APPENDIX 1

Copy of Voluntary Planning Agreement

Mt Owen Annual Funding for Community programs, sustaining maintenance and capital works

Purpose of the Development Contribution	Term	Date for payment of Development Contribution	Amount of Development Contribution	Total
Economic Development Initiatives - Riverfront Beautification The purpose of this contribution is to contribute towards the cost of undertaking a significant economic development project within the Singleton Local Government Area. Council will propose the details of the project for approval by the Developer. Once approved by the Developer, the project will be implemented in accordance with an Operational Plan.	Whilst ever coal mining operations are undertaken on site unless otherwise agreed.	• 10 yr term -$50,000 per annum to SSC for the first five years with $30,000 per annum thereafter for remaining five yrs.	$400,000	$1,024,000
Completion of the All Abilities Playground at Rose Point Park Stage 8 – Climbing Challenge Stage 9 – Gradulated balancing challenges Stage 10 Spinning, balancing and rocking including new accessible equipment Stage 11 – Sensory trail Extension of junior cycleway Extension of boundary fence to include third shelter Landscaping and seating	Contributions made in line with the SC project plan approved by Mt Owen and whilst ever coal mining operations are undertaken on site.	• Initiated at the end of quarter following DA approval. • $177,000 contribution for stages 8&9, • $192,000 contribution for stage 10, • $95,000 contribution for stage 11 & cycleway, • $36,000 contribution for boundary fence & shelter.	$500,000	
Five year sponsorship of the community groups (Softcogs/ Singleton Rotary) proposed establishment and annual conduct of a national signature tourism/healthy lifestyle cycle event from Singleton to Lake St Clair to build on Glencore's support of Lake St Clair's facility improvement.	Whilst ever coal mining operations are undertaken on site and while ever the event is held and not to exceed the term nominated.	• 5 yr term -$20,000 per annum to SSC.	$100,000	
Support for Aboriginal Cultural Events Annual Aboriginal Art Award	Whilst ever coal mining operations are undertaken on site and while ever the event is held and not to exceed the term nominated.	• 3 yr term -$8,000 per annum for funding of art award show.	$24,000	

Mt Owen VPA Total	**$1,024,000**

APPENDIX 2

Updated Air Quality Impact Assessment

Report

Mount Owen Continued Operations – Refined Project

Document Control Number: AQU-NW-004-21206

Date: 26 May 2016

Pacific Environment Limited

Technologies Consulting Monitoring

Project Name:	Mount Owen Continued Operations – Refined Project
Document Control Number:	AQU-NW-004-21206
Prepared For:	Umwelt (Australia) Pty Ltd
Approved For Release By:	Jane Barnett
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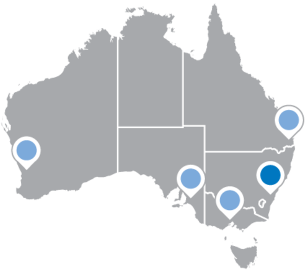
Version	Date	Comment	Prepared by	Reviewed by
DRAFT01	2/05/2016	Working draft	Jane Barnett	Judith Cox
DRAFT02	9/05/2016	Second draft for review	Jane Barnett	Judith Cox
DRAFT03	20/05/2016	Umwelt / Glencore / Jacobs	Jane Barnett	Judith Cox
FINAL	26/05/2016	After final review	Jane Barnett	Judith Cox



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Executive Summary

This report presents the results of new monitoring data analysis, additional modelling results for the Mount Owen Continued Operations (MOCO) Refined Project, and some sensitivity analyses for the changes in mining operations at other sites in the vicinity of Mount Owen.

The original MOCO assessment was completed in 2014. Glencore has since made changes to the mine plan and are not proposing to extract coal resources from the Ravensworth East Resource Recovery (RERR) mining area, considered in the original Year 10 scenario. This report presents modelling results which exclude RERR contributions in Year 10. It also presents some additional discussion on the cumulative assessment for the Refined Project, including updated monitoring data, the inclusion of Rix's Creek and the removal of Ashton South East Open Cut.

The differences in assessment outcomes, compared to the original 2014 assessment, were as follows:

- there are no longer predicted exceedances of the project only 24-hour average PM_{10} criterion at privately owned residence R23 due to the removal of RERR operations,
- using additional data from the Upper Hunter Air Quality Monitoring Network (UHAQMN) now available up to the end of 2015, does not alter the outcomes of the original 2014 assessment,
- there are no changes to the outcomes of the original 2014 assessment for annual average cumulative PM_{10} scenarios as a result of the changes to the Project,
- the inclusion of the proposed Rix's Creek Continuation of Mining Project in Year 5 and Year 10 does not alter the outcomes of the original 2014 assessment,
- the removal of Ashton South East Open Cut Project in Year 1 and Year 5 does not alter the outcomes of the original 2014 assessment, and
- presenting the annual average model predictions for other non-Project mines without any corrections for model over-prediction (that is, not applying the calibration factors), does not alter the outcomes of the assessment at the most affected private residences in the Middle Falbrook area.

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1. Introduction

Pacific Environment (PE) completed an Air Quality Impact Assessment (AQIA) for Glencore's Mount Owen Continued Operations Project (the Project) in October 2014 (**Pacific Environment, 2014**). This report is an addendum to the AQIA and should not be read in isolation.

Since the completion of that assessment, Glencore has made changes to the mine plan towards the end of the life of the Project, and is not proposing to extract coal resources from the Ravensworth East Resource Recovery (RERR) mining area. This was previously considered in the Year 10 scenario modelled in the 2014 AQIA. In addition, the final landform treatments for the Bayswater North Pit (BNP) void will no longer involve the haulage of any waste material from North Pit or adjacent emplacement areas and these final landform works will commence following cessation of mining in North Pit. Dump batters surrounding the void will be flattened using bulldozers and the high wall may be blasted in order to flatten. The intent is for these softening works to occur as part of mine closure (i.e. as part of achieving the Final Landform). Prior to mine closure, the BNP void will be used as a water storage and supply dam to the CHPP or a contingency tailings emplacement area later in the Project life.

The purpose of this report is to review the proposed changes in the context of the Project in Year 10, and determine whether these changes will result in any material difference to the outcomes of the original 2014 assessment. In the process of reviewing the changes for the Project, additional relevant analysis has been carried out using new data that have become available since the 2014 AQIA was completed. This new information includes monitoring data up to the end of 2015, for both the UHAQMN and the Mount Owen monitoring stations in the vicinity of the Project.

The report also presents the following information:

- Incorporation of additional monitoring data from the UHAQMN and Mount Owen sites (2012 – 2015).
- Comparison of Year 10 contours from the 2014 assessment with the Refined Project which excludes the RERR mining area.
- Update of the cumulative assessment for annual averages, applying the method used in the 2014 assessment (and accepted by the NSW EPA in their response to the Response to Submissions Report). The annual average cumulative assessment includes the following revisions:
    - the use of the additional UHAQMN data to December 2015 for Jerrys Plains, Merriwa and Wybong to recalculate the non-mining background value to be added to predictions,
    - the inclusion of the proposed Rix's Creek modification (not considered in Years 5 or 10 of the 2014 assessment as details of that project were not known at that time),
    - a comparison of annual average cumulative results with and without the inclusion of the Ashton South East Open Cut (SEOC) project, and
    - A presentation of calibrated results for the above scenarios.

Section 2 focuses on the analysis of additional data that have become available since the completion of the 2014 AQIA. For convenience, Figure 1.1 and Figure 1.2 are presented below to show the locations of the relevant monitoring stations for both the Mount Owen monitoring network and the UHAQMN, respectively.

Figure 1.1: TEOM and HVAS locations in the Mount Owen monitoring network

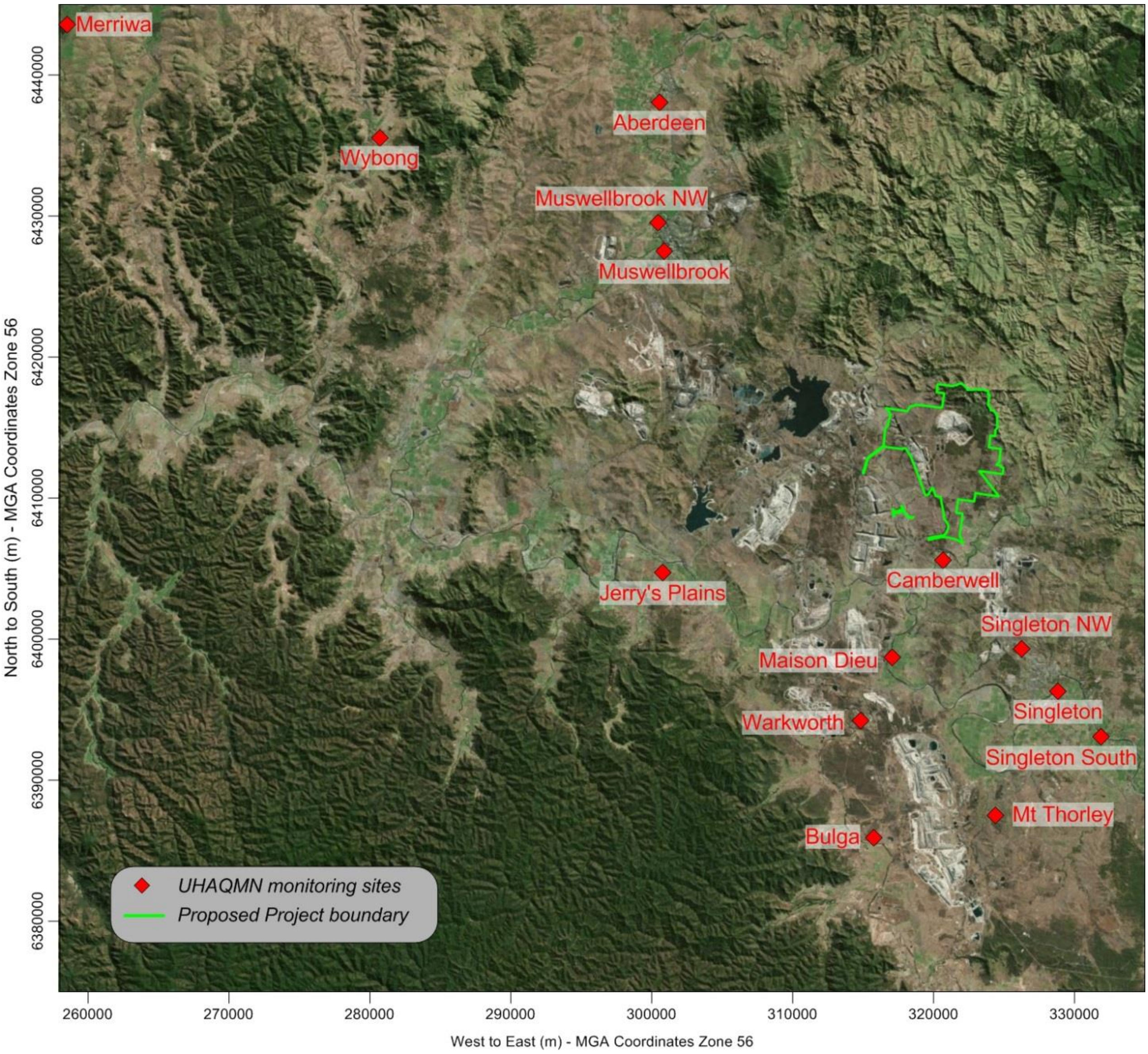

Figure 1.2: Monitoring locations in the Upper Hunter Air Quality Monitoring Network

2. Analysis of additional monitoring data

When the AQIA was completed in 2014, monitoring data were only available until the end of 2013. The existing air quality in the Project area was described using the Mount Owen monitoring data, and also further afield using the UHAQMN data available at that time. The results of the analysis of these data are presented in Section 5.3 of the AQIA (**Pacific Environment, 2014**).

