Procedure		Document No.	2791
Document Title	**Monitoring Program – Groundwater**		
Area	Olympic Dam Shared Services	**Issue Date**	2019
Major Process	Environment	**Sub Process**	Environment
Authoriser	Laura Tyler – Asset President Olympic Dam	**Version Number**	16

TABLE OF CONTENTS

1 SCOPE

This Monitoring Program (MP) describes the environmental monitoring activities undertaken by BHP Billiton Olympic Dam Corporation Pty Ltd (ODC) for the purpose of quantifying any change in the extent or significance of impacts of ODC's operations on groundwater, assessing the performance of the control measures employed to limit these impacts, and to meet relevant legal and other requirements.

This MP addresses a number of distinct elements of groundwater monitoring. For each element, the MP sets out background information, the purpose of the monitoring and the deliverables which are produced as a result of the monitoring. The MP also includes a description of the methods for measuring achievement of **compliance criteria** and the movement of trends towards **leading indicators** (where applicable).

The groundwater monitoring described in this MP relates solely to groundwater in the Olympic Dam region and Stuart Shelf (radius of approximately 85 kilometres (km)).

Groundwater monitoring relating to the Great Artesian Basin, approximately 100 km north of the Olympic Dam operation, is discussed in the Great Artesian Basin (GAB) Monitoring Program (Document No. 2789).

1.1 Groundwater

There are two important groundwater systems in the Stuart Shelf: the Andamooka Limestone aquifer and the Tent Hill aquifer. These form the overlying cover sequence at Olympic Dam and consist of Cambrian shale and limestone, and Late Proterozoic quartzite, sandstone and shale members, mostly of very low permeability. A schematic cross-section of these units as they occur beneath the current operation is shown in Figure 1-1 and regionally in Figure 1-2.

The upper Andamooka Limestone aquifer is the shallowest of the aquifers in the Stuart Shelf and forms the regional 'water table' aquifer north of Olympic Dam. The water table typically occurs about 50 metres (m) below ground (i.e. 50 m Australian Height Datum (AHD), with groundwater in the aquifer moving from west of the Stuart Shelf to the northern end of Lake Torrens, where the water table typically occurs less than 10 m below ground. Groundwater salinity is typically in the range of 20,000 to 60,000 milligram per litre (mg/L) on the **Special Mining Lease** (SML), increasing to as much as 200,000 mg/L closer to Lake Torrens. For comparison, seawater salinity is generally around 35,000 mg/L.

The Tent Hill aquifer is extensive and is the most important aquifer within the southern portion of the Stuart Shelf, where the Andamooka Limestone aquifer is either very thin or absent. It includes the lower parts of the Arcoona Quartzite and the Corraberra Sandstone units of the Tent Hill Formation and is therefore sometimes referred to as the Arcoona Quartzite aquifer or the Corraberra Sandstone aquifer. The aquifer occurrences reduce north of the SML due to a deepening of the unit and reduction in permeability.

At Olympic Dam, the Tent Hill aquifer typically occurs 160 to 200 m below ground level (about -60 mAHD to -100 mAHD). The depth increases moderately to the north, west and south, with the base of the unit around 225 m below ground level (-125 mAHD) near the existing underground mine and more than 400 m below ground level (-300 mAHD) north of Olympic Dam.

Groundwater salinity in the Tent Hill aquifer is generally higher than in the Andamooka Limestone aquifer, with reported concentrations ranging from about 35,000 to more than 100,000 mg/L in the vicinity of Olympic Dam, and ranging to around 200,000 mg/L closer to Lake Torrens.

The upper section of the Arcoona Quartzite unit forms an aquitard. This is a low permeability layer that restricts the movement of groundwater between the Andamooka Limestone and Tent Hill aquifers.

The aim of this program is to manage the **environmental impacts** on groundwater associated with the existing surface and underground facilities by:

- Assessing the magnitude of groundwater abstraction and groundwater discharge into the mine, and determining the mine water balance;
- Determining the changes in groundwater levels for both aquifers across site, particularly in the vicinity of the Tailings Storage Facility (TSF) and the mine water evaporation pond
- Determining any changes in radionuclide concentrations in groundwater;

- Identifying possible changes in groundwater chemistry that may occur.

To meet these objectives, data are collected on the local aquifers, and a monitoring program is conducted to measure groundwater levels and chemistry across site and regionally.

