that the Bungaroo Creek Water Reserve, its priority area and WHPZ's be recognised in the Shire of Ashburton town planning scheme No. 7 (district scheme). The Bungaroo Creek Water Reserve is located over rural zoned land within the town planning scheme. Any development proposals within the Bungaroo Creek Water Reserve that are inconsistent with advice in our WQPN no.25: *Land use compatibility in public drinking water source areas* or recommendations in this plan, need to be referred to the Department of Water for advice.

For further information on the integration of land-use planning and water source protection, please refer to our WQPN no.36: *Protecting public drinking water source areas*. This protection note describes the findings of two Parliamentary Committee reviews instrumental in the integration of water quality protection and land use planning in WA.

The department's protection strategy for PDWSAs provides for approved developments to continue even if those facilities would not be supported under current water quality protection process. In these instances, the department can provide advice to landowners or operators on measures they can use to improve their facilities and reduce water quality contamination risks (see section *4.5: Using best management practices*).

4.5 Using best management practices

There are opportunities to reduce water contamination risks by carefully considering design and management practices. To help protect water sources, the Department of Water will continue to encourage the adoption of best management practices in PDWSA.

Guidelines on best management practices for many land uses are available in the form of industry codes of practice, environmental guidelines and water quality protection notes. They outline the recommended practices to ensure the protection of water quality and can thus help managers reduce any detrimental effects of their operations. These guidelines have been developed in consultation with stakeholders such as industry groups, agricultural producers, state government agencies and technical advisers. Examples include the *Water Quality Protection Guidelines – Mining and Mineral Processing 2000*, and *Water Quality Protection Note No. 35: Pastoral activities within rangelands* which are listed in this plan's *References and further reading* section.

Education and awareness-raising (such as signage and publications) are key mechanisms for protecting water quality, especially for people visiting the area.

We will produce a brochure once this plan is finalised, describing the Bungaroo Creek Water Reserve, its location, threats to its water quality and solutions. The brochure will inform people in simple terms about the drinking water source and why it is important to protect it. We will make it available to the community and other stakeholders.

4.6 Enforcing by-laws and surveying the area

The quality of water in PDWSAs within country areas of the state is protected under the *Country Areas Water Supply Act 1947*. Proclamation of PDWSAs allows by-laws to be applied to protect water quality.

The Department of Water considers by-law enforcement, through surveillance of land-use activities in PDWSAs, to be an important mechanism to protect water quality.

Signs will be erected on the boundaries of this water reserve to educate and advise the public about activities that are prohibited or regulated.

4.7 Responding to emergencies

The escape of contaminants during unforeseen incidents and the use of chemicals during emergency responses can result in water contamination. The Shire of Ashburton local emergency management committee (LEMC), through the Pilbara emergency management district, should be familiar with the location and purpose of the Bungaroo Creek Water Reserve.

A locality plan will be provided to the fire and rescue services headquarters for the hazardous materials (HAZMAT) emergency advisory team. RTIO should have an advisory role to the HAZMAT team for incidents in the Bungaroo Creek Water Reserve.

Personnel who deal with WESTPLAN–HAZMAT (Western Australian plan for hazardous materials) incidents within the area should have access to a map of the Bungaroo Creek Water Reserve. These personnel should have an adequate understanding of the potential impacts of spills on this drinking water source and public health.

4.8 Putting this plan into action

Table 1 (found at the end of Section 3) identifies the potential water quality risks associated with existing land uses in the Bungaroo Creek Water Reserve. Further information and the recommended protection strategies to deal with those risks are outlined in Appendix C.

When the final *Bungaroo Creek Water Reserve drinking water source protection plan* is complete, an implementation strategy will be drawn up based on the recommendations in Appendix C.