2.1 Mount Owen monitoring data

The rolling annual average PM_{10} concentrations for Mount Owen monitoring sites were shown in Figure 5.5 of the AQIA. The data were presented in this way to show trends over the monitoring period. When comparing annual average PM_{10} predictions to the assessment criterion the rolling average is not used in the assessment of impacts at particular locations, but rather the annual average at a fixed point in time (for example, the 12 month period up to and including 31st December each year). This current assessment seeks to clarify the use of annual average data for assessment purposes. The simple fixed point annual averages are presented in Figure 2.1. This figure also includes additional data for some sites that have become available since 2014 (SX8, SX9, SX10, SX13 and PM10-2).

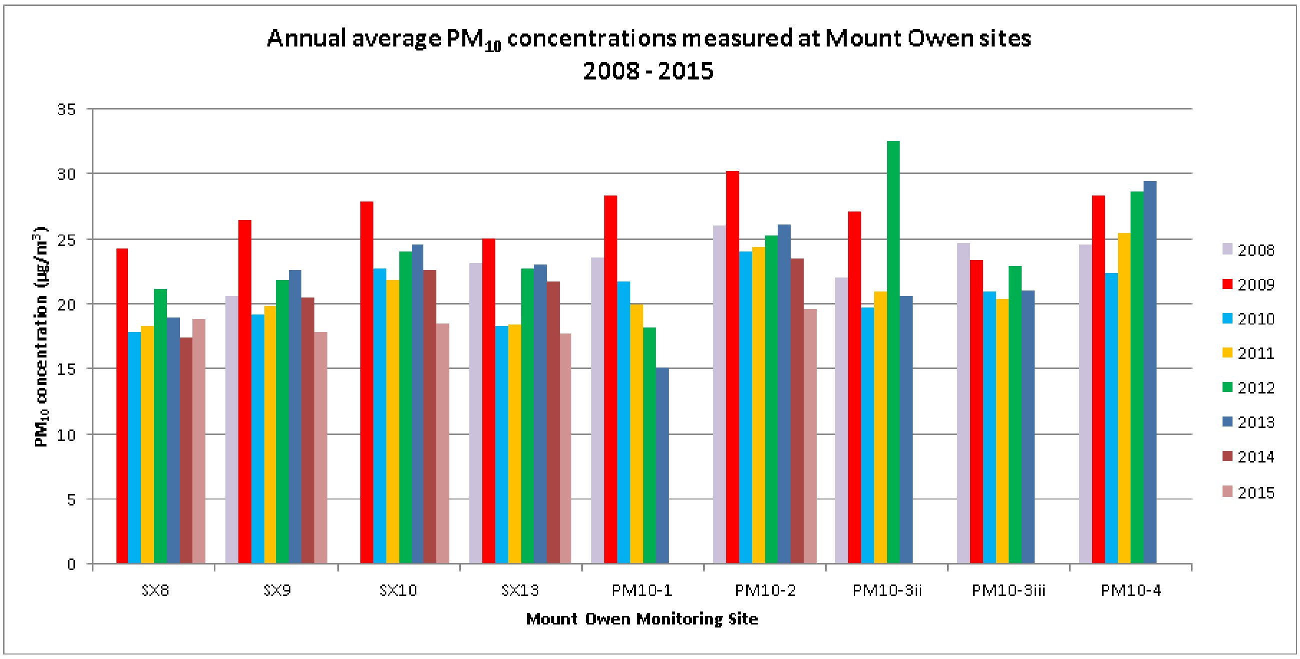

Figure 2.1: Annual average PM_{10} concentrations measured at Mount Owen sites from 2008 – 2015

It is clear that 2009 was an anomalous year, with a significant dust storm (23 September) and a number of bushfires occurring later that year. It is also interesting to note that at PM10-1 there has been a steady decrease in annual average PM_{10} since 2008 (with the exception of 2009). However, given that this site lies to the northwest of the North Pit, which has been progressively moving to the southeast, this is perhaps not unusual. A similar argument could be made for PM10-4, to the southeast of Liddell. Levels there have been increasing which may be due to the progression of Liddell operations towards that site in recent years (it is noted that there are no residences in the vicinity of PM10-4).

It is important to note that in general (excluding 2009), levels at SX9, SX10, PM10-2 and PM10-3iii have remained reasonably consistent, varying by about 6 µg/m^3 or less over seven years. In fact, these four sites have been the most consistent of all the Mount Owen sites. Overall, it can be seen that there is significant variability between sites in any one year (approximately 14 µg/m^3 between PM10-1 and PM 10-3ii in 2012 and 14 µg/m^3 between PM10-1 and PM10-4 in 2013) and significant variability within some sites between years (approximately 13 µg/m^3 at PM10-3ii). The observed variability is most likely driven by changes in emissions from the mining operations located around the network. As noted in the 2014 AQIA, this temporal and spatial variability in emissions poses challenges for using these data to determine appropriate background levels for the assessment of cumulative impacts associated with the Project. For this reason, the wider regional background monitoring network is considered in seeking to establish a reasonable approximation of the relevant background dust levels (that is, estimating what the background dust level may be in this area, if current mining operations were not present).

2.2 UHAQMN monitoring data

The UHAQMN is the regional air quality monitoring network in the Upper Hunter, established by NSW OEH and managed by the NSW EPA. By the beginning of 2012 there were 14 sites operating in strategic locations across the region. These sites include those in major population areas, Muswellbrook and Singleton, as well as near large mining operations. There are a smaller number of more remote sites that were specifically sited to provide an estimate of levels less influenced by mining (NSW OEH, 2012). These include the Wybong and Merriwa sites, and also Jerrys Plains as it is outside the predominant NW-SE wind direction axis in the valley relative to mining operations in the area.

Given the number of existing mining operations in the locality surrounding the Project, the Wybong, Merriwa and Jerrys Plains sites were chosen to represent a non-mining background value for the cumulative annual average PM_{10} assessment. That is, the AQIA used the UHAQMN sites that are less influenced by contributions from mining operations within the Hunter Valley to determine a non-mining background level to which the modelled contributions from the Project and other existing and approved mines in its vicinity were added to estimate cumulative annual average levels. This approach is consistent with the original purpose for those monitoring stations, that is background stations monitoring PM_{10} concentrations in air brought into the Hunter Valley from the northwest, as noted in the Upper Hunter Valley Monitoring Network Design report (HAS, 2008).

This approach was considered to more accurately capture the spatial and temporal variability in mining around the Project area over the period being assessed when compared to the approach of deriving a non-Project background level from the (understandably) variable monitoring data from the Mount Owen Network.

Figure 2.2 shows the annual average PM_{10} levels recorded at each of the 14 UHAQMN sites for the period 2012 – 2015 (inclusive).

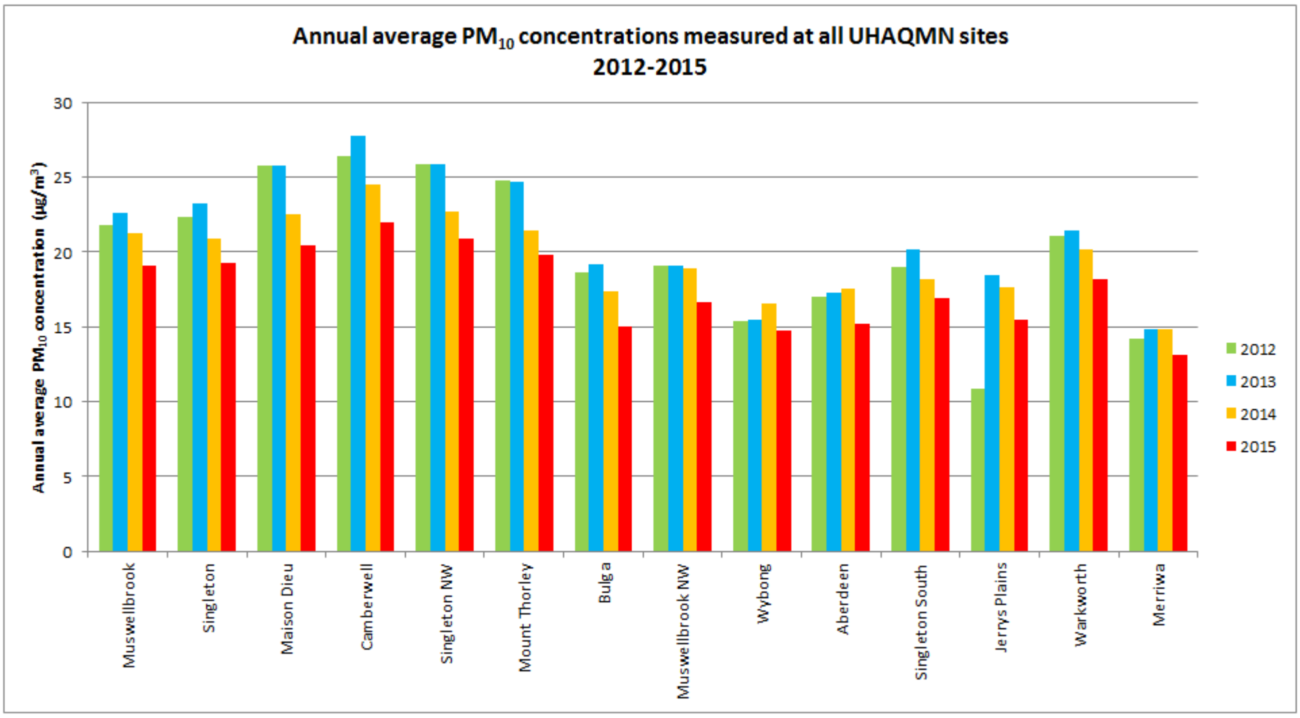

Figure 2.2: Annual average PM_{10} concentrations measured at UHAQMN sites from 2012 – 2015

As can be seen from Figure 2.2, the measured levels over the monitoring period at Wybong, Jerrys Plains and Merriwa are lower than other stations in the network which are closer to mining operations. As can also be seen in Figure 2.2, concentrations have been decreasing at most sites since monitoring began, however the data from the Wybong, Jerry's Plains and Merriwa stations have remained reasonably static. This indicates that these stations were likely to have been less influenced by changes in mining activity over this period. The annual average PM_{10} concentration from 2012 – 2015 at Wybong, Jerry's Plains and Merriwa is 15.1 µg/m^3 (discussed further in Section 4.1). This is only slightly higher than the value of 14.9 µg/m^3 used in the most recent evaluation of cumulative annual average PM_{10}, in the Response to Submissions regarding the AQIA (Umwelt, 2015). It is also noted that both the Bulga and Aberdeen stations recorded similar levels in 2015 (15.0 and 15.2 µg/m^3, respectively)). Concentrations in the vicinity of Mount Owen Mine have, at times, also been around 15 µg/m^3. For example, the PM10-1 monitor in the Mount Owen network recorded 15.1 µg/m^3 in 2013 (refer to Figure 2.1) and measurements at this station would include a contribution from Mount Owen as well as other nearby mines. The analysis of the data indicates that a level of 14.9-15.1 µg/m^3 is therefore a reasonable, if not slightly conservative, assumption of non-mining background levels present in the Hunter Valley as similar levels are recorded in locations known to be influenced by mining.