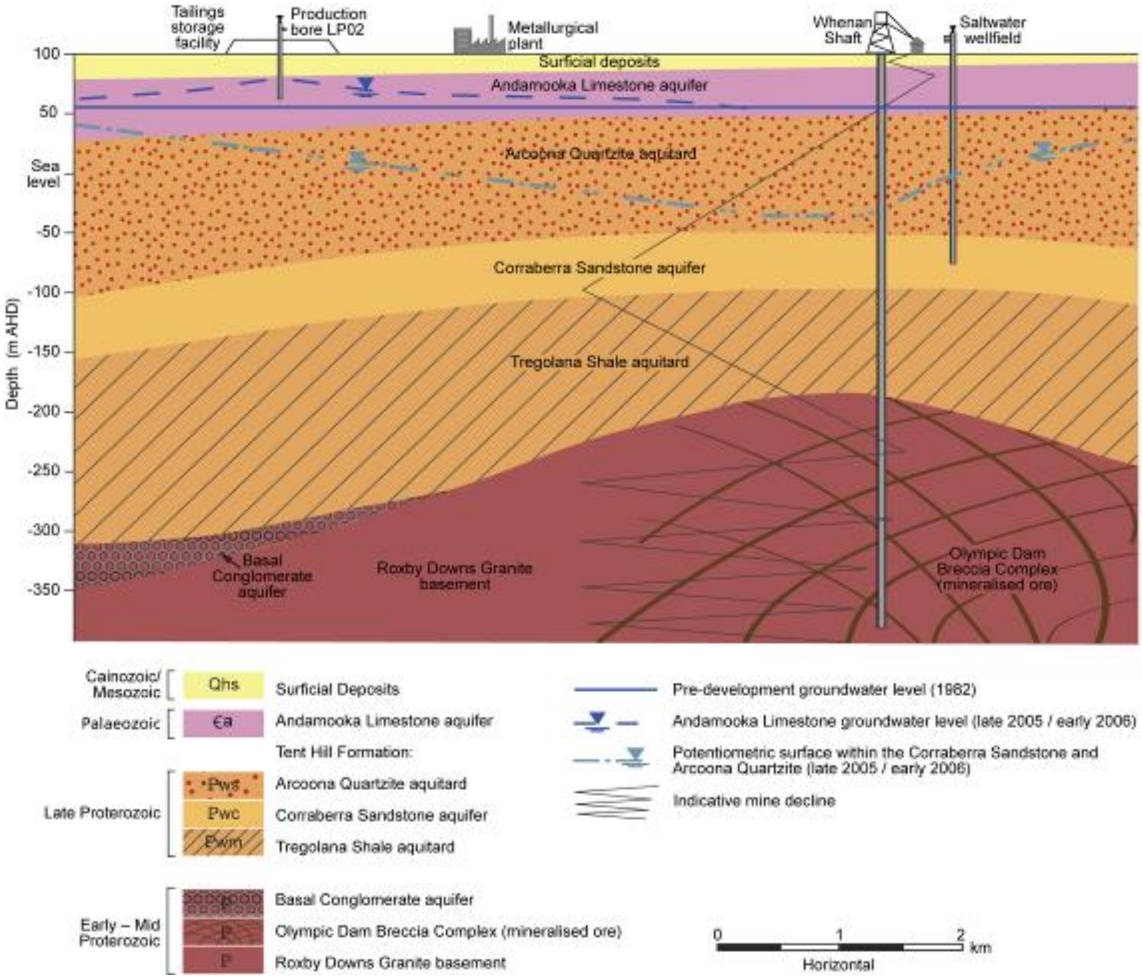

Figure 1-1: Simplified geological cross-section beneath the existing operations

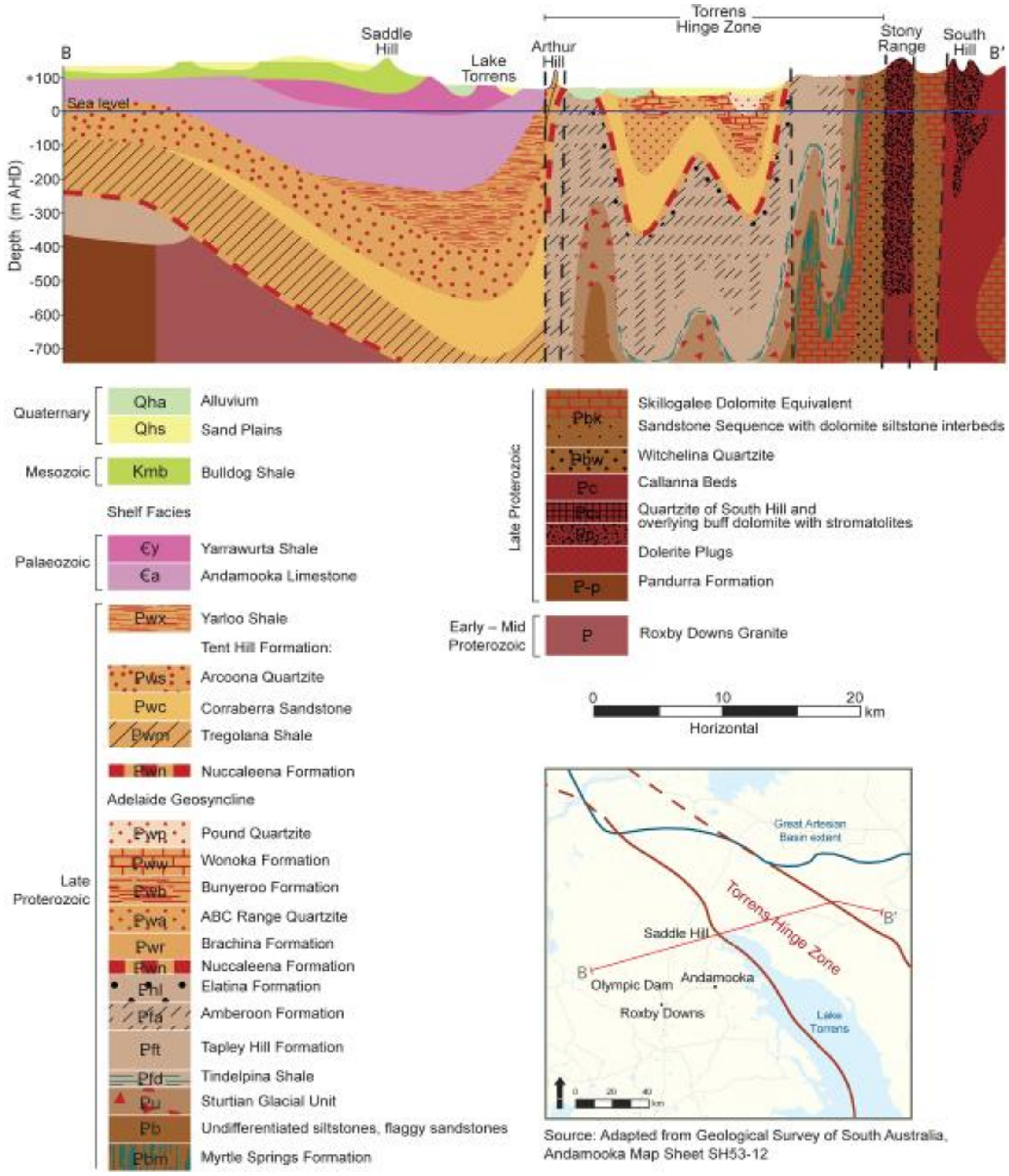

Figure 1-2: Schematic regional geological cross-section

1.2 Responsible ODC personnel

The Olympic Dam Asset President is responsible for ensuring that all legal and other requirements described in the Groundwater MP are met.

ODC employs an environmental scientist and sufficient other staff with experience and qualifications to fulfil the requirements of the Groundwater MP.

1.3 Review and modification

This MP is reviewed annually. Major changes or amendments following the review are documented in the Annual EM Program Targets, Actions and Major Changes document.

It should be noted that as a result of operational activities or through optimisation of sample design some existing monitoring sites may be lost and others added (where possible) to maintain the integrity of the sampling program. Access restrictions due to operational activities can result in some sites occasionally being unable to be monitored.

2 DETAILED PROCEDURE

Groundwater related data have been collected by ODC for over 25 years in the vicinity of Olympic Dam. The data provide baseline information to aid in the understanding of the natural systems. Data continue to be collected according to the schedules in section 5.

2.1 Groundwater abstraction and mine water balance

2.1.1 Background

ODC abstracts groundwater from the Andamooka Limestone and Tent Hill aquifer systems within the SML. The shallow Andamooka Limestone is completely dewatered in the underground mine area with inflows into the underground mine only from the deeper Tent Hill aquifer. In the TSF area and around the process plant there is considerable saturated thickness in the limestone due to seepage-induced mounding. Local groundwater is used primarily for dust suppression, construction work, underground mining operations and in the Backfill Plant.

