Olympic Dam

Annual Radiation Protection Report

1 July 2015 to 30 June 2016
OLYMPIC DAM

Annual Radiation Protection Report
1 July 2015 to 30 June 2016

DISTRIBUTION

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1 Introduction

This document is the annual report on radiation protection for BHP Billiton Olympic Dam Corporation Pty Ltd.

In fulfilment of clauses 2.10.1, 3.8.1 and 3.10.1 of the Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Processing 2005, employee dose assessments, dose calculation methodologies, dose parameters and dose conversion factors for the period 1 July 2015 to 30 June 2016 are presented. Personal doses and dose components for the period 1 July 2015 to 30 June 2016 are forwarded with this document on electronic media.
2 Employee Dose Assessment Method

2.1 Exposure Calculation Methodology

2.1.1 Exposure Calculation at the Mine

The main exposure pathways for Mine workers are inhalation of Radon Decay Products (RDP), irradiation by gamma radiation and inhalation of Long-Lived Radioactive Dust (Dust). Assessment of exposure from dust and RDP are based on employee time sheet information and measurements from the approved monitoring program.

Medgate™ is the data and dose management system, which is used to assess and record individual radiation exposures. The site security database (CARDAX) is used to determine the daily hours for employees working on site. The information in CARDAX is categorised into 3 major areas: surface, underground safe zone and underground blasting zone. Medgate™ records employee name, employee number, occupation, date, work location and hours in location information.

Locations at the Mine End are separated into three main zones: Surface, Safe, and Blast. Surface includes all above ground locations, including the quarry and backfill areas. The Safe Zone includes the 420 Platform and adjacent offices and workshops and is considered a fresh air base. The Blast Zone includes all other underground areas. The RDP concentrations are determined for each zone for each week using measurements from the approved monitoring program, which monitor the most active work areas. Where no samples were taken for the week an overall average of all samples from that zone is used to determine the RDP concentration for that week. This average is calculated from all readings for that particular zone over the quarter.

RDP exposure for certain workgroups is also assessed through the use of Personal Alpha Dosimeters (PADs). PADs are typically allocated to workgroups with higher RDP exposures such as Ventilation and Raise Drilling.

Employee exposure to radioactive dust is calculated using quarterly occupational-based averages. The averages are obtained from monitoring performed under the approved monitoring program.

The occupation-based dust concentration information and location-based RDP concentration information is then combined with the employee time card information to derive individual exposure data. Dust concentration is measured in units of Becquerel-hours per cubic metre (Bq.hr/m³) and RDP concentration is measured in units of micro Joule-hours per cubic metre (µJ.hr/m³). Exposure details are combined to give quarterly personal exposures.

The system is designed such that the Radiation Safety Officer is required to perform checks in each step of the process. This is in addition to a built-in auditing system within the program, as set out in section 8.10 of Olympic Dam’s Radiation Management Plan.

Respiratory protection in the form of airstream helmets is available for high-risk workers. They are typically worn by some workgroups such as Ore Handling Beltrunners and Services Ventilation Crew. Airstream helmets are also
mandatory for specific tasks or in certain conditions. Routine and non-routine use of airstream helmets is monitored and logged. Further respiratory protection includes the P2 dust masks, which are now mandatory for all workers that are not located in fresh-air bases or closed cabins. No respiratory protection factors are used in exposure calculations, and therefore actual individual exposures could be lower than reported.

Exposure to gamma radiation is assessed using Optically Stimulated Luminescence Dosimeters (OSLD) badges from the Landauer Personal Radiation Monitoring Service. OSLD badges are worn for a period of three months; non-badge wearers are allocated an occupation-based average exposure.

2.1.2 Exposure calculation in the Metallurgical Plant

The main exposure pathways for Metallurgical Plant workers are inhalation of radioactive dust and fumes, and irradiation by gamma radiation. Assessment of exposure from dust and fumes is based on employee time information and measurements from the approved monitoring program. Dust exposure in the Metallurgical Plant may involve exposure to different types of dust. The dust can differ in particle size and radionuclide composition, which results in different dust Dose Conversion Factors (DCFs). Appendix A provides a table of DCFs used in 2015/2016.

Information from employee and contractor time cards or employee activity sheets is captured by the radiation management software, Medgate™, which contains daily time sheet/card information. Medgate™ contains an up-to-date list of all locations and occupations on-site. Occupations and Locations which have similar exposure characteristics are grouped into similar exposure groups (SEGs). A quarterly mean of dust radioactivity concentration is determined for each of the exposure groups based on the results of the monitoring program.