3. Project only assessment – comparison of Year 10 contours

In the original 2014 AQIA, the predicted concentrations were presented as contour plots for each operational year assessed. In Years 1 and 5, this included combined operations in the North and Bayswater North Pits. By Year 10, the Bayswater North Pit was completed and operations were commenced in the RERR mining area. The Refined Project will no longer include the RERR mining area operations and will include the North Pit only. As a result, the modelled Year 10 scenario in the 2014 AQIA will overstate the predicted impacts from the Refined Project due to the inclusion of emissions associated with activities in the RERR mining area.

Table 1 shows the difference in PM_{10} emissions in Year 10 between the original assessment and the Refined Project, a reduction of approximately 20%.

Table 1. Summary of total PM_{10} emissions estimated in Year 10 for the original assessment and the Refined Project

Original assessment (North Pit and RERR)	Refined Project (North Pit only)
1,000,249 kg	807,715 kg

Figure 3.1 and Figure 3.2 show the predicted 24-hour and annual average $PM_{2.5}$ concentrations for Year 10, for both the original and Refined Project.

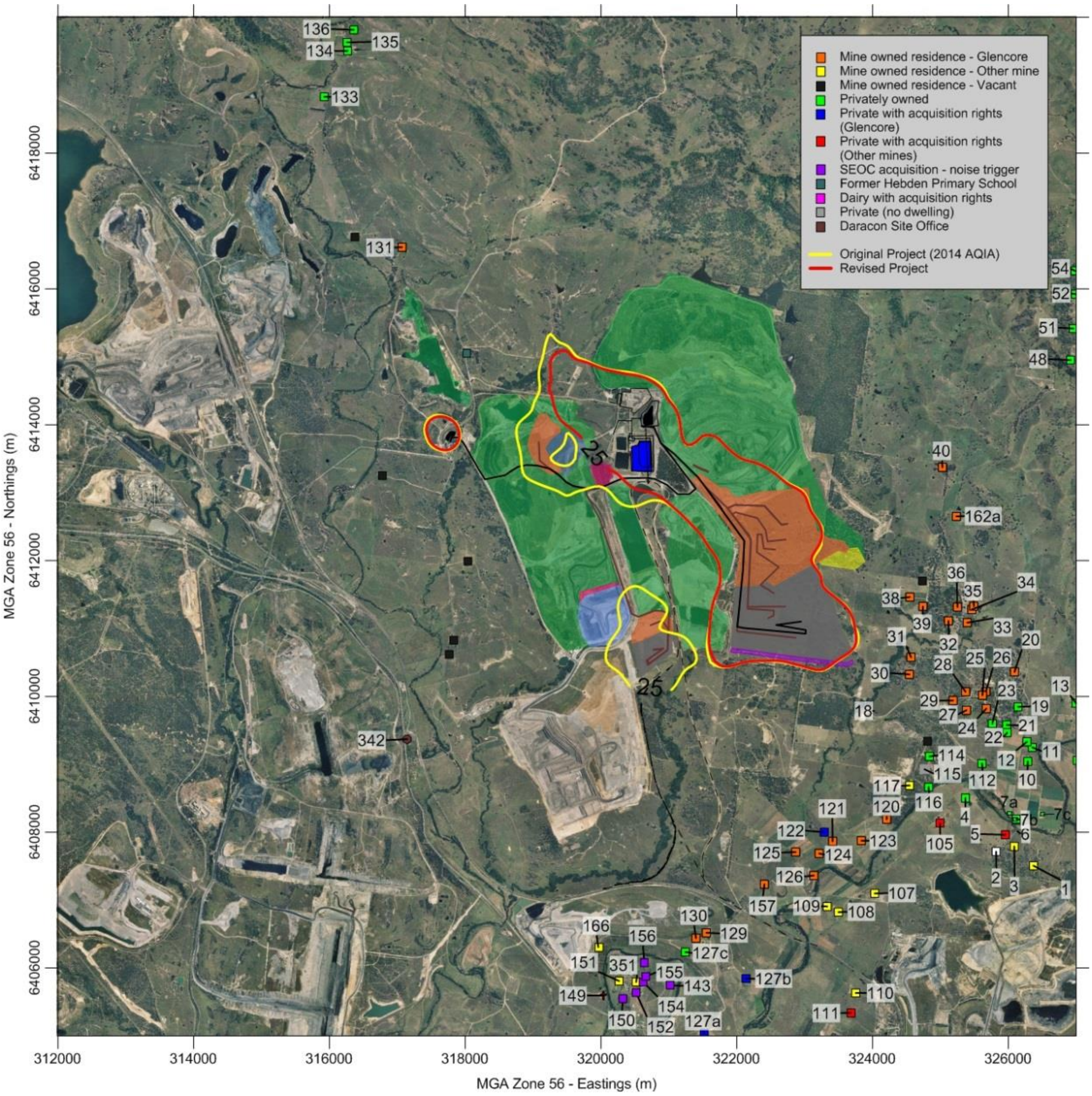

Figure 3.1: Maximum predicted 24-hour average $PM_{2.5}$ concentrations in Year 10 – Project only (µg/m^3)

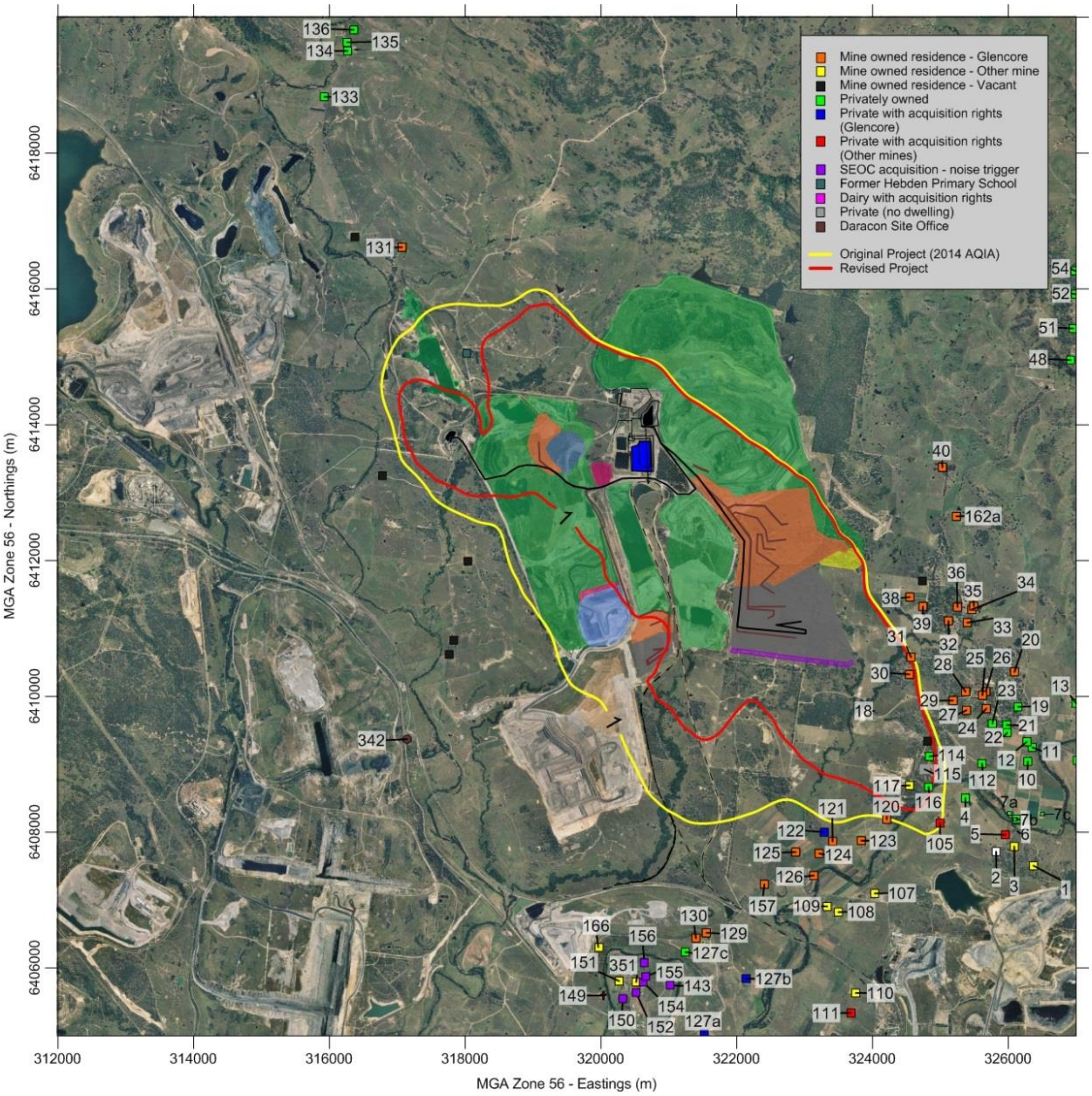

Figure 3.2: Predicted annual average $PM_{2.5}$ concentrations in Year 10 – Project only ($\mu g/m^3$)

Figure 3.3 and Figure 3.4 show the maximum predicted 24-hour average and annual average PM_{10} concentrations for Year 10, for both the original and Refined Project. It is noted that in the 2014 AQIA, the only residence predicted to exceed the maximum 24-hour average PM_{10} criterion for Project only was R23. As shown in Section 10.2.3 of the 2014 AQIA (Figure 10.13), this criterion was only predicted to exceed on one day per year. This exceedance is not predicted to occur for the Refined Project, as shown in Figure 3.3.

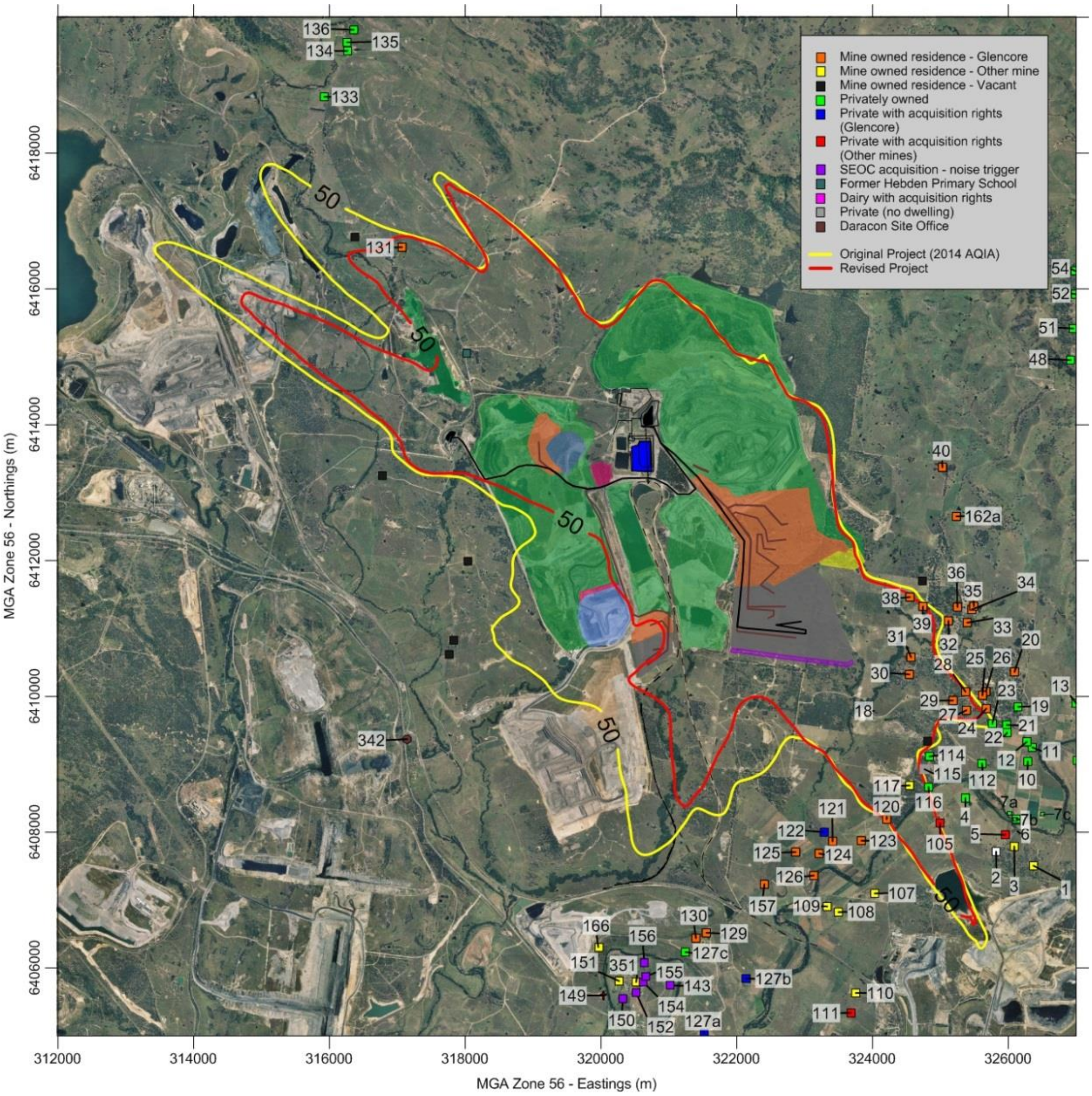

Figure 3.3: Predicted maximum 24-hour average PM_{10} concentrations in Year 10 – Project only ($\mu g/m^3$)