Current water supply facilities include:

- A saline wellfield, comprising several bores which intersect a high-permeability area of the Tent Hill aquifer;
- Underground mine dewatering, primarily from the Tent Hill aquifer;
- Production bore LP2 located north of the TSF (adjacent to LT2), and the TSF5 dewatering system (located on the eastern wall of TSF5) producing from the TSF seepage mound in the Andamooka Limestone aquifer.

2.1.2 Purpose

- Derive a total groundwater extraction number for the mine area, as the basis for impact assessment.
- Monitor abstraction rates from all saline water supply sources.
- Maintain an understanding of the mine saline water balance through measurement, derivation or estimation of key parameters.
- Estimate groundwater discharge to the underground mine workings.

2.1.3 Deliverable(s)

- A review of abstraction rates and trends, and an assessment with respect to groundwater levels.
- A definition and map of the underground mine water balance.
- An estimate of the volume of groundwater discharge to underground.

2.1.4 Method

The following monitoring and recording is undertaken in relation to groundwater:

- Average daily abstraction (ML/d) from minor saline wellfields and bores.
- Total monthly abstraction (ML/d) from all groundwater abstraction sources.
- The abstraction rates are recorded in an on-site database for analysis and reporting.
- The mine water balance is calculated annually from a combination of measured, derived and estimated data.