Dust concentration averages are calculated for each SEG on a quarterly basis. These averages are then combined with the previously captured time and location information to produce a dust exposure for each employee.

Exposure to gamma radiation is assessed using OSLD badges provided by Landauer. OSLD badges are worn for a period of three months. They are issued to a randomly selected subset of workers from each SEG. Workers who do not receive an OSLD have a dose calculated based on the average OSLD dose rate for their corresponding SEG and their time sheet/card information.

Although the exposure to RDP within the Metallurgical Plant is much less than other pathways, it is assessed in the same way as for Mine workers. The same time information used for calculation of dust exposure is used for calculating RDP exposure. All surface locations/occupations are grouped into one surface airway. This surface airway has its RDP concentration calculated on the basis of a grab sampling method.

2.2 Dose Calculations

Conversion of dust exposure to committed effective dose is achieved by the use of dose conversion factors, which are derived using the methodologies in International Commission on Radiological Protection (ICRP) Publication
The parameters physically measured to determine the factors are; particle size and radionuclide content. These measurements are undertaken in a number of areas of the Mine and Metallurgical Plant.

Analysis of the samples used to determine the radionuclide content was carried out by the Olympic Dam Analytical Laboratory. These results were used to determine dose conversion factors, which remain unchanged from last year.

Changes to existing conversion factors will only occur in the event of introduction of new processing techniques, major changes to plant or ore type or new recommendations published by the ICRP. Appendix A provides a summary of the dose conversion factors used for 2015/2016.

To calculate committed dose for airborne dust exposure, the airborne dust exposure is multiplied by the appropriate dose conversion factor. The committed doses for the different dusts are then added to give a total airborne dust dose.

The RDP dose equivalent is calculated by multiplying the RDP exposure by the default dose conversion factor recommended by ICRP65 of 1.41 mSv.m$^3$/mJ.hr (5 mSv/WLM).
3 Employee Doses

Occupational doses received by all Olympic Dam workers remain well below the internal dose constraint of 10 mSv/y. Olympic Dam remains committed to the principle of “as low as reasonably achievable” (ALARA).

3.1 Doses to Mine Workers

3.1.1 Descriptive Statistics

A total of 1708 full-time and 847 part-time Mine workers’ doses were calculated for the period 1 July 2015 to 30 June 2016. This included all BHP Billiton Olympic Dam Mine workers and associated contractors. The distribution of doses for these work classifications is given in Figure 1.

![Annual Dose Distribution 2015/2016 for All Mine Workers](image)

Figure 1 – Annual Dose Distribution 2015/2016 for All Mine Workers

The selection criteria for determining whether workers are categorised as ‘full-time’ or ‘part-time’ is as follows:

A ‘full-time’ employee is an employee whose dose has been assessed for a total of three or more quarters within the financial year. A ‘part-time’ employee therefore has dose assessment for less than three quarters within the financial year. This eliminates any unintentional biasing of the analysis of data due to short exposure periods.

The mean dose to all Mine workers was 1.4 mSv in 2015/2016, an decrease from 1.8 mSv in 2014/2015. The mean dose for full-time Mine workers was 1.9 mSv in 2015/2016, a decrease from 2.1 mSv in 2014/2015. The mean dose for part-time Mine workers was 0.4 mSv in 2015/2016, remaining the same as 2014/2015.
Of the three major exposure pathways (gamma irradiation, inhalation of radioactive dust and inhalation of RDP), RDP exposure for full-time workers has decreased from 53% to 47% of the total dose since last year, gamma irradiation has increased from 33% to 35% and the dust component has increased from 14% to 18% of the total dose. Table A consolidates the results for the exposures at the mine.

Table A – Statistics for Mine Workers

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Full Time Workers</th>
<th>Part Time Workers</th>
<th>All Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>1708</td>
<td>847</td>
<td>2555</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>1.9</td>
<td>0.4</td>
<td>1.4</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>3.7</td>
<td>1.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>6.1</td>
<td>2.4</td>
<td>6.1</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>18%</td>
<td>18%</td>
<td>18%</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>47%</td>
<td>45%</td>
<td>47%</td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>35%</td>
<td>37%</td>
<td>35%</td>
</tr>
</tbody>
</table>

No Mine worker received an annual dose greater than 10 mSv. The highest dose was 6.1 mSv, compared to a maximum value in 2014/2015 of 8.0 mSv.

3.1.2 Review of doses by work category

Table B displays the breakdown of doses for all workgroups for Full-Time Mine workers. The primary focus of our monitoring programs has remained on these workgroups that are currently working in the underground mine.