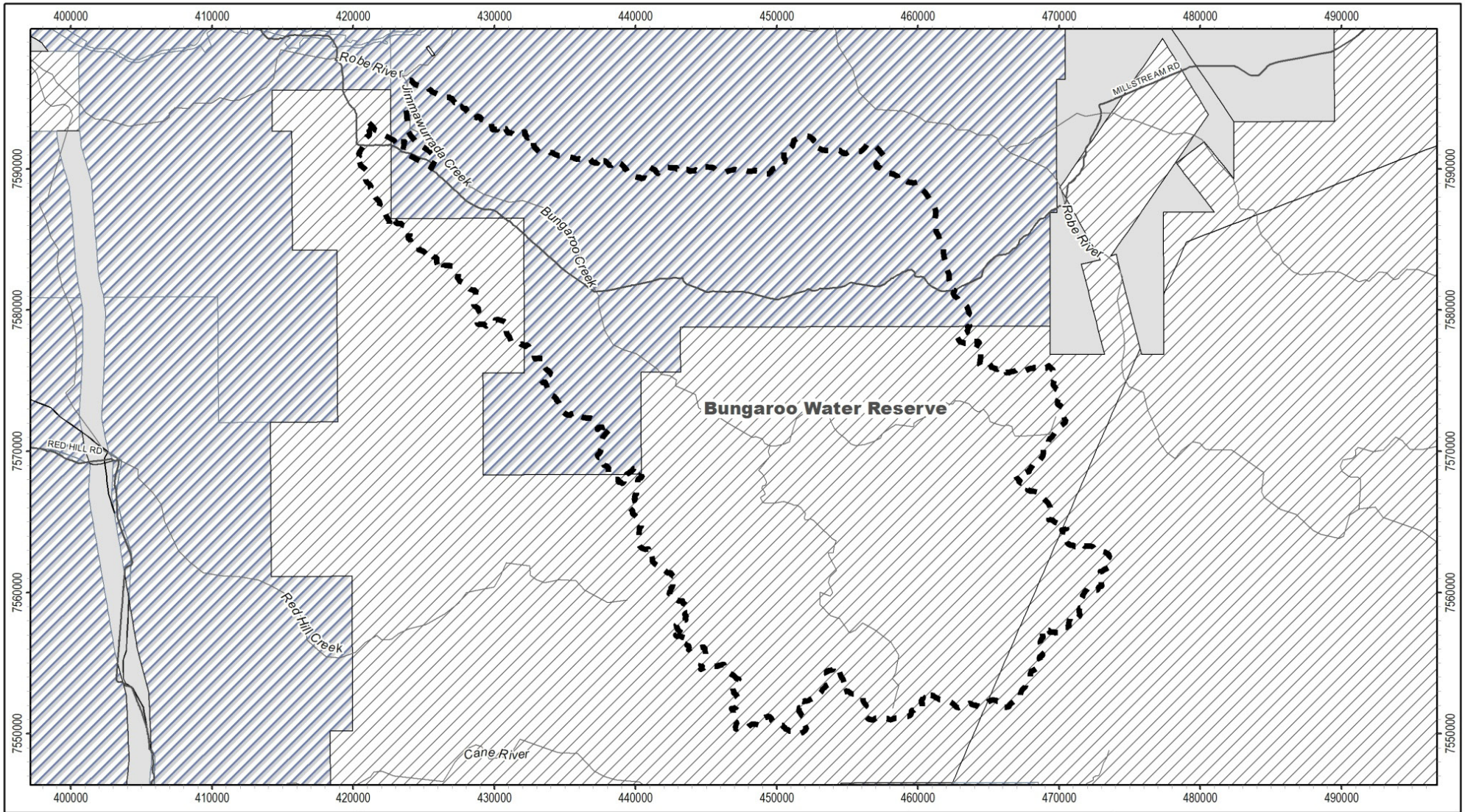
5 Recommendations

The following recommendations apply to the entire Bungaroo Creek Water Reserve. Stakeholders (in brackets) are those expected to have a responsibility for, or an interest in, the relevant recommendation being implemented.

1. Proclaim the Bungaroo Creek Water Reserve under the *Country Areas Water Supply Act 1947* – (Department of Water).
2. Develop an implementation strategy for this plan's recommendations (including the recommended protection strategies as detailed in Appendix C) – (Department of Water, Kuruma Marthudunera People and Rio Tinto Iron Ore).
3. Incorporate this plan and reflect the identified Bungaroo Creek Water Reserve boundary, priority 1 area and protection zones in the Shire of Ashburton local planning scheme in accordance with the WAPC's Statement of planning policy no.2.7: *Public drinking water source policy* – (Shire of Ashburton).
4. All development proposals within the Bungaroo Creek Water Reserve that are inconsistent with the Department of Water's Water quality protection note no. 25: *Land use compatibility in public drinking water source areas* and recommendations in this plan should be referred to the Department of Water – (Department of Planning, Shire of Ashburton, proponents of proposals).
5. Incidents covered by WESTPLAN–HAZMAT in the Bungaroo Creek Water Reserve should be addressed by ensuring that:
    - Shire of Ashburton LEMC is aware of the location and purpose of the Bungaroo Creek Water Reserve
    - the locality plan for the Bungaroo Creek Water Reserve is provided to Fire and Emergency Services Authority of Western Australia headquarters for the HAZMAT emergency advisory team
    - Department of Water acts in an advisory role during incidents in the Bungaroo Creek Water Reserve
    - personnel dealing with Westplan–HAZMAT incidents in the area have ready access to a locality map of the Bungaroo Creek Water Reserve and information to help them recognise the potential impacts of spills on drinking water quality – Department of Water
    - signs are erected along the boundary of the Bungaroo Creek Water Reserve, including an emergency contact telephone number – (Rio Tinto Iron Ore).
6. Review this plan after five years – (Department of Water).
7. Rio Tinto Iron Ore should prepare a catchment strategy for the water reserve, in consultation with the Department of Water's regional office – (Rio Tinto Iron Ore, Department of Water).
8. Prevention of stock entering the wellhead protection zones and areas sensitive to contamination – (Rio Tinto Iron Ore).

Appendices

Appendix A – Figures



SOURCE DATA

Department of Water acknowledges the following datasets and their custodians in the production of this map:

Dataset Name - Custodian - Metadata Date
Roads – Landgate – 2010
Cadastre - Landgate - 2011