(EPA 31543.U-518)

2.2 Groundwater level

2.2.1 Background

Underground mine dewatering and seepage from surface facilities has resulted in altered groundwater levels in both the Andamooka Limestone and Tent Hill aquifers. Pre-mining, the potentiometric surface was approximately 50 m below the surface. Changes in groundwater levels due to mining activity are shown conceptually in Figure 1-1.

In the centre of the mine area, groundwater is constantly being depleted in both aquifers, creating a cone of drawdown which extends for approximately 5 km in the Tent Hill aquifer and approximately the same distance to the north, south and east in the Andamooka Limestone aquifer.

To the west, seepage from the TSF has created a groundwater mound in the Andamooka Limestone aquifer which has risen to a maximum height of approximately 30 m below the ground surface. The mound changed very little over extended periods, i.e. years, because of the low transmissivity in the limestone aquifer, limited hydrogeological interconnection to the Tent Hill aquifer and the limited number of man-made interconnections (exploration drill holes, ventilation shafts etc.). Abstraction from production bore LP2 since January 2000 has reduced the groundwater mound. Commissioning approval for TSF Cell 4 and Construction approval for TSF Cell 5 requires BHP Olympic Dam to ensure that groundwater levels do not rise above 80 mAHD (20 m below ground level). A contingency plan nominates remedial action that can be undertaken if required in future (BHP Billiton 2011).

The groundwater has no natural surface expression in the vicinity of the Olympic Dam operation, and is at sufficient depth as to not adversely affect native vegetation.

2.2.2 Purpose

- Define the extent of groundwater level changes that have resulted from Olympic Dam's activities.
- Provide information that can be used to regulate the volume of abstraction from pumping wells near the TSF, in order to maintain groundwater levels in the region of the TSF to below a level at which native vegetation could be affected.

2.2.3 Deliverable(s)

- A review of the trends in local and regional groundwater levels and a comparison with historical groundwater levels.
- Data showing the tracking of trends towards **leading indicators** for groundwater impacts, and triggering an alert to management when levels approach the **leading indicators**.

2.2.4 Method

Groundwater levels are monitored annually, utilising a network of exploration and groundwater monitoring bores in both the Andamooka Limestone and Tent Hill aquifers (see section 5 – Appendix A).

Local groundwater levels are monitored at or adjacent the existing and expanded TSF, backfill limestone quarry and underground mine. Regional groundwater levels are monitored at locations on the Stuart Shelf outside the SML

If for some reason a groundwater level cannot be obtained (e.g. blocked bore), the nearest suitable bore will be located and monitored if appropriate. Olympic Dam will maintain sufficient monitoring bores to satisfy the requirements for monitoring of groundwater levels around the TRS.

Groundwater levels at regional wells are used to infer any impact to third-party wells. To confirm a stable baseline groundwater level, the frequency of monitoring of regional wells in the vicinity of the Motherwell wellfield will be increased 12 months prior to commissioning of the wellfield. Regional monitoring frequency will also be increased in response to a propagating pattern of change in groundwater levels that may occur as a result of other groundwater affecting activities.

The groundwater levels are recorded in a database for subsequent analysis and reporting.

2.3 Groundwater Quality

(MC 2.8.2(e))

2.3.1 Background

Groundwater in the vicinity of the operation is of poor quality and, as defined by *Environment Protection (Water Quality) Policy 2015*, ANZECC (2000), is not suitable for supporting the **environmental value** categories (aquatic ecosystems; recreation and aesthetics; drinking supply; primary industry). Local groundwater is also unsuitable for ore processing at Olympic Dam.

Modification of local groundwater, such as through desalination, is not beneficial to the current mineral processing requirements at Olympic Dam. The use of local groundwater has been limited to dust suppression, soil conditioning during construction and some underground drilling activities.

Analysis of seepage from the base of the existing TSF has shown that it undergoes a process of **in-situ** neutralisation and attenuation as it passes through the upper layers of the Andamooka Limestone. Groundwater chemistry around the TSF is similar to the regional groundwater chemistry, with the exception of slightly increased uranium concentrations and slightly reduced pH. Effects on groundwater quality as a result of the expanded TSF are expected to be similar. ODC has been granted an exemption from certain requirements of the **Environment Protection Act** (specifically clauses 13 and 17 of the Environment Protection (Water Quality) Policy 2015. The exemption pertains and applies to an attenuation zone roughly equivalent to the expanded SML.

2.3.2 Purpose

- Quantify any possible impacts of seepage from the TSF and mine water evaporation pond.

2.3.3 Deliverable(s)

- A review of trends in groundwater quality and a comparison to ANZECC criteria.