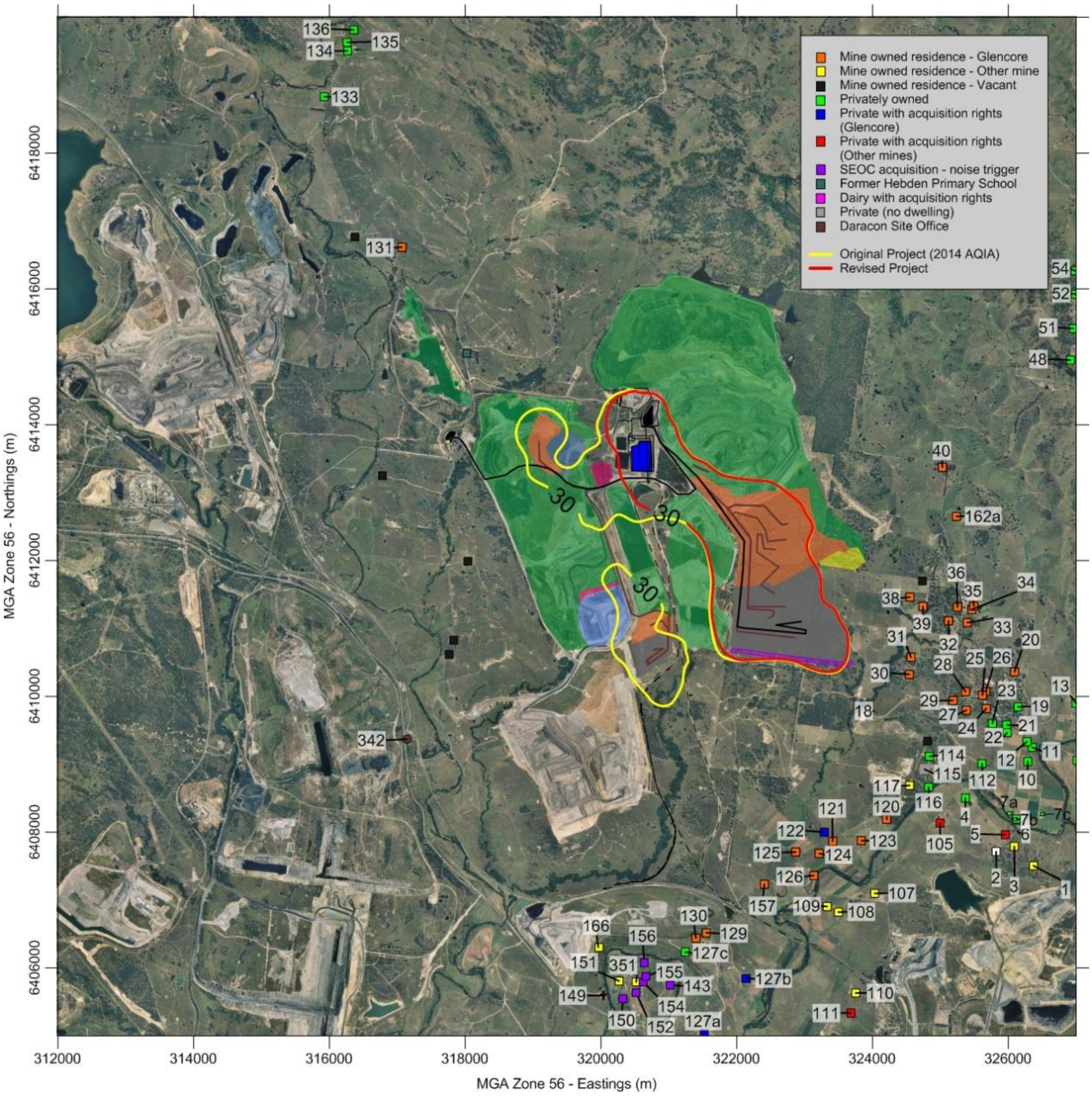

Figure 3.4: Predicted annual average PM_{10} concentrations in Year 10 – Project only ($\mu g/m^3$)

Figure 3.5 shows the predicted annual average TSP concentrations for Year 10, for both the original and Refined Project.

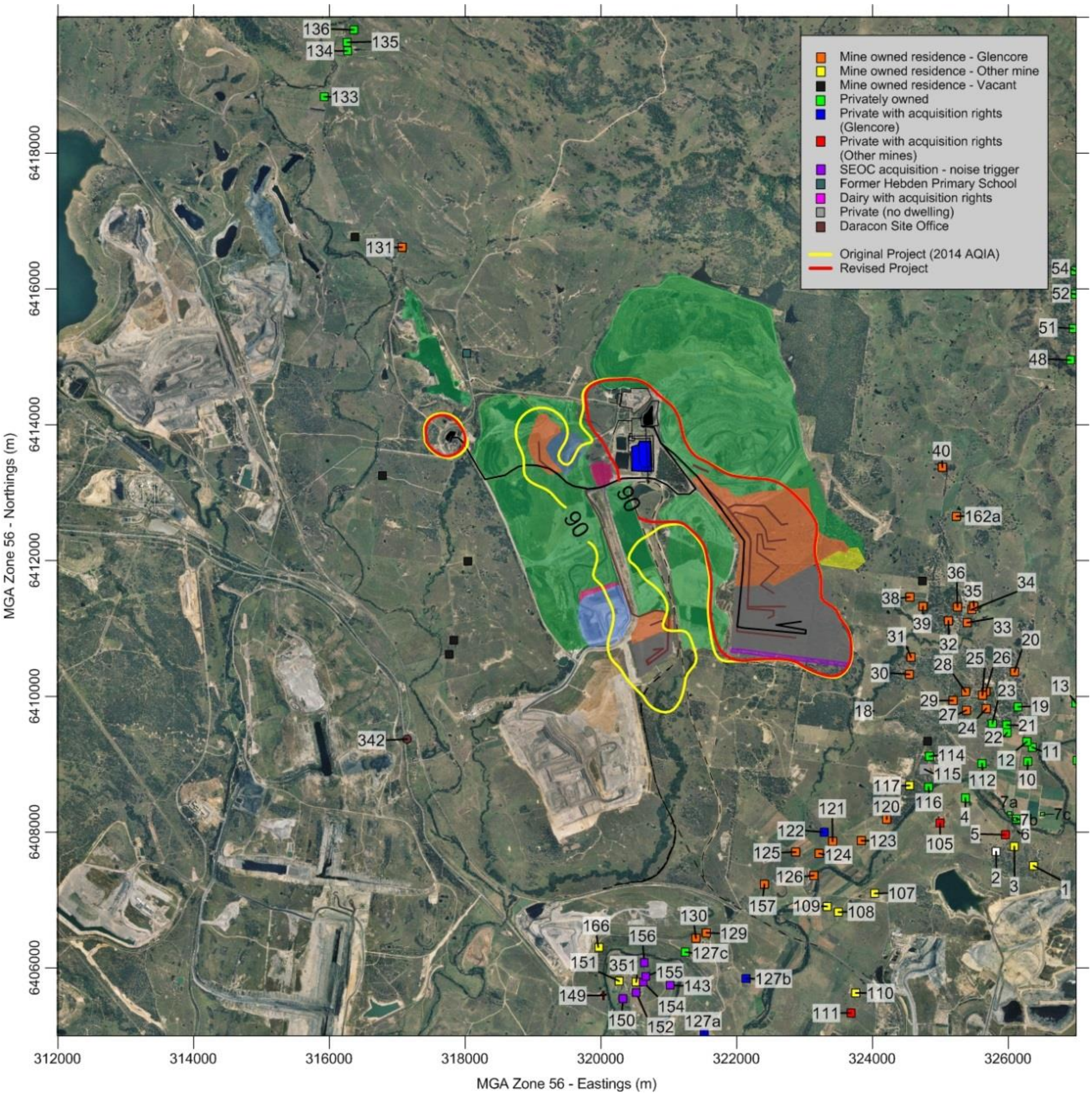

Figure 3.5: Predicted annual average TSP concentrations in Year 10 – Project only (µg/m^3)

Figure 3.6 shows the predicted annual average dust deposition levels for Year 10, for both the original and Refined Project.