LEGEND

- Towns
- Roads
- Proposed Bungaroo WR

Cadastre, Land Tenure

- Crown Reserve
- Crown Lease
- Unallocated Crown Land

N

0 4 8
Kilometres

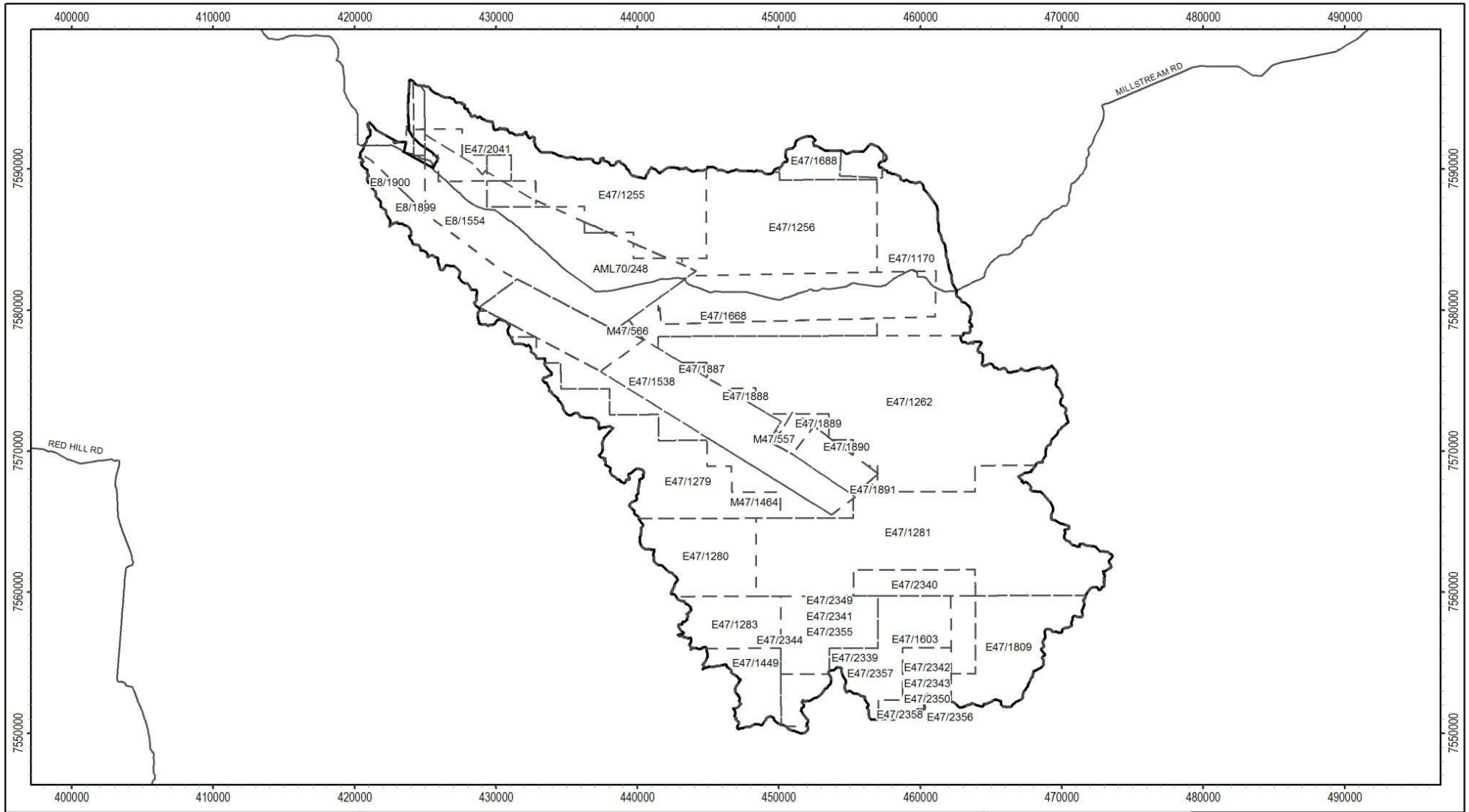
LOCATION

Water and Land Use Division
Water Source Protection Planning Branch

Project officer: C. Robertsn Drawn by: C Qiu
Date: 13/09/2012
File path: J:\gisprojects\Project\B_Series\B2010\0120_Bungaroo_WR\mxd
File name: Bungaroo_Fig2.mxd
Coordinate system: MGA94 Zone 50

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

FIGURE 2 PROPOSED BUNGAROO WATER RESERVE AND LAND TENURE.



SOURCE DATA

Department of Water acknowledges the following datasets and their custodians in the production of this map:

Dataset Name - Custodian - Metadata Date
Roads – Landgate – 2010
Cadastre, Land Tenure - Landgate - 2011
Mining Tenement Data - Dept. of Industry and Resources - 2010

LEGEND

- Towns
- Roads
- Mining Tenements
- Proposed Bungaroo WR

N

0 4 8
Kilometers

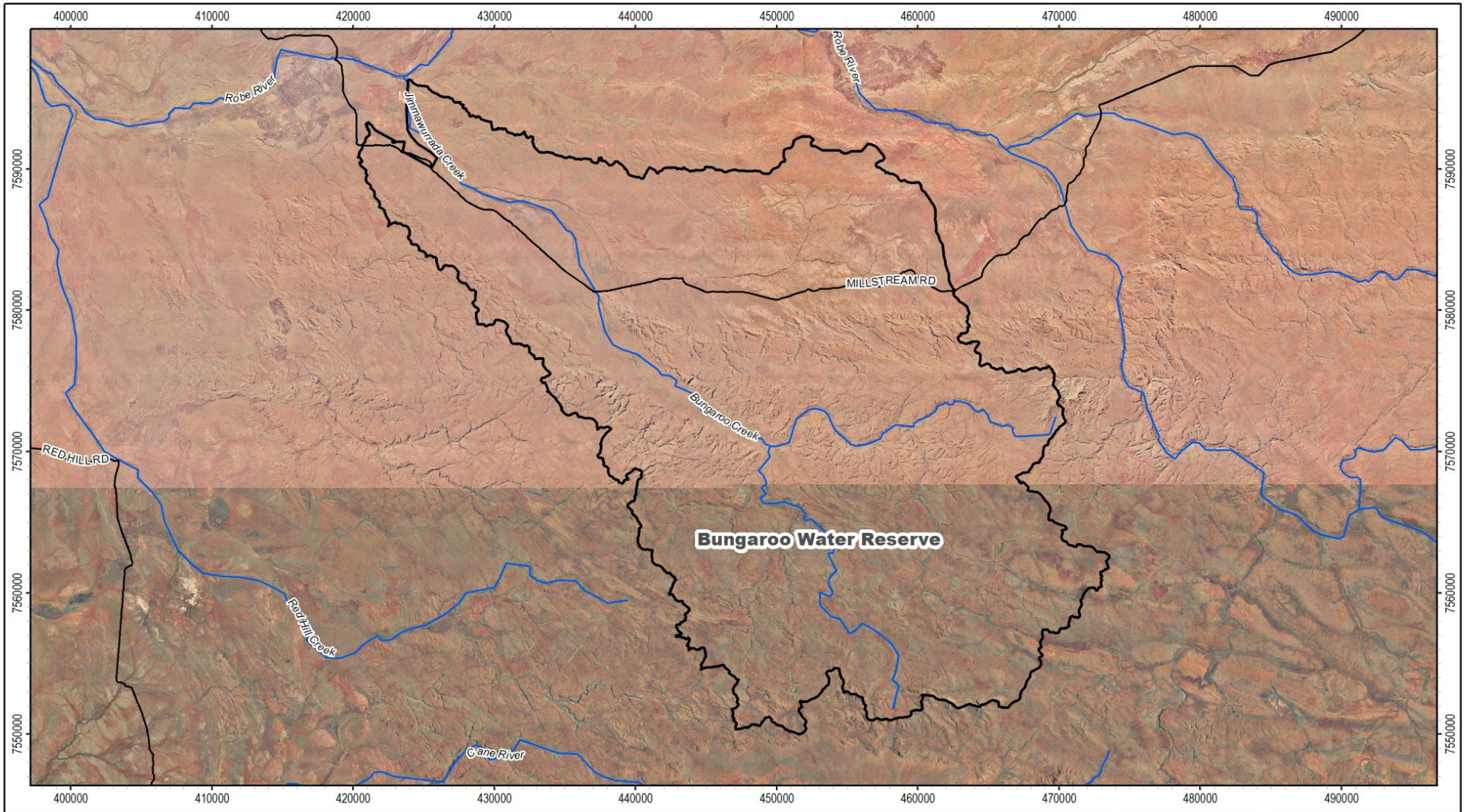
LOCATION

Water and Land Use Division
Water Source Protection Planning Branch

Project officer: C. Robertsn Drawn by: C Qiu
Date: 13/09/2012
File path: J:\gisprojects\Project\B_Series\B2010\0120_Bungaroo_WR\mxd
File name: Bungaroo_Fig3.mxd
Coordinate system: MGA94 Zone 50

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

FIGURE 3 MINING TENEMENTS IN THE PROPOSED BUNGAROO WATER RESERVE



SOURCE DATA

Department of Water acknowledges the following datasets and their custodians in the production of this map:

Dataset Name - Custodian - Metadata Date
Roads – Landgate – 2010
Rivers, DoW - DoW - 2007
Aerial Photography - Landgate - 2005