2.3.4 Method

Aquifer-specific monitoring bores (see Appendix A – Table 5-1) are pumped or bailed in order to obtain a representative groundwater sample for quality analysis. The samples are analysed for the following analytes (samples are filtered prior to metals analysis):

- TDS, pH, calcium, chloride, copper, iron, manganese, sulphate and uranium.

In addition, samples from monitoring bores listed in Table 5.1 will be analysed for the following radionuclides:

- ^{238}U, ^{226}Ra, ^{230}Th, ^{210}Pb and ^{210}Po.

If for some reason a groundwater sample cannot be obtained (e.g. blocked bore), the nearest suitable bore is located and sampled if appropriate. Groundwater quality at regional wells is used to infer any impact to third-party wells.

2.4 Use of local groundwater for dust suppression

(MC 2.8.2(e))

2.4.1 Background

Sources of local groundwater are used around site for watering of roads to suppress dust. This may include water obtained from the mine as a result of underground mine dewatering or extracted from ventilation fan outflow, which may have elevated radionuclide content relative to other local groundwater sources. As noted in section 2.3, local groundwater is of very low quality and is unsuitable for other industrial or environmental uses. Radionuclide concentrations in locally sourced groundwater used for road watering are monitored annually.

Upper limits for radionuclide content are shown in Table 2-1, below.

Table 2-1: Upper limits for radionuclide content

Radionuclide	Upper limit (Bq/L)
^{238}U	50
^{226}Ra	5

2.4.2 Purpose

- Monitor sources of local groundwater used for road watering.
- Ensure negligible long-term effects from the release of mine water.

2.4.3 Deliverable(s)

- Data demonstrating that radionuclide concentrations are below upper limits.
- A review of results and provision for increased monitoring frequency where concentrations are trending towards upper limits.

2.4.4 Method

Sources of local groundwater used for dust suppression, including raise bore ponds and storage dams, are sampled at least once a year and checked for radionuclide concentrations. Where readings for a source are close to or above upper limits, additional monitoring will be conducted more frequently. Use of water from a source found to exceed the limit will cease until the radiation level has been found to have dropped below that limit.

2.5 TSF5 Dewatering System

2.5.1 Background

Construction approval for TSF Cell 5 requires BHP Olympic Dam to ensure that groundwater levels do not rise above 80 mAHD (20 m below ground level). A contingency plan nominates remedial action that can be undertaken if required in future (BHP Billiton 2011). In 2017 it was identified that the level of groundwater rise under TSF5 was at risk of exceeding the leading indicator of 70 mAHD.

A groundwater dewatering project was installed in early 2018 to address the rise and maintain groundwater levels below the 80 mAHD approval requirement.

2.5.2 Purpose

- Quantify any possible impacts of clay pan discharge and seepage from the TSF5 dewatering system.
- Provide information from pumping wells at TSF5, in order to maintain groundwater levels in the region of the discharge clay pan to below a level at which native vegetation could be affected

2.5.3 Deliverable(s)

- A review of trends in clay pan discharge water quality from the dewatering system and a comparison to baseline data.
- A review of abstraction rates and trends, and an assessment with respect to local clay pan groundwater levels.
- A review of the trends in local clay pan groundwater levels and a comparison with historical groundwater levels.
- Data showing the tracking of trends towards **leading indicators** for local clay pan groundwater impacts, and triggering an alert to management when levels approach the **leading indicators**.
- Data demonstrating that clay pan discharge water radionuclide concentrations are below upper limits (as per section 2.4).
- A review of results and provision for increased monitoring frequency where concentrations are trending towards upper limits.

2.5.4 Method

The following monitoring and recording is undertaken in relation to TFS5 groundwater dewatering prior to and during a discharge to the clay pan only:

- Groundwater levels in the vicinity of the TSF5 discharge clay pan are monitored monthly (see section 5.2 – Appendix A) to observe any clay pan discharge and TSF4 infiltration interactions.
- Average daily flow rates to the discharge clay pan
- . Field parameters are determined for the following at the clay pan discharge:
    - pH, EC
- Sampling of radionuclides concentrations is undertaken to demonstrate negligible long term effects due to the spread of radionuclides. Water samples are taken from the clay pan discharge. Where readings for a source are close to or above upper limits, additional monitoring will be conducted more frequently. Water discharge found to exceed the limit will cease until the radiation level has been found to have dropped below that limit.

Table 2-2: Upper limits for radionuclide content

Radionuclide	Upper limit (Bq/L)
^{238}U	50
^{226}Ra	5

3 COMMITMENTS

3.1 Reporting

The results and a discussion of the results are presented in the Annual EPMP Report as outlined in the **Environmental Management Manual** (EMM).