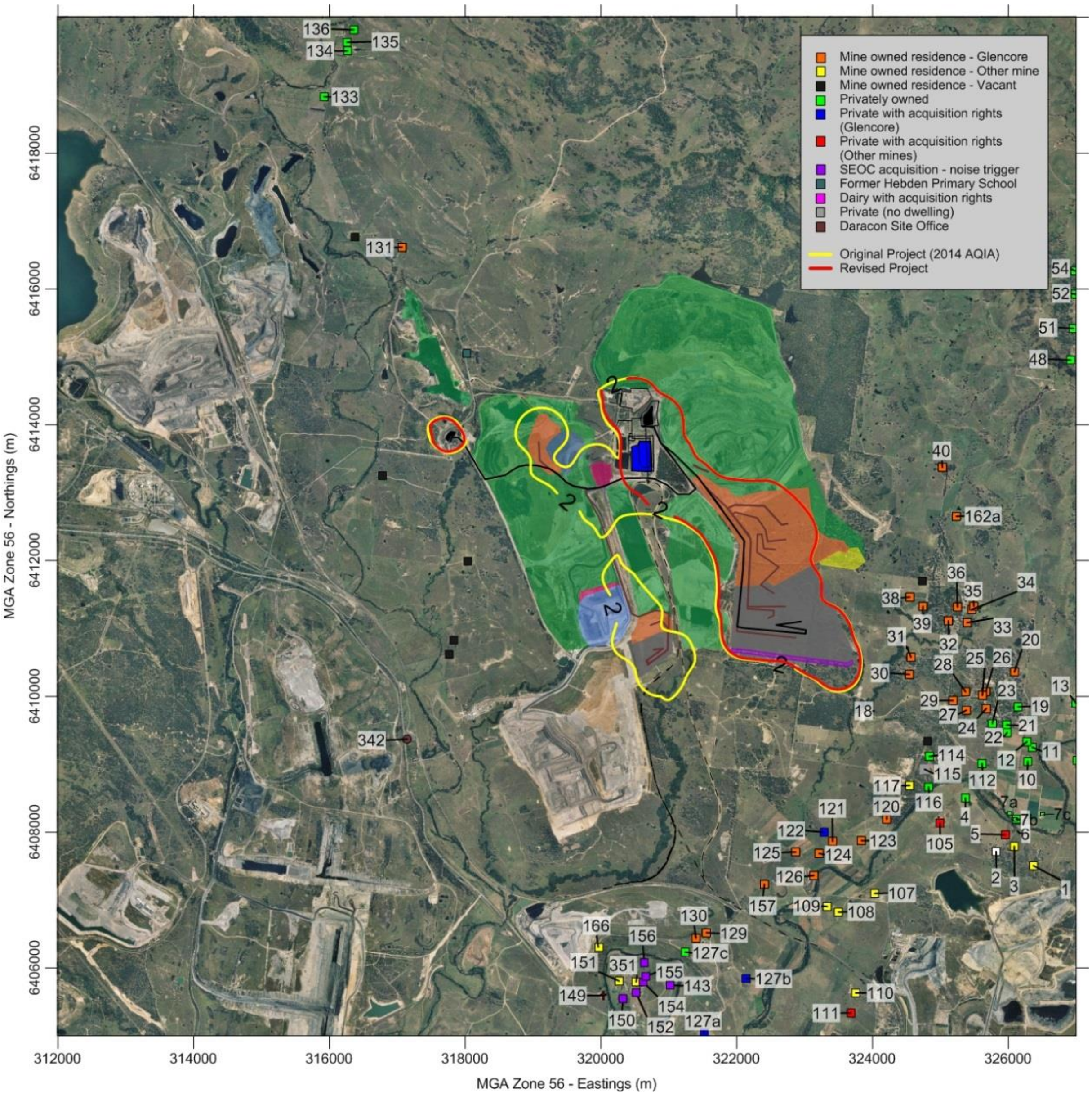

Figure 3.6: Predicted annual average dust deposition in Year 10 – Project only (g/m^2/month)

From the information presented in Figure 3.1 to Figure 3.6 it is clear that the removal of the RERR mining area has a small effect in the immediate area surrounding the RERR operations, but almost no impact in the vicinity of residences.

4. Cumulative assessment – annual average

4.1 Using the updated UHAQMN data analysis

As discussed in Section 2.2, additional data from the UHAQMN have become available since the 2014 AQIA and subsequent Response to Submissions (RTS) were completed. To briefly summarise, the UHAQMN data were used to determine an annual average PM_{10} level which is predominantly unaffected by mining and therefore more representative of general background conditions without the influence of large mining operations. This has been referred to in the AQIA and subsequent documents as the non-mining background, to which the contribution from modelled mines can then be added. As has been described in previous reports for this Project, the total cumulative annual average is described as:

Total cumulative = [Non-Project mines x calibration factor] + [non-mining background x 100%] + [Project x 100%]

In the AQIA this non-mining background was calculated using the median values for the Wybong, Merriwa and Jerrys Plains sites. In the RTS documents, further analysis was carried out which showed that using the mean rather than the median had no impact on the outcomes of the original AQIA. It is noted that the NSW EPA accepted the methodology using the mean and considered the value appropriate to represent the non-mining background. This mean was calculated to be 14.9 µg/m^3 in the Response to Submissions Report using data to 2013. As noted in Section 2.2, this value very slightly increases to15.1 µg/m^3 when using the additional data now available. Table 2 shows the two data sets and how these values were calculated. The values shaded in blue were those available for the 2014 AQIA and average to 14.9 µg/m^3, while the total dataset to the end of 2015 average to 15.1 µg/m^3. This difference would be imperceptible in the atmosphere.

Table 2. Summary of annual average PM_{10} concentrations measured at UHAQMN non-mining background sites

Site	2012	2013	2014	2015	Average
Wybong	15.4	15.5	16.5	14.8	15.5
Merriwa	14.2	14.9	14.8	13.2	15.6
Jerrys Plains	10.8	18.5	17.7	15.5	14.3
Average	**14.9**				**15.1**

Concentrations in the vicinity of Mount Owen Mine have, at times, been around 15 µg/m^3 (see Section 2.1). This measured level at PM10-1 in 2013 will include influences from both Mount Owen and other mines in the area. Accordingly, it is not unreasonable to assume that the adopted 15.1 µg/m^3 non-mining background level derived from the Merriwa, Wybong and Jerrys Plains UHAQMN stations retains a degree of conservatism.

The derived 15.1 µg/m^3 non-mining background value was used to recalculate the cumulative annual average PM_{10} for the Refined Project in Year 10 and these results are presented in Figure 4.1 together with the results from the original 2014 AQIA. Appendix A presents the results for $PM_{2.5}$, cumulative annual average for the Refined Project using the methodology applied in the Response to Submissions.

Figure 4.1 shows that the modifications to the original Project do not alter the outcomes of that assessment.

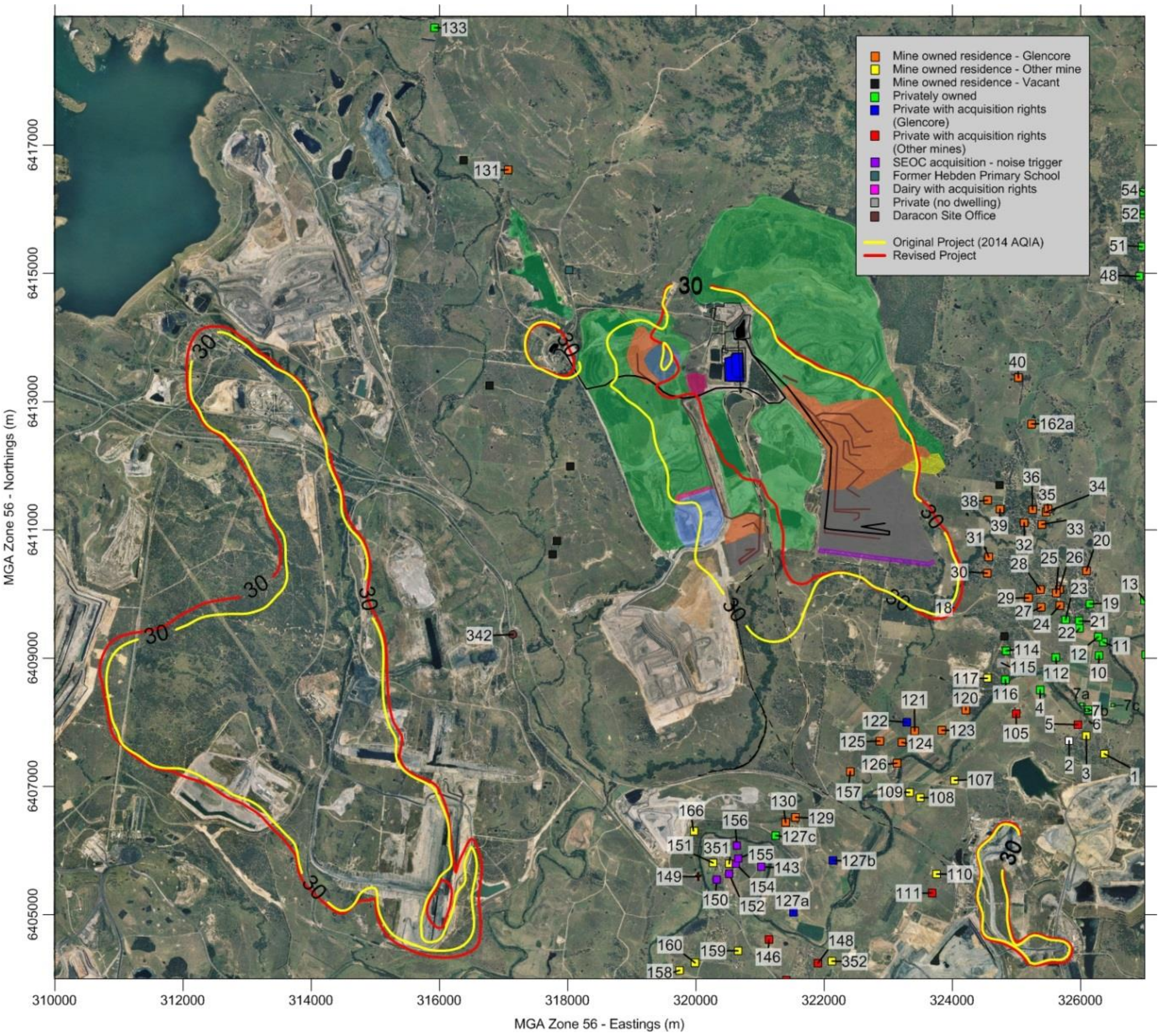

Figure 4.1: Predicted annual average PM_{10} concentrations in Year 10 – Cumulative (µg/m^3)

4.2 Sensitivity to Rix's Creek Modification Project in Years 5 and 10

As shown in Section 8.5 of the original AQIA, Rix's Creek operations were not included in the cumulative assessment for Year 5 and Year 10 at the time the AQIA was completed. An assessment for the Rix's Creek Continuation of Mining (COM) Project was submitted in late 2015 (TAS, 2015) and so this section presents an analysis of the potential impact of Rix's Creek operations on the Middle Falbrook residences in Years 5 and 10.

The emissions estimated in the AQIA for mines other than the MOCO Project were reasonably coarse as they were based on information that was available in the public domain. This issue was highlighted in the AQIA and the likelihood that emissions from other mines were overestimated was discussed, particularly in relation to the likely resulting overestimation of emissions from these other operations. Indeed, the intent of the calibration of other mines used in the 2014 AQIA was to specifically address this issue.

The estimated TSP emissions for Rix's Creek, noted in Table 8.14 of the MOCO AQIA, were approximately 3.4 Mt in Year 1. The TSP emissions for the closest corresponding year in the Rix's Creek AQIA (2017), was approximately 1.8 Mt, just over half of the estimated emissions used in the Project. This is not surprising as significantly more detail about the dust generating activities, such as truck sizes, haul road lengths, extent of exposed areas and quantities of material excavated and moved, was known for the Rix's Creek COM assessment. In effect, it was quite a different operation to the one assessed in 2009 and from which emission estimates were drawn for the MOCO AQIA. In terms of addressing the potential effect that the Rix's Creek COM Project would have on cumulative annual average concentrations in Year 1 at Middle Falbrook, these could potentially be about half of what was modelled.

It is important to note that the average calibration factor applied to other mines at Middle Falbrook, an area where Rix's Creek is one of the more dominant contributors, was approximately 0.6. This means that model predictions for non-Project mines were reduced by 40% at that location. Given the information presented above, this appears to be an entirely appropriate value to have applied at that location.

Going forward then, and trying to determine what the potential effect Rix's Creek COM may have in Year 5 and Year 10, particularly in the Middle Falbrook area, the results from the 2014 AQIA cumulative assessment for Year 1 have been applied to both Year 5 and Year 10. The TSP estimates in 2017, 2020 and 2026 are reasonably consistent (see Table 5-1 in TAS (2015)) and so this approach is reasonable however, given the lower predicted levels of TSP from Rix's Creek COM relative to that modelled in Year 1 of the AQIA, is likely to overestimate the influence from Rix's Creek during years 5 and 10.

It is understood that the relationship between emissions and predicted impacts is not necessarily linear, but in the absence of other information and no contours extending to the Middle Falbrook area available in the Rix's Creek COM AQIA, it is likely to be a reasonable approximation.