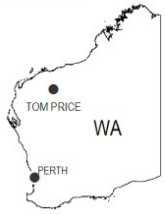
LEGEND

- Towns
- Roads
- River
- Proposed Bungaroo WR

N

0 4 8
Kilometres

LOCATION

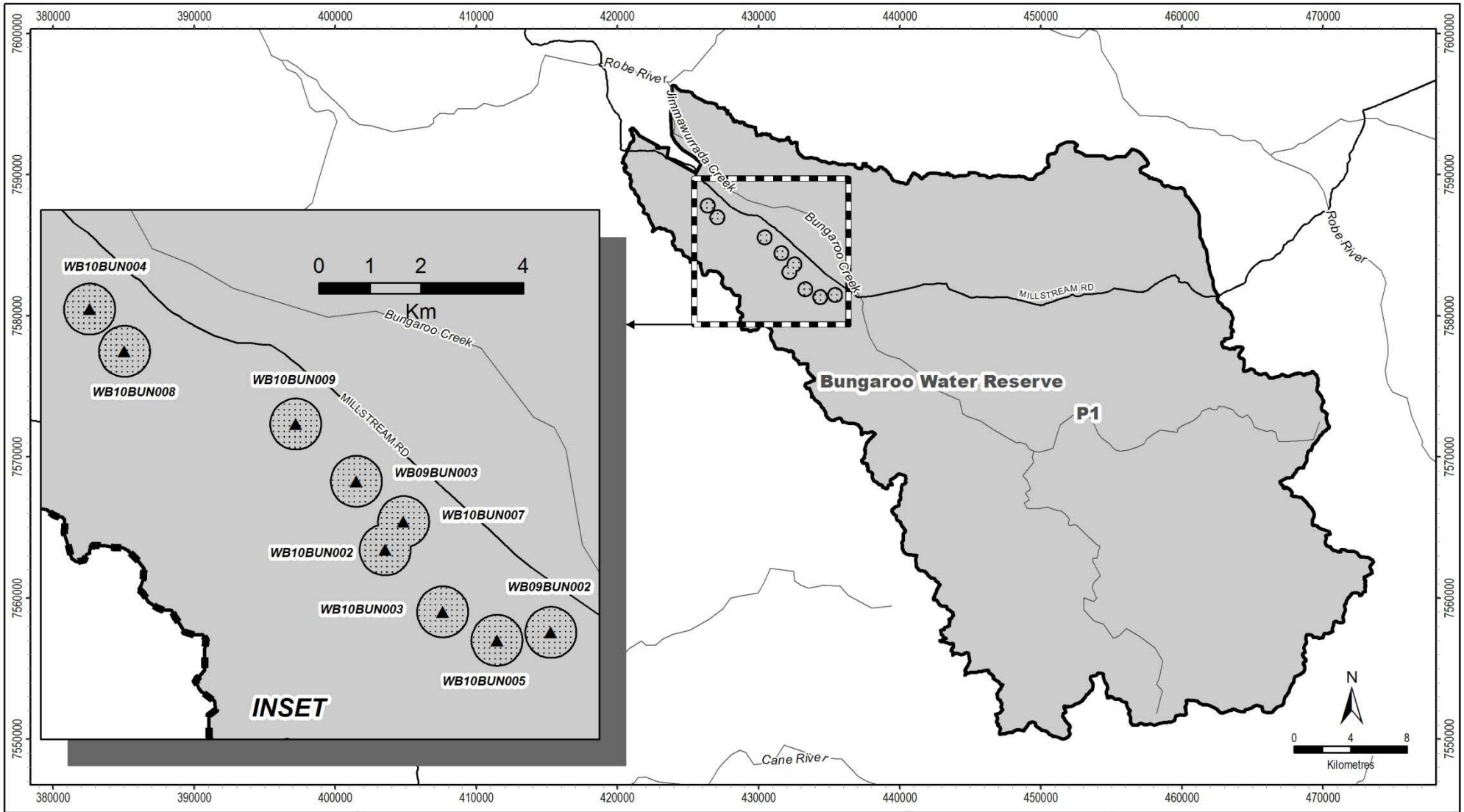


Water and Land Use Division
Water Source Protection Planning Branch

Project officer: C. Robertsn Drawn by: C Qiu
Date: 13/09/2012
File path: J:\gisprojects\Project\B_Series\B2010\0120_Bungaroo_WR\mxd
File name: Bungaroo_Fig4.mxd
Coordinate system: MGA94 Zone 50

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

FIGURE 4 AERIAL PHOTOGRAPHY IN AND AROUND THE PROPOSED BUNGAROO WATER RESERVE



SOURCE DATA

Department of Water acknowledges the following datasets and their custodians in the production of this map:

Dataset Name - Custodian - Metadata Date
Roads – Landgate – 2010
Aerial Photography - Landgate - 2005

LEGEND

- Towns
- Production bore
- Roads
- River
- Proposed Bungaroo WHPZ
- Proposed Bungaroo WR
- Priority One Area

LOCATION

Water and Land Use Division
Water Source Protection Planning Branch

Project officer: C. Robertsn Drawn by: C Qiu
Date: 13/09/2012
File path: J:\gisprojects\Project\B_Series\B2010\0120_Bungaroo_WR\mxd
File name: Bungaroo_Fig5.mxd
Coordinate system: MGA94 Zone 50