Average annual doses for all mine work groups have varied but are still well within historical variations. The CC Machine Operator Workgroup received the highest average dose of 3.4 mSv. The highest individual annual dose for Mine workers was also received by a CC Machine Operator with a dose of 6.1 mSv, who worked a total of 2334 hours during the reporting period. The Full-Time Equivalent (FTE) dose for that individual over 2000 hours was calculated to be 5.2 mSv.

The dose components for work categories are shown graphically in Figure 2.
Table B – Statistics for Full Time Mine Workers

<table>
<thead>
<tr>
<th>Workgroups</th>
<th>No. of Workers</th>
<th>Mean (mSv)</th>
<th>Minimum (mSv)</th>
<th>Maximum (mSv)</th>
<th>90th Percentile (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>420 Workers</td>
<td>141</td>
<td>1.7</td>
<td>0.0</td>
<td>3.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Backfill</td>
<td>155</td>
<td>1.2</td>
<td>0.0</td>
<td>3.7</td>
<td>1.6</td>
</tr>
<tr>
<td>CC Machine Operators</td>
<td>257</td>
<td>3.4</td>
<td>0.1</td>
<td>6.1</td>
<td>4.4</td>
</tr>
<tr>
<td>Coreprocessing</td>
<td>5</td>
<td>0.5</td>
<td>0.3</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Development</td>
<td>120</td>
<td>2.5</td>
<td>0.1</td>
<td>4.4</td>
<td>3.4</td>
</tr>
<tr>
<td>Diamond Drilling</td>
<td>46</td>
<td>2.5</td>
<td>0.7</td>
<td>3.8</td>
<td>3.5</td>
</tr>
<tr>
<td>Electricians</td>
<td>58</td>
<td>2.2</td>
<td>0.2</td>
<td>4.1</td>
<td>3.0</td>
</tr>
<tr>
<td>Fitters/Maintenance</td>
<td>109</td>
<td>1.8</td>
<td>0.0</td>
<td>4.0</td>
<td>3.4</td>
</tr>
<tr>
<td>General Service Miner</td>
<td>66</td>
<td>3.2</td>
<td>0.1</td>
<td>5.0</td>
<td>4.3</td>
</tr>
<tr>
<td>Mine Offices</td>
<td>269</td>
<td>0.7</td>
<td>0.0</td>
<td>3.8</td>
<td>1.1</td>
</tr>
<tr>
<td>Mine Surface Worker</td>
<td>171</td>
<td>0.8</td>
<td>0.0</td>
<td>3.9</td>
<td>1.4</td>
</tr>
<tr>
<td>Ore Handling</td>
<td>18</td>
<td>1.8</td>
<td>0.8</td>
<td>2.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Production Charging</td>
<td>26</td>
<td>3.3</td>
<td>1.8</td>
<td>5.0</td>
<td>4.1</td>
</tr>
<tr>
<td>Production Drilling</td>
<td>19</td>
<td>3.2</td>
<td>1.3</td>
<td>4.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Raise Drilling</td>
<td>20</td>
<td>3.3</td>
<td>0.1</td>
<td>4.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Mine Shutdown</td>
<td>59</td>
<td>0.8</td>
<td>0.0</td>
<td>3.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Underground Services Full Time</td>
<td>47</td>
<td>1.2</td>
<td>0.0</td>
<td>2.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Underground Supervisors</td>
<td>68</td>
<td>1.9</td>
<td>0</td>
<td>4.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Ventilation Officers</td>
<td>54</td>
<td>2.7</td>
<td>1.1</td>
<td>4.7</td>
<td>3.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workgroups</th>
<th>Dust Average (mSv)</th>
<th>Dust % of Total Dose</th>
<th>RDP Average (mSv)</th>
<th>RDP % of Total Dose</th>
<th>Gamma Average (mSv)</th>
<th>Gamma % of Total Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>420 Workers</td>
<td>0.2</td>
<td>12%</td>
<td>0.8</td>
<td>46%</td>
<td>0.7</td>
<td>42%</td>
</tr>
<tr>
<td>Backfill</td>
<td>0.2</td>
<td>15%</td>
<td>0.1</td>
<td>11%</td>
<td>0.9</td>
<td>74%</td>
</tr>
<tr>
<td>CC Machine Operators</td>
<td>0.5</td>
<td>13%</td>
<td>2.1</td>
<td>61%</td>
<td>0.9</td>
<td>26%</td>
</tr>
<tr>
<td>Coreprocessing</td>
<td>0.2</td>
<td>50%</td>
<td>0.1</td>
<td>18%</td>
<td>0.2</td>
<td>32%</td>
</tr>
<tr>
<td>Development</td>
<td>0.5</td>
<td>22%</td>
<td>0.9</td>
<td>37%</td>
<td>1.0</td>
<td>40%</td>
</tr>
<tr>
<td>Diamond Drilling</td>
<td>0.5</td>
<td>20%</td>
<td>1.2</td>
<td>47%</td>
<td>0.8</td>
<td>33%</td>
</tr>
<tr>
<td>Electricians</td>
<td>0.4</td>
<td>17%</td>
<td>0.8</td>
<td>37%</td>
<td>1.0</td>
<td>46%</td>
</tr>
<tr>
<td>Fitters/Maintenance</td>
<td>0.3</td>
<td>17%</td>
<td>1.1</td>
<td>64%</td>
<td>0.4</td>
<td>20%</td>
</tr>
<tr>
<td>General Service Miner</td>
<td>0.6</td>
<td>20%</td>
<td>1.5</td>
<td>48%</td>
<td>1.0</td>
<td>32%</td>
</tr>
<tr>
<td>Mine Offices</td>
<td>0.3</td>
<td>35%</td>
<td>0.2</td>
<td>33%</td>
<td>0.2</td>
<td>32%</td>
</tr>
<tr>
<td>Mine Surface Worker</td>
<td>0.2</td>
<td>27%</td>
<td>0.3</td>
<td>34%</td>
<td>0.3</td>
<td>39%</td>
</tr>
<tr>
<td>Ore Handling</td>
<td>0.6</td>
<td>31%</td>
<td>0.5</td>
<td>27%</td>
<td>0.8</td>
<td>42%</td>
</tr>
<tr>
<td>Production Charging</td>
<td>0.4</td>
<td>13%</td>
<td>1.4</td>
<td>43%</td>
<td>1.4</td>
<td>44%</td>
</tr>
<tr>
<td>Production Drilling</td>
<td>0.4</td>
<td>13%</td>
<td>1.3</td>
<td>40%</td>
<td>1.5</td>
<td>47%</td>
</tr>
<tr>
<td>Raise Drilling</td>
<td>0.8</td>
<td>25%</td>
<td>1.3</td>
<td>40%</td>
<td>1.1</td>
<td>35%</td>
</tr>
<tr>
<td>Mine Shutdown</td>
<td>0.3</td>
<td>32%</td>
<td>0.4</td>
<td>50%</td>
<td>0.2</td>
<td>18%</td>
</tr>
<tr>
<td>Underground Services Full Time</td>
<td>0.3</td>
<td>24%</td>
<td>0.5</td>
<td>47%</td>
<td>0.3</td>
<td>29%</td>
</tr>
<tr>
<td>Underground Supervisors</td>
<td>0.4</td>
<td>18%</td>
<td>1.0</td>
<td>50%</td>
<td>0.6</td>
<td>32%</td>
</tr>
<tr>
<td>Ventilation Officers</td>
<td>0.5</td>
<td>17%</td>
<td>1.4</td>
<td>50%</td>
<td>0.9</td>
<td>33%</td>
</tr>
</tbody>
</table>
Figure 2 – Annual Dose for Mine Workgroups