Figure 4.2 shows the individual mine, Project, and non-mining background concentrations, for the most affected residences in Middle Falbrook (between the Project and Rix's Creek). The same information is presented for Year 10 in Figure 4.3. Even though the calibration factors used in this area have been demonstrated to be reasonable, at least for the major contributors to concentrations in the Middle Falbrook area, <u>these figures only present the results where no calibration factors have been applied to the contribution from non-Project mines</u>.

No properties are predicted to exceed the cumulative annual average PM_{10} criterion of 30 µg/m^3 when the calibration factor is applied to the raw modelled contributions from other mines. When the calibration of 'other mines' is removed, R114 and R116 are predicted to exceed the 30 µg/m^3 criterion in Year 5. These two residences are located on landholdings that are predicted to experience exceedances of the 24-hour average, Project only PM_{10} DP&E voluntary acquisition criteria over more than 25% of the landholding in Years 1 and 5 and, in the case of R116, Year 10, and are therefore already identified as having voluntary acquisition rights under the Voluntary Land Acquisition and Mitigation Policy (VLAMP). As noted above, the contribution from the Rix's Creek COM project in these years is based on significantly higher TSP levels than is predicted in the TAS 2015 assessment of that project and therefore likely represents a significant over prediction of the contribution from that project at the receivers shown in Figures 4.2 to 4.3. The Rix's Creek COM project is still undergoing assessment and, without the contribution from the Rix's Creek COM project in year 5, there would be no exceedance of the annual average PM_{10} criterion of 30 µg/m^3 at any residences.

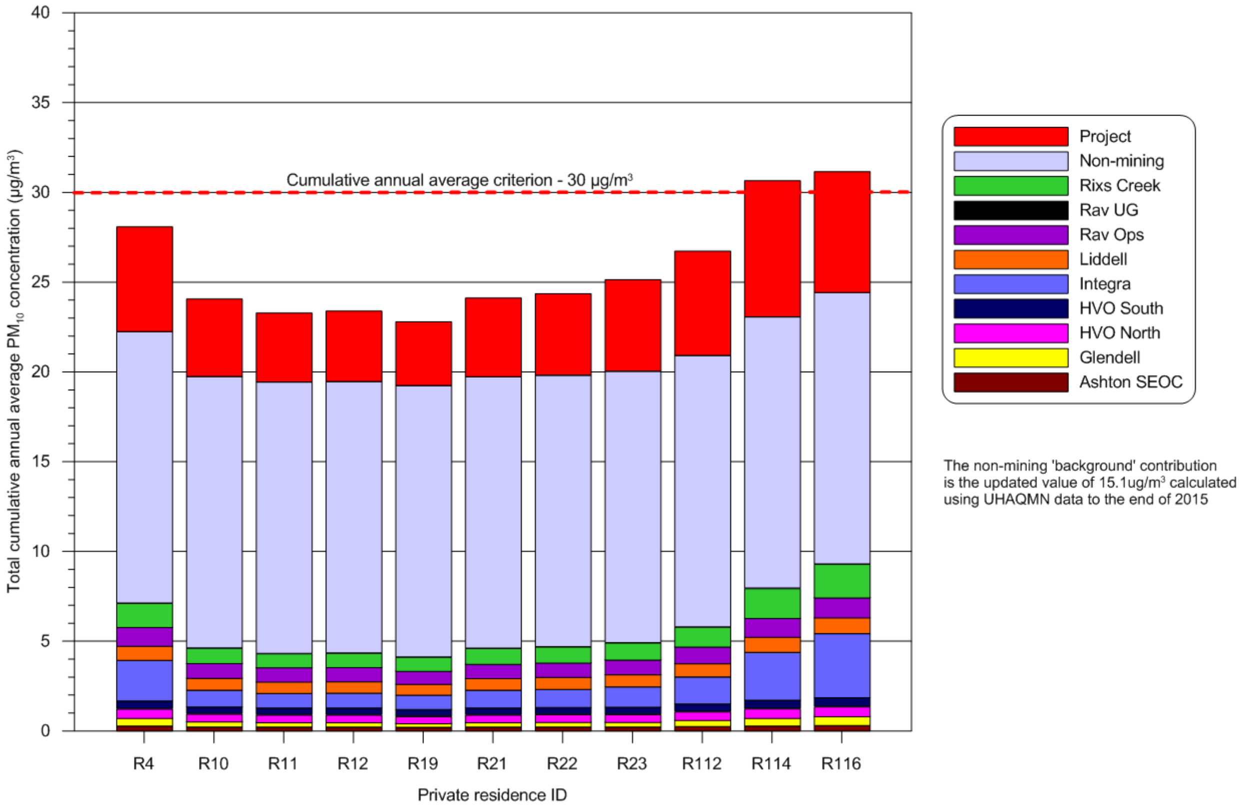

Figure 4.2: Individual contributions of annual average PM_{10} concentrations in Year 5 – Contribution from other mines have no calibration factor applied and include the Rix's Creek COM (µg/m^3)

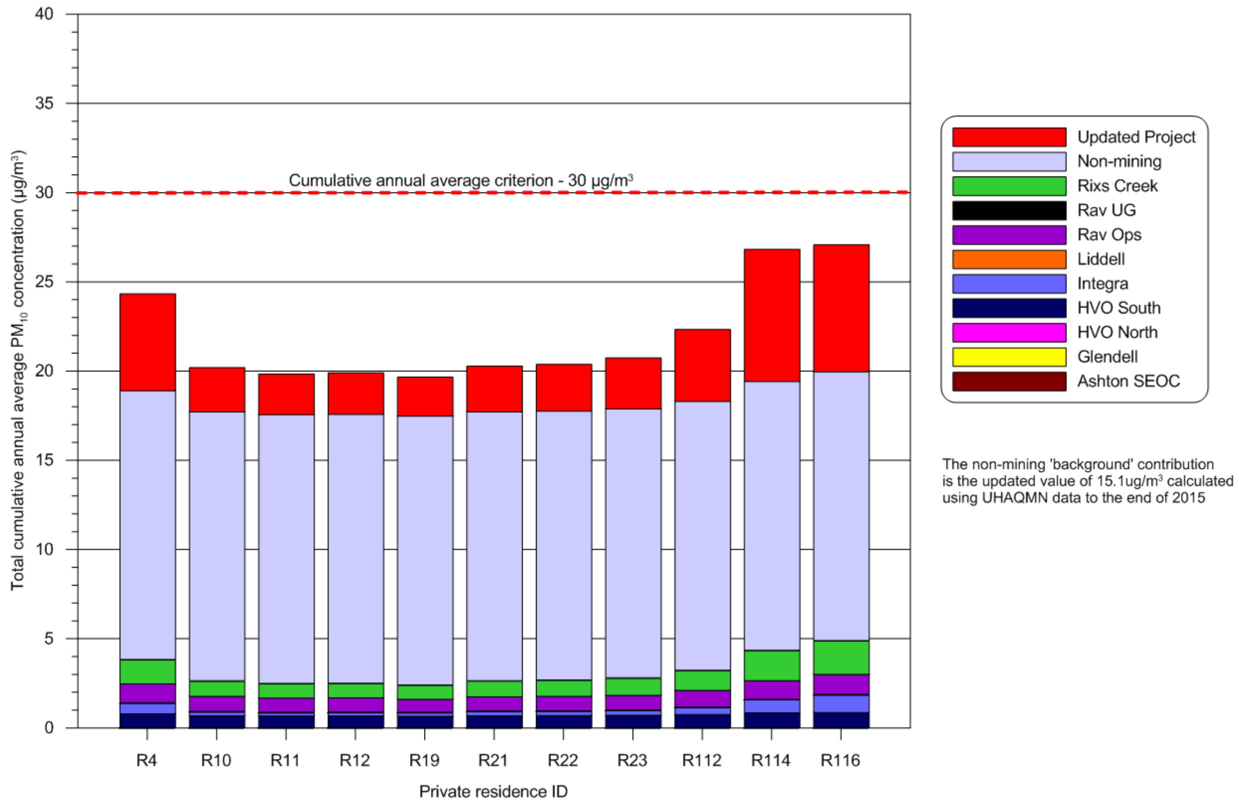

Figure 4.3: Individual contributions of annual average PM_{10} concentrations in Year 10 – Other mines have no calibration factor applied and include the Rix's Creek COM (µg/m^3)

4.3 Sensitivity to Ashton South East Open Cut

The proposed Ashton South East Open Cut (SEOC) operations were included in the 2014 AQIA, to coincide with Years 1 and 5 of the Project. At that time it was approved but is subject to conditions that may limit proceeding with this Project. This section presents the predicted cumulative annual average PM_{10} concentrations at the nearest Middle Falbrook residences in the absence of the Ashton SEOC Project.

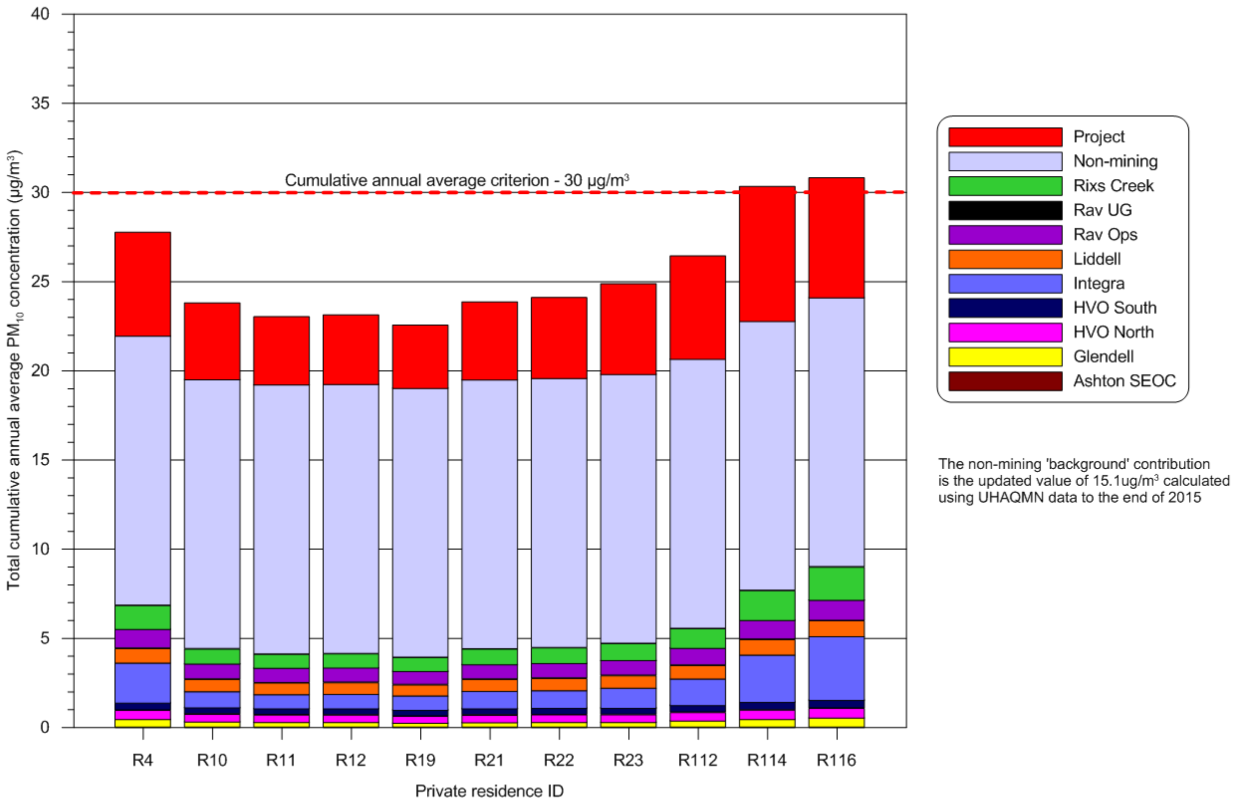

Figure 4.4: Individual contributions of annual average PM_{10} concentrations in Year 1 – Other mines have no calibration factor applied and do not include the Ashton SEOC ($\mu g/m^3$)