3.2 Summary of commitments

Table 3-1: Summary of commitments

Action	Parameter	Frequency
Monitor	Groundwater abstraction and mine water balance	Daily-monthly
Monitor	Groundwater level – Andamooka Limestone and Tent Hill aquifers	As per Table 5-1
Monitor	Groundwater quality – Andamooka Limestone and Tent Hill aquifers	As per Table 5-1
Monitor	Quality of mine water used for dust suppression	Annual
Monitor	TSF5 Dewatering System	As per Table 5-2
Employ	An environmental scientist to undertake the requirements of the Groundwater MP	Ongoing
Report	Monitoring results in the Annual EPMP Report to the Indenture Minister	Annual
Review	The Groundwater MP and modify as appropriate	Annual

4 DEFINITIONS AND REFERENCES

4.1 Definitions

Throughout the EPMP some terms are taken to have specific meaning. These are indicated in bold text in the documentation and are defined in the glossary in section 5 of the EMM. Defined terms have the same meaning wherever they appear in bold text. Some other terms and acronyms are also defined in the glossary, but do not appear in bold text.

4.2 References

ANZECC 2000, ‘Australian and New Zealand Guidelines for Fresh and Marine Water Quality’, Australian and New Zealand Environment and Conservation Council and Agriculture Resource Management Council of Australia and New Zealand, Paper No. 4, vol. 1–3, ch. 1–9.

BHP Billiton 2011, Olympic Dam Expansion Supplementary Environmental Impact Statement 2011, BHP Billiton, Adelaide, SA.

BHP Billiton Olympic Dam 2011, ‘Contingency measures and response plan for addressing unexpected groundwater level increase below the Olympic Dam Tailings Storage Facility (TSF) Cells 4 and 5, Report ODENV030’.

Environment Protection (Water Quality) Policy 2015 and Explanatory Report, Environment Protection Authority (SA)

4.3 Bibliography

Kinhill Engineers Pty Ltd 1997, ‘Olympic Dam Expansion Project Environmental Impact Statement’.

Licence to Mine and Mill Radioactive Ores **(Licence LM1)** 1988.

Radiation Protection and Control Act 1982.

South Australian Parliament 1996, ‘Roxby Downs water leakage’, 19th report of the Environment, Resources and Development Committee of the Parliament of South Australia, Adelaide.

WMC (Olympic Dam Operations) Pty Ltd 1998, Environmental Management Program Annual Report. 1/3/97 – 28/2/98', Olympic Dam.

5 APPENDIX A: LOCATION PLANS AND GROUNDWATER BORE MONITORING FREQUENCY

5.1 Olympic Dam existing operations

Table 5-1: Groundwater monitoring bores and frequency

Bore	Unit No.	Level	Quality	Bore	Unit No.	Level	Quality
LT1	6237-200	Annual	Annual	LT58		Annual	
LT2	6237-201	Annual	Annual	LT59		Annual	
LT3	6237-202	Annual		LT60		Annual	Annual
LT8	6237-207	Annual		LT61		Annual	
LT9	6237-208	Annual		LT62		Annual	
LT11	6237-200	Annual		LT63		Annual	
LT13	6237-201	Annual		LT64		Annual	Annual
LT14	6237-202	Annual		LT65		Annual	
LT15	6237-207	Annual	Annual	LT66		Annual	
LT16	6237-208	Annual		LT67		Annual	Annual
LT17	6237-200	Annual	Annual	LT68		Annual	
LT18A		Annual		LT69		Annual	Annual
LT19	6237-202	Annual	Annual	LT70		Annual	
LT20	6237-207	Annual		LT71		Annual	
LT21	6237-220	Annual	Annual	LR1	6237-237	Annual	
LT22	6237-221	Annual	Annual	LR2	6237-238	Annual	Annual
LT23	6237-222	Annual		LR3	6236-94	Annual	Annual
LT25	6237-224	Annual	Annual	LR4	6237-21	Annual	
LT28	6237-227	Annual		LR6	6236-92	Annual	
LT29	6237-228	Annual		LR7	6236-91	Annual	
LT31	6237-230	Annual		LR8	6237-22	Annual	Annual
LT33	6237-232	Annual		LR9	6237-23	Annual	Annual
LT34	6237-254	Annual	Annual	LM01		Annual	
LT35	6237-255	Annual	Annual	LM02		Annual	
LT37		Annual		LM05		Annual	
LT38		Annual		LM09		Annual	
LT39A		Annual	Annual	LM11		Annual	
LT40B		Annual		LM13		Annual	
LT41	6237-258	Annual		LM14		Annual	
LT50	6237-272	Annual		LM15		Annual	
LT51	6237-273	Annual		LM16		Annual	
LT56		Annual		LM17		Annual	