The average and maximum effective dose for Full-Time Mine workers and the annual dose trends are provided in Figure 3 - Figure 40 for all underground Workgroups.
420 Workers

The average dose for the 420 workgroup has increased from 1.6 mSv in 2014/2015 to 1.7 mSv, whereas the maximum dose in this workgroup has decreased from 3.7 mSv to 3.6 mSv. The average dose to 420 workers reflects the nature of the employee’s work, mostly on the 420-Plat level with minimal time in blast zones underground.

Figure 3 – Annual Dose Distribution for the 420 Workers Workgroup

Figure 4 – Annual Dose Trends for the 420 Workers Workgroup
Backfill

The average dose for the Backfill workgroup has increased from 0.8 mSv in 2014/2015 to 1.2 mSv and the maximum dose to this workgroup has increased from 1.4 mSv to 3.7 mSv. The maximum dose was received by an employee who worked 2690 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 2.8 mSv. The average dose has increased in FY16 but remains within historical variations and will continued to be monitored.

Figure 5 – Annual Dose Distribution for the Backfill Workgroup

Figure 6 – Annual Dose Trends for the Backfill Workgroup
CC Machine Operators

The average dose to the CC machine operator workgroup has slightly increased from 3.3 mSv 2014/2015 to 3.4 mSv this year. However, the maximum dose for the workgroup has decreased from 6.7 mSv in 2014/2015 to 6.1 mSv. The maximum dose was received by an employee who worked 2334 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 5.2 mSv. The average dose to CC Machine Operators reflects the nature of their work, mostly underground with minimal time on the surface.