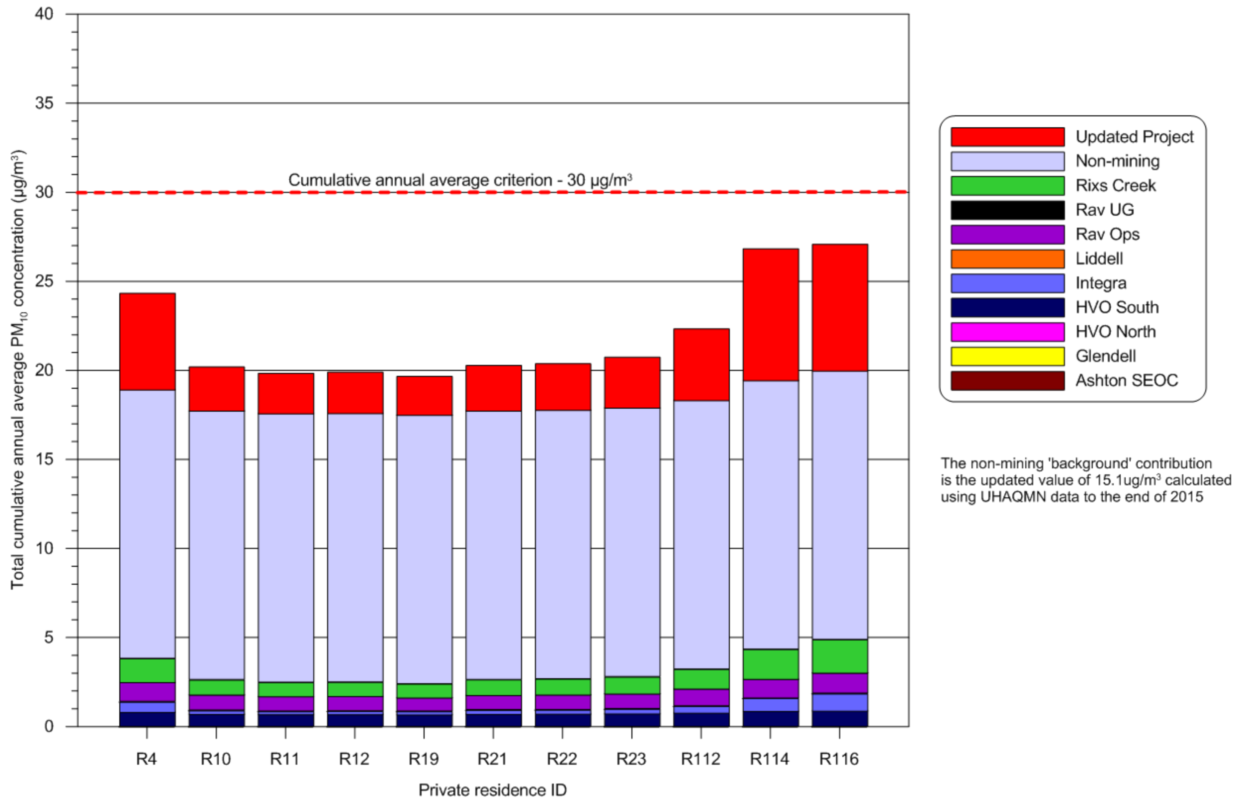

Figure 4.5: Individual contributions of annual average PM_{10} concentrations in Year 10 – Other mines have no calibration factor applied and do not include the Ashton SEOC (µg/m^3)

No properties are predicted to exceed the cumulative annual average PM_{10} criterion using the calibrated contributions from other mines. Only R114 and R116 are predicted to exceed this criterion when there are no calibration factors applied. As noted above, these two residences are located on landholdings that are predicted to experience exceedances of the 24 hour, project only PM_{10} voluntary acquisition criteria over more than 25% of the landholding during the life of the Project, and are therefore already identified as having voluntary acquisition rights under the VLAMP.

4.4 Summary of results

This section presents a summary of some of the sensitivity analyses that have been carried out above, presenting both the calibrated and uncalibrated results for the non-Project mines.

The most affected residences for this Project, on an annual basis, are predicted to be R114 and R116, as demonstrated in the assessment above. As these locations already qualify for voluntary acquisition rights due to predicted 24-hour average Project alone PM_{10} impacts, the next most affect receptor, R4, has been used to compare the various scenarios investigated here. All the following information for Year 10 pertains to the Refined Project, that is, with the RERR mining area removed.

Predicted cumulative annual average PM_{10} concentrations at R4 (with and without calibration factors applied to the contribution from other mines) are compared against the original 2014 AQIA for the following three scenarios:

- Scenario 1: applies the updated non-mining background value of 15.1 µg/m^3 (accounting for all UHAQMN data from 2012 – 2015),
- Scenario 2: as per Scenario 1 but also includes Rix's Creek COM in Year 5 and Year 10, and
- Scenario 3: as per Scenario 2 but removes the Ashton SEOC in Year 1 and Year 5.

Figure 4.6, Figure 4.7 and Figure 4.8 present these comparisons for Year 1, Year 5 and Year 10, respectively.

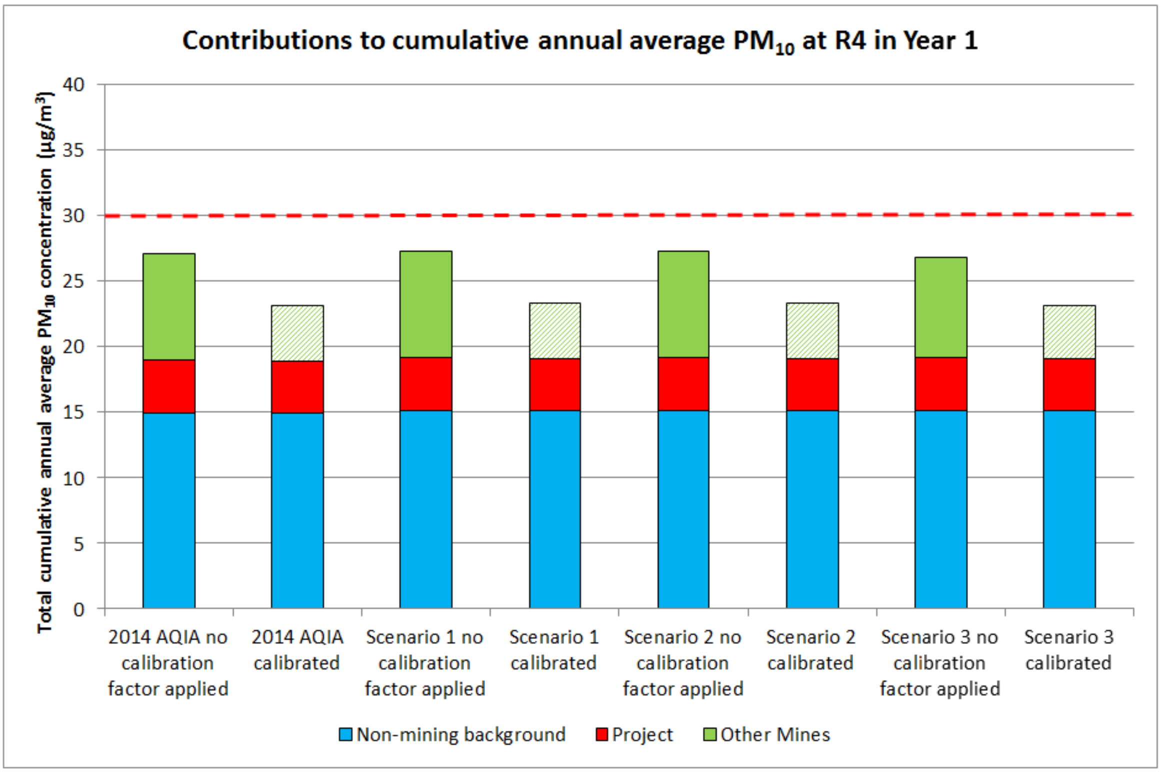

Figure 4.6: Individual contributions to the cumulative annual average PM_{10} concentrations in Year 1 for each scenario at R4 (µg/m^3)

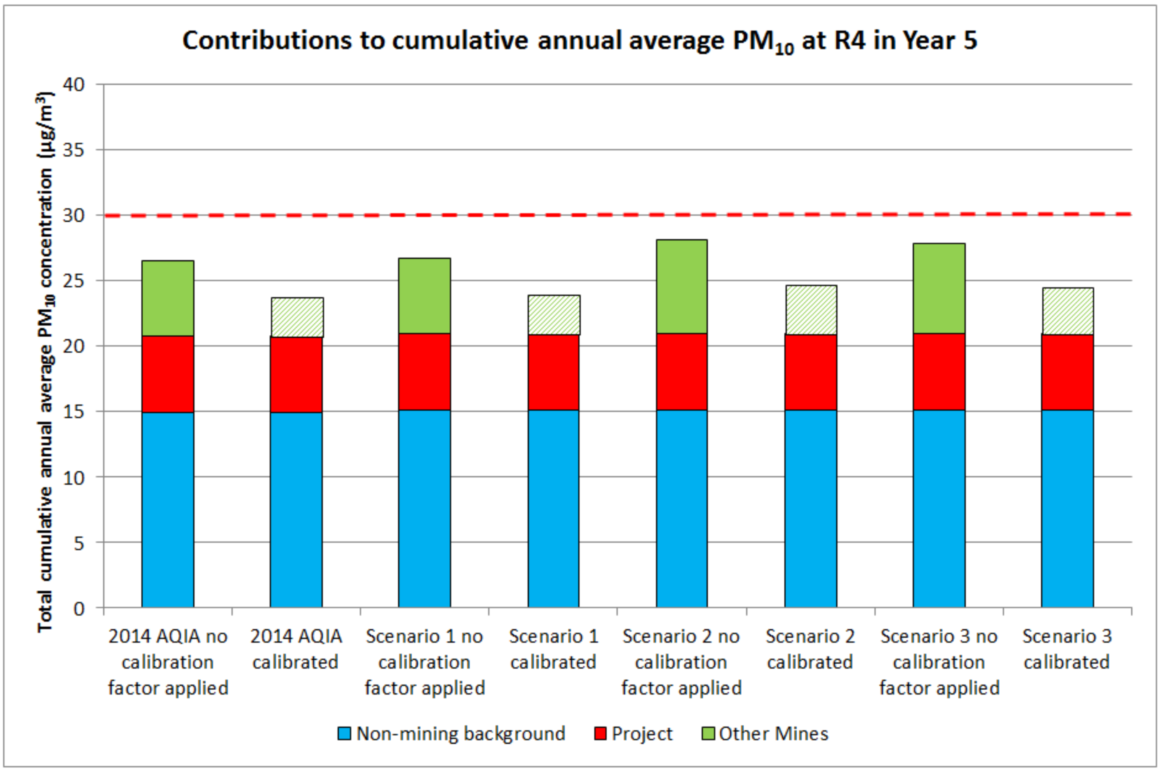

Figure 4.7: Individual contributions to the cumulative annual average PM_{10} concentrations in Year 5 for each scenario at R4 ($\mu g/m^3$)