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

FIGURE 5 PROTECTION ZONE AND PRIORITY AREA FOR THE PROPOSED BUNGAROO WATER RESERVE

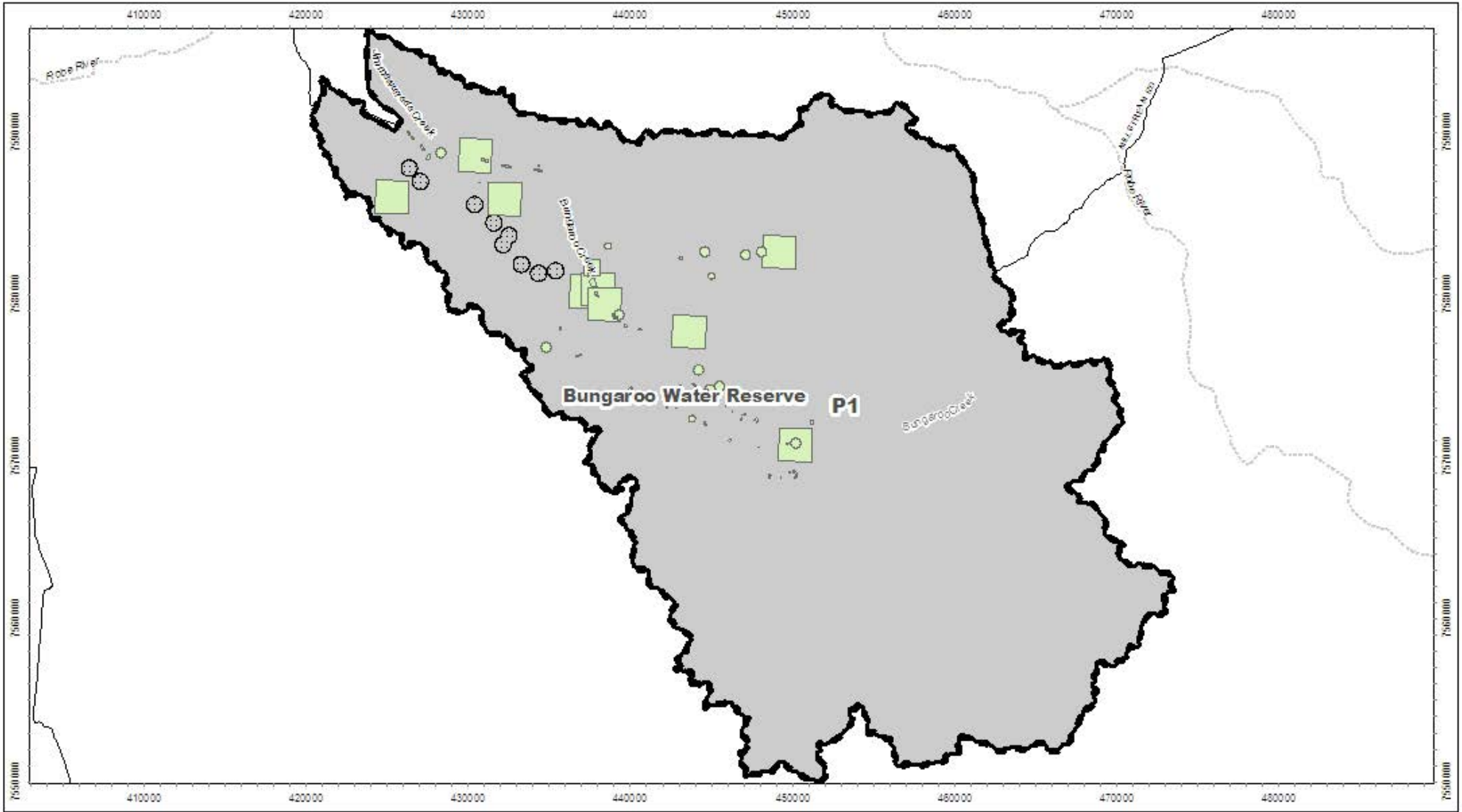


FIGURE 6 ABORIGINAL SITES OF SIGINIFICANCE WITHIN THE PROPOSED BUNGAROO WATER RESERVE

Appendix B – Water quality data

The raw water quality data provided in this appendix has been prepared by Rio Tinto Iron Ore.

The company monitored the raw (source) water quality from Bungaroo Creek borefield.

This data showed the quality of water in the aquifer. An assessment of the drinking water quality was also made in accordance with the *National water quality management strategy: Australian drinking water guidelines 6*, 2004 (ADWG) (NHMRC & NRMMC 2004a), with interpretations agreed to with Department of Health. The raw water will be monitored regularly for:

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

The following data represents the quality of raw water in the Bungaroo Creek aquifer. 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. Results that exceed the guidelines have been shaded to give an indication of potential raw-water quality issues associated with this source.

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. The values are taken from monitoring for the period December 2011. Current water quality data will be provided for the final Bungaroo Creek Water Reserve drinking water source protection plan.

Any water quality parameters that have been detected are reported, with those that on occasion have exceeded the guidelines emphasized with bold and italics.

For more information on the water quality for the towns supplied by the West Pilbara Water Supply Scheme – which include Karratha, Dampier, Roebourne, Cape Lambert and Point Samson – into which water from the Bungaroo Creek borefield will be supplied, see the Water Corporation's most recent drinking water quality annual report at <www.watercorporation.com.au>.

Aesthetic

The aesthetic quality analyses for raw water from Bungaroo Creek are summarised in the following table.

Aesthetic detections for Bungaroo Creek (bold and italics show exceeded values)

			Bungaroo Creek Water Reserve	
Parameter	**Units**	**ADWG aesthetic guideline value[2]**	**Range**	**Median**
Aluminium (acid soluble)	mg/L	0.2	0–***0.3***	0.0
Chloride	mg/L	250	27–62	38
Colour (true)	TCU	15	0–3	0
Conductivity	mS/m	–	230–500	330
Hardness as CaCO3	mg/L	200	53–160	99
Iron unfiltered	mg/L	0.3	0–0.26	0.01
Manganese unfiltered	mg/L	0.1	0–0.07	0.0
Sodium	mg/L	180	17–34	25
Sulfate	mg/L	250	8–17	11
Total filterable solids by summation	mg/L	500	128–382	214.5
Turbidity	NTU	5	0–***5.4***	0.2
pH measured in laboratory	no units	6.5–8.5	***6.0***–8.1	7.0

[2] An aesthetic guideline value is the concentration or measure of a water quality characteristic that is associated with good quality water.

Health related

Health-related chemicals

Raw water from Bungaroo is analysed for chemicals that are harmful to human health, including categories of chemicals such as inorganics, heavy metals, industrial hydrocarbons and pesticides. Health-related parameters that affect water quality are summarised in the following table.

Health-related detections for Bungaroo Creek [bold and italics for exceeded values)

			Bungaroo Creek Water Reserve	
Parameter	**Units**	**ADWG aesthetic guideline value[3]**	**Range**	**Median**
Barium	mg/L	0.7	0–***0.12***	0.01
Boron	mg/L	4	0–0.2	0.0
Nitrite as nitrogen	mg/L	0.91	0–0.11	0.0
Nitrite plus nitrogen as N	mg/L	11.29	0–10.8	1.35

[3] 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 2004a).

Microbiological contaminants

Microbiological testing of raw-water samples from Bungaroo Creek was conducted during December 2011. *Escherichia coli* counts are used as an indicator of the degree of recent faecal contamination of the raw water from warm-blooded animals. A count of less than 20 MPN (most probable number) per 100 millilitre sample is typically associated with low levels of faecal contamination and is used as a microbiological contamination benchmark of the raw water (WHO 2004). As such, counts less than 20 MPN are seen as indicating raw water that has not been recently contaminated with faecal material.