Figure 7 – Annual Dose Distribution for CC Machine Operators

Figure 8 – Annual Dose Trends for CC Machine Operators
Core Processing

The average dose for Core Processing Workgroup has remained low. The average dose for 2015/2016 was 0.5 mSv and the maximum dose was 0.6 mSv.

Figure 9 – Annual Dose Distribution for the Core Processing Workgroup

Figure 10 – Annual Dose Trends for the Core Processing Workgroup
Development

The average dose for Development Workgroup has decreased from 4.8 mSv in 2014/2015 to 2.5 mSv and the maximum dose decreased from 8.0 mSv to 4.4 mSv. The maximum dose was received by an employee who worked 2506 hours for the year, resulting in a Full-Time Equivalent (FTE) dose of 3.5 mSv. Increasing the number of Personal Alpha Dosimeters (PADs) continues to provide a more accurate representation of actual exposures for this workgroup each year.

Figure 11 – Annual Dose Distribution for the Development Workgroup

Figure 12 – Annual Dose Trends for the Development Workgroup
Diamond Drilling

The average dose to the Diamond Driller workgroup decreased from 4.8 mSv to 2.5 mSv and maximum dose to the Diamond Drilling workgroup has decreased from 7.5 mSv to 3.8 mSv. The maximum dose was received by an employee who worked 2974 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 2.6 mSv. Increasing the number of Personal Alpha Dosimeters (PADs) continues to provide a more accurate representation of actual exposures for this workgroup each year.
Electricians

The average dose for the Electrician Workgroup has decreased from 3.1 mSv in 2014/2015 to 2.2 mSv. The maximum dose to this workgroup has also decreased from 6.5 mSv in 2014/2015 to 4.1 mSv. The FTE over 2000 hours was calculated to be 3.2 mSv. Overall, the dose rates are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 15 – Annual Dose Distribution for the Electrician Workgroup

Figure 16 – Annual Dose Trends for the Electrician Workgroup
Fitters/Maintenance

The average dose for the Fitters/Maintenance Workgroup has decreased from 3.2 mSv in 2014/2015 to 1.8 mSv and the average number of hours also decreased from 2068 hours in 2014/2015 to 1666 hours. The maximum dose has also decreased since last year from 6.3 mSv to 4.0 mSv. The maximum dose was received by an employee who worked 2732 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 2.9 mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 17 – Annual Dose Distribution for the Fitter Workgroup

Figure 18 – Annual Dose Trends for the Fitter Workgroup
General Service Miners

The average dose has decreased from 4.5 mSv in 2014/2015 to 3.2 mSv with the maximum dose also decreasing from 7.1 mSv to 5.0 mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.
Mine Offices

The average dose has increased from 0.6 mSv in 2014/2015 to 0.7 mSv with the maximum dose also increasing from 3.5 mSv to 3.8 mSv. The average dose remains in line with the previous year taking into account the 2012 redefinition of the workgroup in Medgate™.

Figure 21 – Annual Dose Distribution for the Mine Offices Workgroup

Figure 22 – Annual Dose Trends for the Mine Offices Workgroup
Mine Surface Worker

The average dose has increased from 0.7 mSv in 2014/2015 to 0.8 mSv, whereas the maximum dose decreased from 4.1 mSv to 3.9 mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 23 – Annual Dose Distribution for the Mine Surface Worker Workgroup

Figure 24 – Annual Dose Trends for the Mine Surface Worker Workgroup
Ore Handling

The average dose has remained the same at 1.8 mSv with the maximum dose decreasing from 3.2 mSv in 2014/2015 to 2.7 mSv. These doses are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 25 – Annual Dose Distribution for the Ore Handling Workgroup

Figure 26 – Annual Dose Trends for the Ore Handling Workgroup
Production Charging

The average dose for the Production Charging Workgroup has increased from 2.9 mSv in 2014/2015 to 3.3 mSv, whereas the maximum dose decreased from 5.4 mSv to 5.0 mSv. The exposures are in line with historical exposures recorded for the workgroup. Personal Alpha Dosimeters (PADs) continue to provide a more accurate representation of actual exposures for this workgroup each year.