Bore	Unit No.	Level	Quality	Bore	Unit No.	Level	Quality
LM18		Annual		RD80		Annual	
LM19		Annual		RD115	6237-64	Annual	
LM20		Annual		RD125	6237-66	Annual	
LM21		Annual		RD148	6237-77	Annual	
LM23		Annual		RD172	6237-84	Annual	
LM25		Annual		RD194	6237-94	Annual	
LM43		Annual	Annual	RD222	6237-101	Annual	
LM46		Annual	Annual	RD305	6237-126	Annual	
QR1	6237-242	Annual	Annual	RD315A		Annual	
QR2	6237-243	Annual	Annual	RD436	6237-144	Annual	
QR3	6236-98	Annual		RD503	6237-151	Annual	
QT1	6237-233	Annual		RD591	6237-160	Annual	
QT2	6237-234	Annual		RD1953		Annual	
QT3	6237-235	Annual		RD2153		Annual	
QT4	6237-236	Annual		RD2501		Annual	
PT14		Annual		RD2551		Annual	
PT17		Annual		RD2709		Annual	
PT31		Annual		RD2719		Annual	
RD66	6237-47	Annual		RD2875		Annual	

LT – Andamooka Limestone aquifer monitoring bore in the tailings area

LM – Andamooka Limestone aquifer monitoring bore in the mine or metallurgical plant area

LR – Andamooka Limestone aquifer monitoring bore in the region

QT – Arcoona Quartzite aquifer (Tent Hill aquifer) monitoring bore in the tailings area

QR / PT – Arcoona Quartzite aquifer (Tent Hill aquifer) monitoring bore in the region

RD – Roxby Downs exploration drillhole not aquifer specific

5.2 TSF5 Dewatering System

Table 5-2: TSF5 Dewatering bores and frequency*

Bore	Unit No.	Level	Quality	Radionuclide	Flow rate
LT1	6237-200	Monthly			
LT19	6237-202	Monthly			
LT33	6237-232	Monthly			
LT34	6237-254	Monthly			
LT35	6237-255	Monthly			
LT39A		Monthly			
LT41	6237-258	Monthly			
LT83		Monthly			
Discharge location (clay pan)			Daily	Quarterly	Daily

*Monitoring only undertaken prior to and during a discharge to the Lake Bennet Clay pan