During the December 2011 monitoring period, no positive *E. coli* counts were detected within the samples taken for each production bore.

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

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
Pastoral lease					
Stock grazing	Pathogens from animal faeces and decaying cattle	High	Consideration of fencing Old Yalleen and provision of water trough for cattle etc Prevention of stock access to the WHPZs	• water quality monitoring • onsite water disinfection	• Ensure adherence to WQPN no. 35: *Pastoral activities within rangelands*. • Pest animal control carried out in accordance with WQPN no. 96: *Pest animal management in PDWSAs*. • Investigate potential for temporary fencing of WHPZs.
	Nutrients from animal faeces and decaying cattle	Medium	Prevention of stock access to the WHPZs		
Stockyards	Pathogens from animal faeces	Medium	Location of future stockyards to be outside of the water reserve.		• Expansion or further development of stockyards should be in accordance with WQPN no. 80: *Stockyards.*
	Nutrients from animal faeces	Medium	Location of future stockyards to be		

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
			outside of the water reserve.		
Future mining					
Vehicle and fuel tanker access and operation	Hydrocarbons from spills, leaks and incidents.	Medium	Hydrocarbon Operational Control Procedures for the existing Bungaroo camp. Response protocols Vehicle HSE standards, driving policies / procedures	• water quality monitoring • Rio Tinto Operational Control Procedures.	• WQPN no.10: *Contaminant spills – emergency response.* • WQPN no. 44: *Roads near sensitive water resources.*
	Chemicals from spills, leaks and incidents.	Medium			
Ore extraction	Hydrocarbons from machinery associated with drill and blast operations	Medium	Current groundwater quality monitoring Chemical approval process / National Pollution Inventory	• water quality monitoring • RTIO Operational Control	• WQPN no.10: *Contaminant spills – emergency response.* • WQPN no. 56: *Tanks for elevated chemical storage.*

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
	Nutrients associated with ammonia nitrate fuel oil (ANFO) explosives during blasting operations.	Medium	(NPI) audits Current groundwater quality monitoring	Procedures.	• WQPG no.10: *Above-ground fuel and chemical storage.*
	Chemical spills from storage failure	Low			
Administration buildings, workshops, wash down and storage facility	Pathogens from septic tanks and waste water.	Medium	Investigate lined evaporation ponds as per Mesa J mine Consider location of admin buildings / treatment plant etc in relation to borefield	• water quality monitoring • onsite water disinfection	• WQPN no. 09: *Community drinking water sources*
	Nutrients from waste water spills.	Medium	Bunding for the tank to be included in design. Chlorination of the water (sodium		• WQPN no. 51: *Industrial wastewater management and disposals*

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
			hypochlorite)		
	Pesticides from termite spraying.	Medium	List of approved chemicals Termite spraying as a shire requirement around buildings	• water quality monitoring	• WQPN no. 65: *Toxic and hazardous substances.* • Public Sector Circular no. 88: *Use of herbicides in catchment areas.* • Statewide policy no. 2: *Pesticide use in Public Drinking Water Source Areas* .
	Hydrocarbons from wash down facilities and maintenance.	Medium	Contained within the workshop – bunding Above ground pipes are included in standard design Drainage across the apron is in standard design Water goes through oil / water separator as part of standard design Existing internal /		• WQPN no.10: *Contaminant spills – emergency response.* • WQPN no. 28: *Mechanical servicing and workshops* • WQPG no. 07: *Mechanical servicing* • WQPG no. 06: *Mine site stormwater*

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
			external audits (HSEQ ISO 14001) Environmental design principles in place		
	Hydrocarbons spills from storage failure.	Medium	Currently stored in dedicated chemical storage cupboards Chemical approval process No significant bulk storage of chemicals	• water quality monitoring	• WQPN no.10: *Contaminant spills – emergency response.* • WQPN no. 56: *Tanks for elevated chemical storage.* • WQPG no.10: *Above-ground fuel and chemical storage.*
	Chemicals from storage failure.	Medium	Currently stored offsite and transported to site		
Landfill	Pathogens from leach ate	High		• water quality monitoring	• WQPN no. 09: *Community drinking water sources.*
	Hydrocarbons within leach ate	Medium	Current arrangement at Evaluation Camp is to remove the landfill waste off the		
	Chemicals within				

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
	leach ate		catchment each day		
	Heavy metals within leach ate		Currently no landfill on site		
	Nutrients within leach ate				
Acid rock drainage (ARD)	Heavy metals associated with the oxidation of pyrites and acid mine drainage	Medium	Based on historical knowledge Robe Valley has no ARD material, though a small amount has been located outside of proposed mine area (25km away)	• water quality monitoring	• WQPG no. 09: *Acid mine drainage.*
Exploration	Hydrocarbons from leaks, spills and refuelling during drilling activities	Medium	Drilling standard operating procedures Environmental Operating Control Procedures Requirement for bunded areas for storage of chemical /	• water quality monitoring	• Department of Mines and Petroleum *Guidelines for the protection of surface and groundwater resources during exploration*
	Pathogens entering in adequately sealed	High			

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
	drill holes		hydrocarbons		
	Nutrients entering inadequately sealed drill holes	Medium			
	Radioactive material from geophysical equipment leaks.	Medium			
Switchyard	Hydrocarbons from electrical transformer oil leakage	Medium	Bunds required in the design standards Chemical approval process Maintenance standards Workplace inspections required on a monthly basis under the H&S standards	• water quality monitoring	• WQPN no.10: *Contaminant spills – emergency response.*
	Pesticides from	Medium	Generally not		• WQPN no. 65: *Toxic and*

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
	routine spraying to the yard		required to be used on site.		*hazardous substances.* • Public Sector Circular no. 88: *Use of herbicides in catchment areas.* • Statewide policy no. 2: *Pesticide use in Public Drinking Water Source Areas.*
Access roads					
Light vehicle access within the WHPZs	Hydrocarbons from vehicle incidents	Medium	Monitoring bores in place Signage stating no-unauthorised access in place Design of bore head is elevated Vehicle HSE standards, driving policies / procedures	• water quality monitoring	• WQPN no. 44: *Roads near sensitive water resources.* • WQPN no. 09: *Community drinking water sources.* • WQPN no.10: *Contaminant spills – emergency response.*
	Pathogens from human interaction within WHPZs	Medium			
Haulage roads in close proximity to WHPZs	Hydrocarbons from vehicle incidents	Medium	Standard design includes windrows Vehicle HSE standards, driving		
	Pathogens from	Medium			