Figure 27 – Annual Dose Distribution for the Production Charging Workgroup

Figure 28 – Annual Dose Trends for the Production Charging Workgroup
Production Drilling

The average dose for production drillers has decreased from 3.5 mSv to 3.2 mSv and the maximum dose has also decreased from 5.4 mSv to 4.2 mSv. Doses remain in line with historical exposures recorded for the workgroup and the Personal Alpha Dosimeters (PADs) continue to provide high quality data.
Raise Drilling

The average dose has increased from 2.3 mSv in 2014/2015 to 3.3 mSv with the average number of hours for employees also increasing from 1772 hours in 2014/2015 to 2167 hours. The maximum dose increased from 3.8 mSv to 4.8 mSv and the maximum dose was received by an employee who worked 2749 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 3.5 mSv. Overall, the dose rates remain in line with historical variations and do not reflect any significant changes in work practices for this workgroup.

Figure 31 – Annual Dose Distribution for the Raise Drilling Workgroup

Figure 32 – Annual Dose Trends for the Raise Drilling Workgroup
Mine Shutdown

The average dose has increased from 0.6 mSv in 2014/2015 to 0.8 mSv and the maximum dose also increased from 2.0 mSv to 3.6 mSv. The maximum dose was received by an employee who worked 2489 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 2.9 mSv. The annual doses and number of workers for the Mine Shutdown Workgroup vary on a yearly basis and will continued to be monitored over time.

Figure 33 – Annual Dose Distribution for the Mine Shutdown Workgroup

Figure 34 – Annual Dose Trends for the Mine Shutdown Workgroup
Underground Services Full Time

The average dose has decreased from 1.8 mSv to 1.2 mSv and the maximum dose decreased from 3.3 mSv to 2.5 mSv.
Underground Supervisors

The average dose has increased from 1.8 mSv in 2014/2015 to 1.9 mSv, whereas the maximum dose decreased from 4.6 mSv to 4.2 mSv. The maximum dose was received by an employee who worked 2973 hours for the year, which results in a Full-Time Equivalent (FTE) dose of 2.8 mSv.

Figure 37 – Annual Dose Distribution for the Underground Workers Workgroup

Figure 38 – Annual Dose Trends for the Underground Supervisors Workgroup
Ventilation Officers

The average dose has decreased from 3.5 mSv to 2.7 mSv and the maximum dose decreased from 6.1 mSv to 4.7 mSv. Overall, the dose rates are in line with normal variations and do not reflect any significant changes in work practices for this workgroup.

Figure 39 – Annual Dose Distribution for the Ventilation Officers Workgroup

Figure 40 – Annual Dose Trends for the Ventilation Workgroup
3.1.3 Strategies for Dose Reduction

The Mine Ventilation department has continued to focus on ensuring that exposure to radon decay products are kept low through continued extensions of the Mine ventilation systems when required.

3.1.4 Cumulative Five Year Dose

As outlined in ICRP 103, the total dose of any individual radiation worker should not exceed 100 mSv in any five-year period. To this end, a five-year total dose has been determined for all full-time currently designated Mine workers who were employed at Olympic Dam over the previous five years.

There were a total of 1828 Mine workers who worked at the Mine during the period 1 July 2011 to 30 June 2016. This number has increased from the 1507 workers reported for the period 1 July 2010 to 30 June 2015. The maximum dose for a Mine worker was 27.2 mSv for the five-year period ending 30 June 2016, as compared with 29.9 mSv for the 2009/2010 to 2014/2015 five-year dose period. The arithmetic mean for the group was 7.9 mSv, a decrease from 9.1 mSv for the five-year dose period 2010/2011 to 2014/2015.

The cumulative five-year dose distribution is shown in Figure 41.

Figure 41 – Five-Year Cumulative Dose Distribution Mine
A summary of the cumulative five-year dose is given in Table C.

Table C – Five-Year Dose Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Cumulative 5 Year Doses</th>
<th>Equivalent Average Yearly Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>1828</td>
<td>1828</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>7.9</td>
<td>1.6</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>18.3</td>
<td>3.7</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>27.2</td>
<td>5.4</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>59%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>32%</td>
<td></td>
</tr>
</tbody>
</table>
3.2 Doses to Metallurgical Plant Workers

3.2.1 Descriptive Statistics

A total of 1017 full-time and 1159 part-time Metallurgical Plant workers’ doses were calculated for the period 1 July 2015 to 30 June 2016. This included both BHP Billiton Olympic Dam Metallurgical Plant workers and associated contractors.

Approximately 9.9 million tonnes of material (ore and slag) was milled producing at total of 203,000 tonnes of copper cathode, 4400 tonnes uranium oxide concentrate, 118,000 ounces gold bullion and 917,000 ounces silver bullion.

The mean dose to all Plant workers was 0.5 mSv in 2015/2016, similar to that of 2014/2015.