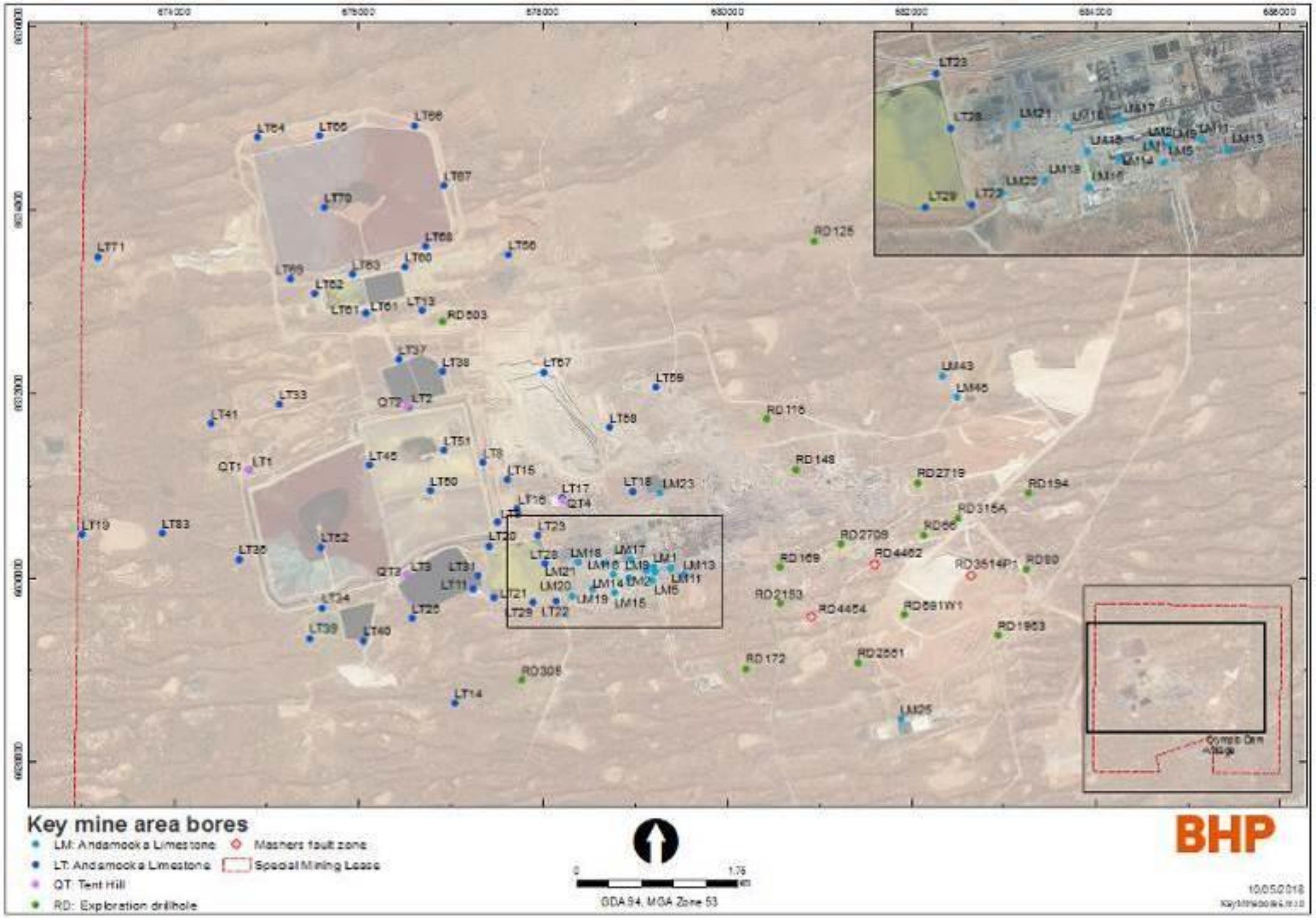

Figure 5-1: Key mine area monitoring bore locations

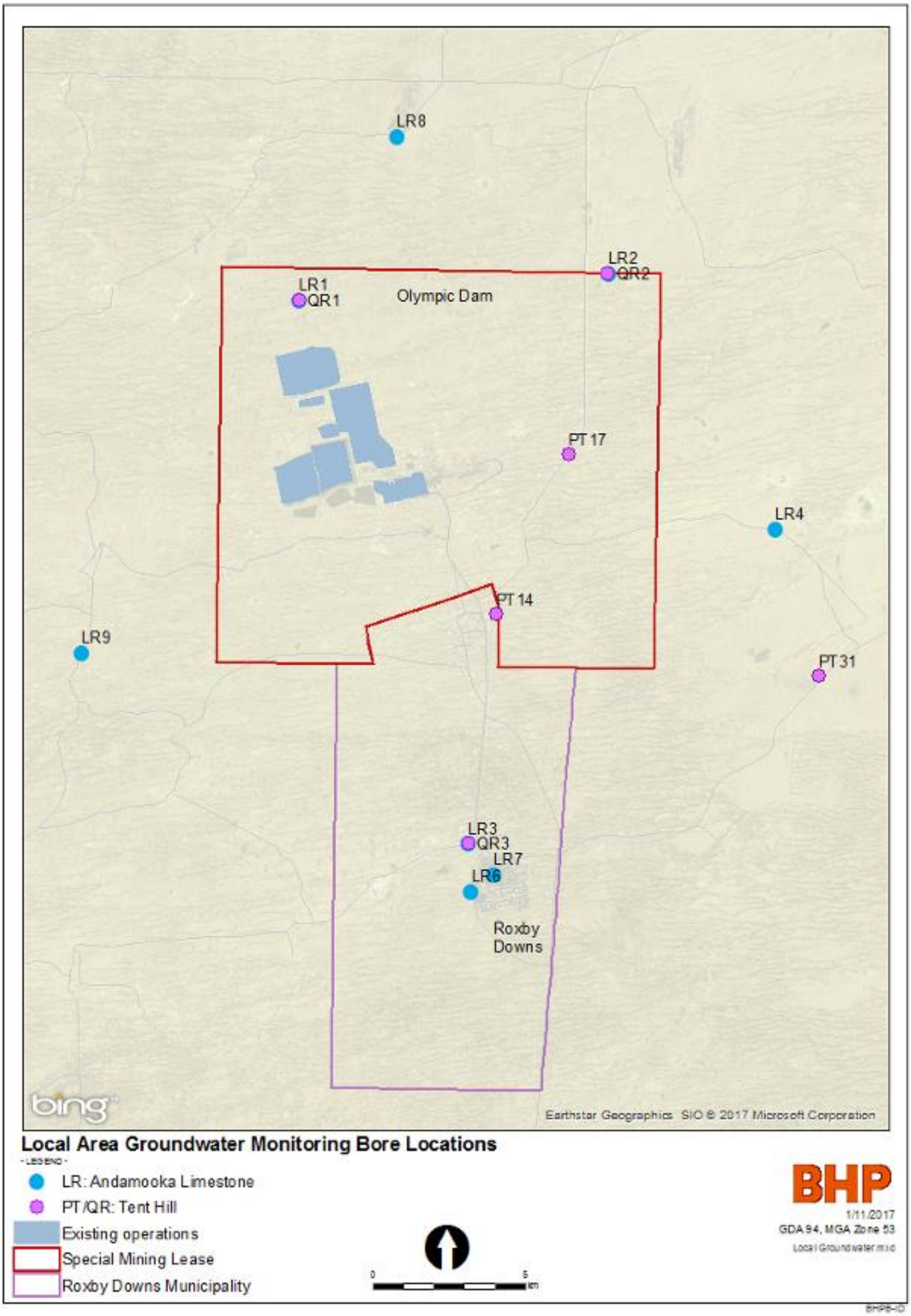

Figure 5-2: Local area groundwater monitoring bore locations