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
	human interaction within WHPZs		policies / procedures		
Other mining leases					
Mining leases	Pathogens from faecal matter, hydrocarbons, other chemicals and nutrients.	High–low	Mining is compatible with conditions in P1 areas	• water quality monitoring	• WQPG 1–11: *Mining and mineral processing.* • Administrative Agreement between Department of Mines and Petroleum and the Department of Water for mining referrals under the *Mining Act 1978.*
Borefield					
Diesel generators	Hydrocarbons from spills/ leaks from backup generators	Medium	Standards for diesel gen-sets – ie self-contained Auditing process in place Monitoring bore	• water quality monitoring	• WQPN no.10: *Contaminant spills – emergency response.* • WQPN no. 56: *Tanks for elevated chemical storage.* • WQPG no.10: *Above-ground fuel and chemical storage.*
Cyclone activity	Nutrients transported to borefield through floods	Low	Sealed bores Bore head design is elevated.	• water quality monitoring • Cyclone management	• National Minimum Bore Specification Committee's *Minimum construction requirements for water bores in Australia.*

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
	Pathogens transported to borefield from floods	High	Turn the borefield off while water subsides Cyclone management plan	plan	
Monitoring activities	Pathogens from human interaction within WHPZs	Medium	Signage stating no-unauthorised access in place	• water quality monitoring	• WQPN no.10: *Contaminant spills – emergency response.* • WQPN no. 30: *Groundwater monitoring bores.* • National Minimum Bore Specification Committee's *Minimum construction requirements for water bores in Australia.*
	Nutrients from human interaction within WHPZs	Medium			
	Hydrocarbons from vehicles	Medium	Standard design includes windrows Vehicle HSE standards, driving policies / procedures		
Recreation					

Land use/activity	Potential water quality risks		Consideration for management	Current preventive measures	Recommended protection strategies
	Hazard	**Management priority**			
Camping	Pathogens from bodily contact within swimming holes.	Medium	Not known to occur often in the area	• water quality monitoring	• Statewide policy no. 13: *Policy and guidelines for recreation within public drinking water source areas on Crown land.*
	Hydrocarbons from vehicles	Medium			
	Nutrients from camp waste/fires.	Medium			
Traditional land use					
The Kuruma Marthudunera People's Native Title Claim and sites of significance are recognised by the Department of Water (refer to section 3.2.3). Rio Tinto has agreed to develop heritage and environmental management plans as part of the Participation Agreement for the Coastal Water Project. The Kuruma Marthudunera People are also identified as key stakeholders in the development of an implementation strategy (refer to section 5) consistent with the recommendations of this plan.					

Appendix D – Photographs

Figure D1 Six Mile Well

Figure D2 Cattle in Old Yalleen

Appendix E – Aboriginal sites of significance

Site no.	Site name	Site identification no.
	BBR-02	22175
	BBR-03	22176
	BC02-01	24356
	BC02-02	24355
	BC02-03	24354
	BC02-04	24353
	BC02-05	24352
	BC02-06	24351
	BC02-07	24350
	BC02-08	24349
	BC02-09	24348
	BC02-10	24347
	BC02-11	24346
	BC02-12	24345
	BC02-13	24342
	BC02-14	24341
	BC02-15	24340
	BC02-16	24339
	BC02-17	24338
	BC02-18	24337
	BC02-19	24336
	BC02-21	24358

Site no.	Site name	Site identification no.
	BC02-24	24357
	BC04-25	24283
	BC04-26	24284
	BC04-27	24291
	BC04-28	24292
	BC04-30	24294
	BC04-31	24295
	BC04-32	24298
	BC04-33	24299
	BC04-34	24300
	BC04-35	24301
	BC04-36	24302
	BC04-37	24303
	BC04-38	24304
	BC04-39	24305
	BC04-40	24306
	BC04-41	24307
	BC04-42	24309
	BC04-43	24310
	BC04-44	24313
	BC04-45	24312
	BC04-46	24314
	BC04-47	24315
	BC04-48	24316

Site no.	Site name	Site identification no.
	BC04-49	24318
	BC04-50	24329
	BC04-51	24330
	BC04-52	24331
	BC04-53	24332
	BC04-54	24333
	Jatangu Nama Hole	23304
	MAR07-31	24872
	Mesa J East 02-01	19694
	Mesa J East 02-02	19695
P02133	Pannawonica K Ore Body	10069
P02134	Pannawonica K Ore Body	10070
P02135	Weedai Pool/Mesa J 10	10071
P05963	Jimmawurrada Creek 01	6974
P05964	Jimmawurrada Creek 02 (BBR-01)	6975
P05965	Jimmawurrada Creek 03	6976
P05966	Jimmawurrada Creek 04	6977
P05967	Jimmawurrada Creek 05	6978
P05968	Jimmawurrada Creek 06	6979
P06052	Jimmawurrada Creek 07	6905
P06053	Jimmawurrada Creek 08	6906
P06054	Jimmawurrada Creek 09	6907
P06055	Bungaroo Creek 1	6908

Site no.	Site name	Site identification no.
P06056	Bungaroo Creek 2	6909
P06057	Bungaroo Creek 3	6910
P06058	Bungaroo Creek 4	6911
P06059	Jimmawurrada Creek 10	6859
P06060	Jimmawurrada Creek 11	6860
P06061	Jimmawurrada Creek 12	6861
P06062	Bungaroo Creek 5	6862
P06063	Bungaroo Creek 6	6863
P06064	Six Mile Well and Dam	6864
P06383	Jimmawurrada 14/Mesa J 47	6588
P06384	Jimmawurrada 15/Mesa J 49	6589
P06385	Jimmawurrada 16/Mesa J 48	6590
P06386	Jimmawurrada 17/Mesa J 50	6591
P06387	Jimmawurrada Creek 18	6592
P06388	Jimmawurrada Creek 19	6593
P06389	Jimmawurrada Creek 20	6594
P06390	Jimmawurrada Creek 21	6595
P06391	Jimmawurrada Creek 22	6546
P06456	Nyirimugga Gap	6506
P06457	Ngarawanja	6507
P06463	Yathala Well Burial 1	6513
P06464	Yathala Well Burial 2	6514