The mean dose for full-time Plant workers was 0.9 mSv in 2015/2016, a decrease from the 2014/2015 value of 1.1 mSv.

The mean dose for part-time Plant workers remained low at 0.1 mSv.

For this period the distribution of doses is shown in Figure 42, and the statistics are given in Table D.

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Full Time Workers</th>
<th>Part Time Workers</th>
<th>All Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>1017</td>
<td>1159</td>
<td>2176</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>0.9</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>1.5</td>
<td>0.4</td>
<td>1.2</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>4.7</td>
<td>1.4</td>
<td>4.7</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>69%</td>
<td>77%</td>
<td>70%</td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>12%</td>
<td>13%</td>
<td>12%</td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>19%</td>
<td>10%</td>
<td>18%</td>
</tr>
</tbody>
</table>
Figure 42 – Annual Dose Distribution for all Metallurgical Plant Workers
3.2.2 Review of Doses by Work Areas

The analysis of doses by work area is presented in Table E. The dose statistics for the 2015/2016 year from the Metallurgical Plant areas show all areas are in line with historical levels.

Annual dose components for each work area can be seen in Figure 43.

### Table E – Statistics for Full Time Metallurgical Plant Workers

<table>
<thead>
<tr>
<th>Workgroups</th>
<th>No. of Workers</th>
<th>Mean (mSv)</th>
<th>Minimum (mSv)</th>
<th>Maximum (mSv)</th>
<th>90th Percentile (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrator</td>
<td>182</td>
<td>0.5</td>
<td>0.0</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Hydromet</td>
<td>116</td>
<td>0.9</td>
<td>0.0</td>
<td>2.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Plant Services</td>
<td>292</td>
<td>0.6</td>
<td>0.0</td>
<td>2.1</td>
<td>1.0</td>
</tr>
<tr>
<td>Refinery</td>
<td>140</td>
<td>0.9</td>
<td>0.0</td>
<td>2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Smelter</td>
<td>287</td>
<td>1.5</td>
<td>0.0</td>
<td>4.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Workgroups</th>
<th>Dust Average (mSv)</th>
<th>Dust % of Total Dose</th>
<th>RDP Average (mSv)</th>
<th>RDP % of Total Dose</th>
<th>Gamma Average (mSv)</th>
<th>Gamma % of Total Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentrator</td>
<td>0.3</td>
<td>63%</td>
<td>0.1</td>
<td>16%</td>
<td>0.1</td>
<td>20%</td>
</tr>
<tr>
<td>Hydromet</td>
<td>0.5</td>
<td>60%</td>
<td>0.1</td>
<td>12%</td>
<td>0.2</td>
<td>28%</td>
</tr>
<tr>
<td>Plant Services</td>
<td>0.3</td>
<td>48%</td>
<td>0.1</td>
<td>24%</td>
<td>0.2</td>
<td>28%</td>
</tr>
<tr>
<td>Refinery</td>
<td>0.7</td>
<td>79%</td>
<td>0.1</td>
<td>11%</td>
<td>0.1</td>
<td>10%</td>
</tr>
<tr>
<td>Smelter</td>
<td>1.1</td>
<td>78%</td>
<td>0.1</td>
<td>6%</td>
<td>0.2</td>
<td>16%</td>
</tr>
</tbody>
</table>

Figure 43 – Annual Dose for Metallurgical Plant Workgroups

Annual total dose distributions and dose trends for each work area along with dose component profiles for selected workgroups can be seen in Figure 44 to Figure 53.
Concentrator

The average dose for 2015/2016 was 0.5 mSv, which has remained unchanged since last year. The maximum dose has decreased from 2.0 mSv in 2014/2015 to 1.9 mSv. Doses remain in line with historical exposures recorded for the workgroup.

Figure 44 – Annual Dose Distribution for the Concentrator Workgroup

Figure 45 – Dose Trends for the Concentrator Workgroup
Hydromet

The average dose has decreased from 1.3 mSv in 2014/2015 to 0.9 mSv in 2015/2016 while the maximum dose has also decreased from 7.2 mSv to 2.7 mSv. In 2014/2015 the task of repacking UOC caused elevated exposure for the Hydromet Workgroup. As this task was incident related, the doses in 2015/2016 have reduced to expected values that remain in line with historical exposures recorded for the workgroup.
Smelter

Average dose in the Smelter decreased from 1.7 mSv to 1.5 mSv and the maximum dose decreased from 6.3 mSv to 4.7 mSv. The Polonium 210 (Po 210) activity concentration inputs and outputs in the smelter continue to be closely monitored and managed by Smelter Production Team to ensure the smelter does not reach activity concentrations that would adversely affect dust exposures.