Site no.	Site name	Site identification no.
P06465	Yathala Well Burial 3	6515
P06466	Yathala Well Burial 4	6516
P06516	Jimmawurrada Creek	6460
P06517	Kurpinya	6461
P06521	Six Mile Well	6465
P06523	Marlumarlunya	6414
P06525	Marta-Angku	6416
P06527	Waula-Ulari	6418
P06528	Pintorruna	6419
P06529	Warrangka	6420
P06531	Pirintanya	6422
P06534	Yeeni Watji	6425
P06536	Kowithanna	6427
P06540	Wuriyu	6431
P06549	Weedayi	6389
P06550	Puluntjurr-Marrnu	6390
P06551	Mardhuwindhaya	6391
P06552	Nyitpuri	6392
P06553	Tjimura-Urta	6393
P06585	Warumani	6374
P06680	Mesa J 03	6260
P06685	Mesa J 09	6265
P06687	Mesa J 11	6267
P06714	Mesa J 46	6244

Appendix F – Mining tenements

Tenement identification no.	Holder name
E 4701280	De Beers Australia Exploration Ltd
E 4702041	Cazaly Iron Pty Ltd
E 0801900	Iron Ore Holdings Ltd
E 4701688	FMG Pilbara Pty Ltd
E 4701887	BC Iron Ltd
E 0801899	Iron Ore Holdings Ltd
E 4701889	BC Iron Ltd
E 4701283	De Beers Australia Exploration Ltd
E 4701538	PEL Iron Ore Pty Ltd
E 4701890	BC Iron Ltd
E 4701809	FMG Pilbara Pty Ltd
E 4701888	BC Iron Ltd
AML7000248	Robe River Ltd
E 4701170	Helix Resources Ltd
E 4701449	FMG Pilbara Pty Ltd
E 4701891	BC Iron Ltd
M 4701464	PEL Iron Ore Pty Ltd
E 0801554	PEL Iron Ore Pty Ltd
E 4701256	Westiron Pty Ltd
E 4701603	Brockman Iron Pty Ltd
E 4701255	De Beers Australia Exploration Ltd
E 4702339	Giralia Resources Pty Ltd

Tenement identification no.	Holder name
E 4702340	TVN Corporation Limited (Modun Resources LTD
E 4701262	De Beers Australia Exploration Ltd
E 4701279	Westiron Pty Ltd
E 4701281	Aquila Steel Pty Ltd
M 4700557	North Mining Ltd
M 4700566	North Mining Ltd
E 4702356	Wilgus Investments Pty Ltd
E 4702358	FMG Pilbara Pty Ltd
E 4702350	Iron Ore Holdings Ltd
E 4702342	Aquila Steel Pty Ltd
E 4702343	Sheffield Resources Ltd
E 4702341	AMCI (IO) Pty Ltd
E 4702349	Iron Ore Holdings Ltd
E 4702355	Wilgus Investments Pty Ltd
E 4702357	FMG Pilbara Pty Ltd
E 4702344	Sheffield Resources Ltd

List of shortened forms

ADWG	*Australian drinking water guidelines*
AHD	Australian height datum
CFU	colony forming units
DEC	Department of Environment and Conservation
EC	electrical conductivity
GL	Gigalitre
ha	Hectare
HAZMAT	hazardous materials
kL	kilolitre
km	kilometre
km^2	square kilometre
LEMC	local emergency management committee
m	metres
mg/L	milligram per litre
mL	millilitre
ML	megalitre
mm	millimetre
MPN	most probable number
mSv	millisievert
mS/m	millisiemens per metre
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
NTU	nephelometric turbidity units
PSC 88	public sector circular no. 88
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
WHPZ	wellhead protection zone
Westplan–HAZMAT	Western Australian plan for hazardous materials

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, e.g. appearance, taste and odour (NHMRC & NRMMC 2004a).
allocation	The quantity of water that a licensee is permitted to abstract is their allocation, 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*, 2004 (NHMRC & NRMMC 2004a) (ADWG) outlines acceptable criteria for the quality of drinking water in Australia (see this plan's Bibliography).
Australian Height Datum	Australian height datum is the height of land in metres above mean sea level. For example, the AHD is +0.026 m at Fremantle.
bore	A bore is a narrow, lined hole drilled into the ground to monitor or draw groundwater (also called a well).
borefield	A group of bores to monitor or withdraw groundwater is referred to as a borefield (also see *wellfield*).
catchment	The physical area of land which intercepts rainfall and contributes the collected water to surface water (streams, rivers, wetlands) or groundwater.
colony-forming units	Colony-forming units are a measure of pathogen contamination in water.
Department of Environment and Conservation	The Department of Environment and Conservation was established on 1 July 2006, bringing together the Department of Environmental Protection and the Department of Conservation and Land Management.
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.

electrical conductivity	This estimates the volume of TDS or the total volume of dissolved ions in a solution (water) corrected to 25ºC. Measurement units include millisiemens per metre and microsiemens per centimetre.
gigalitre	A gigalitre is equivalent to 1 000 000 000 litres or one million kilolitres.
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 2004a).
hectare	A measurement of area, equivalent to 10 000 square metres.
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 a total dissolved solid in a solution.
microbe	A microorganism, usually one of vegetable nature, a germ. Also known as a bacterium, especially one causing illness.
millisievert	A millisievert is a measure of annual radiological dose, with a natural dose equivalent to 2 mSv/yr.
millisiemens per metre	Millisiemens per metre is a measure of electrical conductivity of a solution or soil-and-water mix that provides a measurement of salinity.
most probable number	Most probable number is a measure of microbiological contamination.
nephelometric turbidity units	Nephelometric turbidity units are a measure of turbidity in water.
nutrient load	The amount of nutrient reaching the waterway over a given timeframe (usually per year) from its catchment area.
nutrients	Minerals, particularly inorganic compounds of nitrogen (nitrate and ammonia) and phosphorous (phosphate) dissolved in water which provide nutrition (food) for plant growth.

palaeochannel	A channel that is no longer part of the contemporary fluvial system, i.e. has been abandoned or buried.
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 parvum* 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 equal to seven is considered to be neutral, less than seven indicates an acidic solution and more than 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	Includes all underground water pollution control areas, catchment areas and water reserves constituted under the *Metropolitan Water Supply Sewerage and Drainage Act 1909* and the *Country Areas Water Supply Act 1947*.
public sector circular no. 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.
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.
semi-confined aquifer	A semi-confined aquifer or leaky aquifer is saturated and bounded above by a semi-permeable layer and below by a layer that is either impermeable or semi-permeable.
stormwater	Rainwater that has run off the ground surface, roads, paved areas etc., and is usually carried away by drains.

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 2004a).
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.
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 *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.
watertable	The upper saturated level of the unconfined groundwater is referred to as the watertable.

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.

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Department of **Water**
168 St Georges Terrace, Perth, Western Australia
PO Box K822 Perth Western Australia 6842
Phone: 08 6364 7600
Fax: 08 6364 7601
www.water.wa.gov.au

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