Figure 48 – Annual Dose Distribution for the Smelter Workgroup

Figure 49 – Dose Trends for the Smelter Workgroup
Refrinery

Average dose in the Refinery has remained unchanged with a value of 0.9 mSv, while the maximum dose increased from 1.6 mSv to 2.0 mSv.
Plant Services

The average dose has decreased from 0.7 mSv to 0.6 mSv, while the maximum dose has also decreased from 2.6 mSv to 2.1 mSv. Doses remain in line with historical exposures recorded for the workgroup.
3.2.3 Strategies for Dose Reduction

The high assay frequency of process streams such as Dust Leach, Concentrate Leach and Furnace inputs and outputs, remain unchanged as this information is a key control for maintaining Po-210 levels throughout the system.

3.2.4 Cumulative Five Year Dose

As recommended in ICRP 103, the total dose of any individual radiation worker should not exceed 100 mSv in any five-year period. To this end, the five-year total dose has been calculated for Full-Time Metallurgical Plant workers who have been employed at Olympic Dam for the previous five years.

There were a total of 673 Metallurgical Plant workers who worked at Olympic Dam during the period 1 July 2011 to 30 June 2016.

The maximum dose for the five-year period was 27.1 mSv, compared to the value of 30.6 mSv calculated in 2014/2015. The arithmetic mean for the five-year dose period for the Metallurgical Plant has decreased to 4.8 mSv from 5.6 mSv. The distribution of doses for the cumulative five-year dose is shown in Figure 54.

Figure 54 – 5 Year Cumulative Dose Distribution for Process Plant Workers
A summary of the cumulative five-year dose is given in Table F below.

Table F – Five-Year Dose Statistics

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Cumulative 5 Year Doses</th>
<th>Equivalent Average Yearly Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count</td>
<td>673</td>
<td>673</td>
</tr>
<tr>
<td>Arithmetic Mean (mSv)</td>
<td>4.8</td>
<td>1.0</td>
</tr>
<tr>
<td>90th Percentile (mSv)</td>
<td>12.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Max (mSv)</td>
<td>27.1</td>
<td>5.4</td>
</tr>
<tr>
<td>Mean % Dose from Dust</td>
<td>55%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from RDP</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>Mean % Dose from Gamma</td>
<td>24%</td>
<td></td>
</tr>
</tbody>
</table>
3.3 Annual Dose Trends

The average total effective dose to all workers at the Mine and Metallurgical Plant since 2011/2012 are shown in Figure 55 and Figure 56, respectively. The annual dose for the last year has been mainly attributed to RDP in the Mine and by radioactive dust exposure in the Metallurgical Plant.
3.4 Doses to Members of the Public

The full assessment of doses to members of the public has been presented separately in the Environmental Management and Monitoring Report.

For all members of the public, the effective dose from the operation, for the period July 2015 to June 2016 was well below the statutory limit of 1.0 mSv per annum. The estimated dose contribution from the operation are provided in Table G.

<table>
<thead>
<tr>
<th>2014/2015 Dose to Members of the Public Living at</th>
<th>Dose (mSv)</th>
<th>Dose Limit (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roxby Downs</td>
<td>0.027</td>
<td>1</td>
</tr>
<tr>
<td>Olympic Dam Village</td>
<td>0.032</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 57 shows the public dose trends for Olympic Dam Village and Roxby Downs since 2006. The 2015/2016 dose to the members of the public has continued to remain below the minimum detection limit of 0.048 mSv.

Figure 57 – Total Dose Trend for Olympic Dam Village and Roxby Downs
Appendix A

Dose Conversion Factors 2015/2016

A summary of the airborne dust dose conversion factors for specific work areas can be viewed in the following table.

Table H – Dust Dose Conversion Factors

<table>
<thead>
<tr>
<th>Location</th>
<th>DCF (µSv.m(^3)/Bq.hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smelter</td>
<td>7.5</td>
</tr>
<tr>
<td>Refinery / STP</td>
<td>5.4</td>
</tr>
<tr>
<td>SX / Precipitation / Calciners</td>
<td>4.5</td>
</tr>
<tr>
<td>Other*</td>
<td>4.1</td>
</tr>
</tbody>
</table>

*All other areas of Mine, Concentrator, Slag Concentrator, Hydromet and Services (Laboratories and Metallurgical Workshop)

The default RDP dose conversion factor used was 1.41 mSv.m\(^3\)/mJ.hr (5 mSv/WLM).