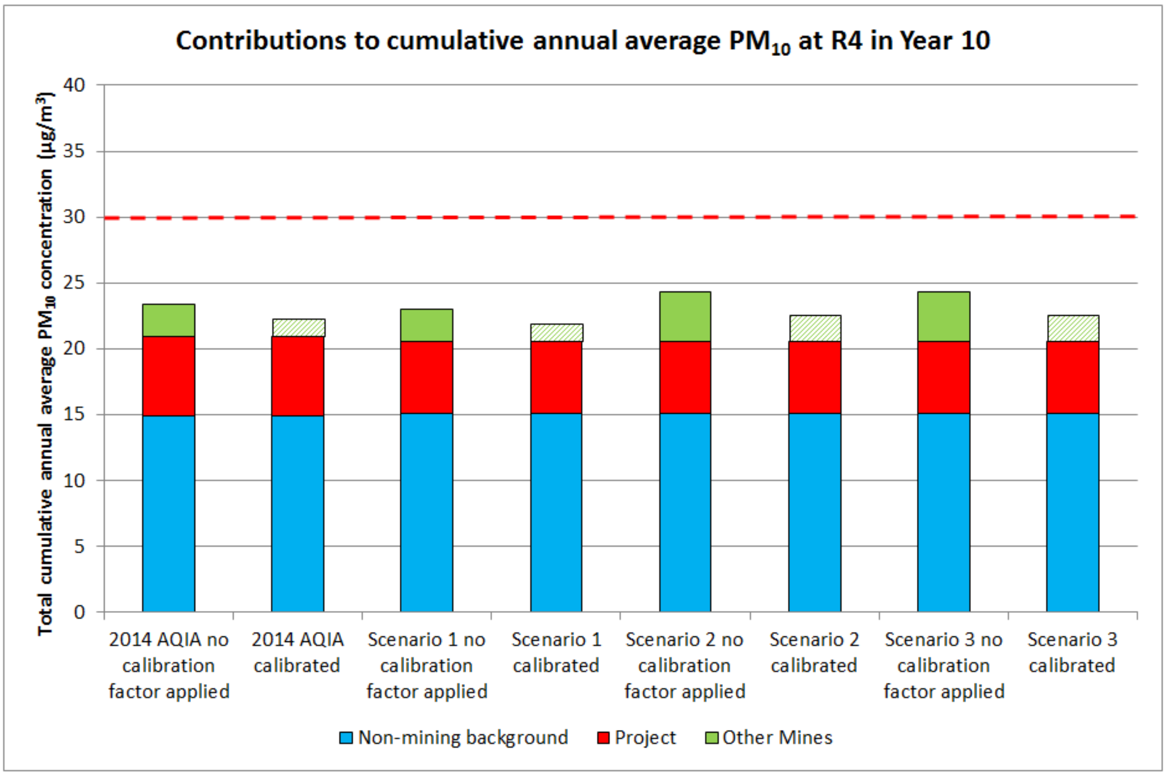

Figure 4.8: Individual contributions to the cumulative annual average PM_{10} concentrations in Year 10 for each scenario at R4 (µg/m^3)

Under all three scenarios considered, there are no predicted exceedances of the cumulative annual average criteria of 30 µg/m^3 at residence R4 in any of the three modelled years.

5. Conclusions

This report presents the results of some additional modelling and data analysis for the Mount Owen Continued Operations (MOCO) Refined Project.

The AQIA for the original MOCO Project was completed in October 2014. Since the completion of that assessment, Glencore has made changes to the mine plan towards the end of the life of the Project, and are not proposing to extract coal resources from the Ravensworth East Resource Recovery (RERR) mining area. These changes only affect Year 10 of the original assessment, and this report presented a comparison between the two sets of modelling results. The only change to the outcomes of the 2014 AQIA was that there were no longer predicted to be exceedances of the maximum 24-hour average PM_{10} criterion (Project only) criterion at privately owned residence R23.

Additional monitoring data from both the UHAQMN and the Mount Owen monitoring network have also become available since mid-2014. This information was analysed to show longer term trends that were previously not available and also to recalculate a non-mining background value to provide a comparison with what was previously used. This analysis showed that there was almost no difference between the new value and that previously used for the Response to Submissions. It was also shown that this updated calculation made no difference to the outcomes of the original assessment.

The analysis of these additional data also showed that the use of Merriwa, Wybong and Jerrys Plains monitors used in the original assessment to represent the non-mining background, was appropriate and is likely to have been slightly conservative.

In addition to this, sensitivity analysis around the inclusion of the proposed Rix's Creek Continuation of Mining (COM) Project was presented. It was shown that the inclusion of this operation in Year 5 and Year 10 would not change the outcomes of the original assessment.

Sensitivity analysis was also completed to determine if the removal of the Ashton South East Open Cut (SEOC) would have any significant impact on the Refined Project in Year 1 and Year 5. It was shown that the outcomes of the original assessment would not change, whether or not Ashton SEOC was operating.

Finally, a summary of the differences between results with and without the use of calibration factors for non-Project mines, was presented for R4. This residence was chosen as it was the most affected private residence not already identified as being subject to voluntary acquisition rights. Pacific Environment has always maintained the validity of the methodology used for the cumulative annual average PM_{10} assessment, which involves the calibration of these non-Project mines within the modelling domain to reduce the uncertainty in the emission estimates for those operations. This methodology was also accepted by the NSW EPA in their letter in response to the Response to Submissions document (Umwelt, 2015). Nevertheless, the analysis presented in this report shows that even without the calibration of non-Project mines, there is no change to the outcomes of the original assessment.

6. References

HAS (2008) “Upper Hunter Valley Monitoring Network Design”, prepared for the NSW Department of Environment and Climate Change, Holmes Air Sciences, February 2008.

OEH (2012), Upper Hunter Air Quality Monitoring Network Interim Performance Report: December 2010 – August 2011, published by the NSW Office of Environment and Heritage, February 2012.

Pacific Environment (2014), Air Quality Impacts Assessment – Mount Owen Continued Operations, prepared for Mount Owen Pty Limited c/- Umwelt (Australia) Pty Ltd, October 2014.

TAS (2015), Air Quality and Greenhouse Gas Assessment – Rix’s Creek Continuation of Mining Project, prepared for Rix’s Creek Mine, August 2015.

Umwelt (2015), Mount Owen Continued Operations Project Environmental Impact Statement – Response to Submissions Report A: NSW Agency and Community Submissions, June 2015.

Appendix A – Year 10 cumulative annual average $PM_{2.5}$ results for the Refined Project

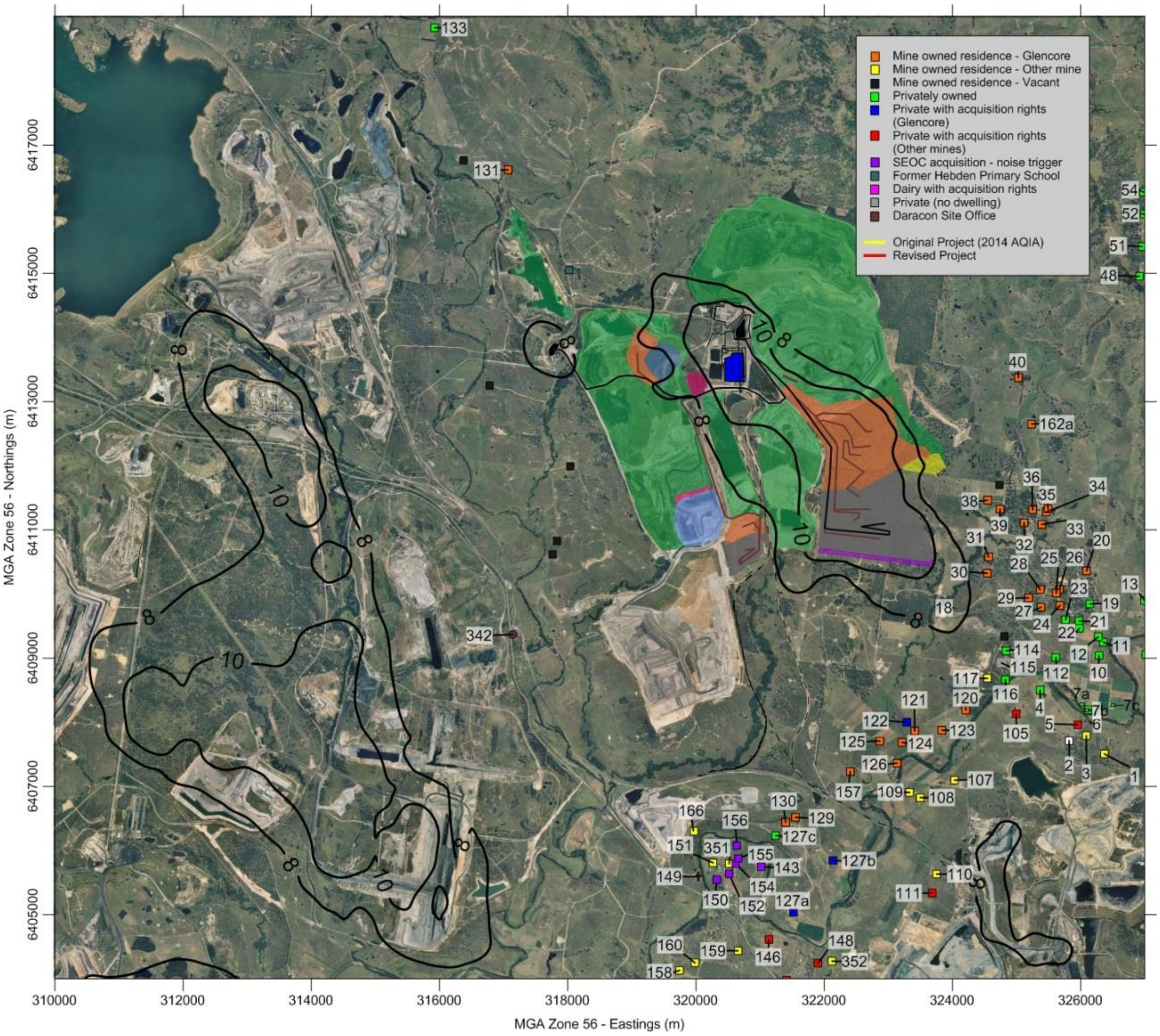

Figure A1: Predicted annual average $PM_{2.5}$ concentrations in Year 10 – Cumulative ($\mu g/m^3$)

The non-mining background value used here is 6.0 $\mu g/m^3$, calculated as 40% of the updated PM_{10} value of 15.1 $\mu g/m^3$. The rationale behind this is described in Appendix B of the Response to Submissions report (Umwelt, 2015).

Appendix B – Year 10 predictions for the Refined Project

Table B1: Predictions for Refined Project Only – Year 10
(shading indicates an exceedance of the relevant criterion)

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
Private Receptors (including those with acquisition rights)						
2	5	32	1	5	14	0.3
4	5	34	1	5	17	0.5
5	5	29	1	4	13	0.3
6	4	27	1	4	12	0.3
7a	5	33	1	4	12	0.3
7b	5	31	1	4	12	0.3
7c	4	26	0	3	9	0.2
10	5	36	0	2	8	0.2
11	5	40	0	2	7	0.2
12	6	41	0	2	7	0.2
13	4	25	0	1	4	0.1
14	3	19	0	1	4	0.1
15b	3	20	0	1	4	0.1
15a	4	22	0	1	4	0.1
17	4	18	0	1	3	0.1
19	4	31	0	2	7	0.2
21	6	44	0	3	8	0.3
22	6	46	0	3	8	0.3
23	7	49	0	3	9	0.3
41	1	9	0	0	1	0.0
42	1	7	0	0	1	0.0
43	1	6	0	0	1	0.0
44a	1	6	0	0	1	0.0
45	1	8	0	0	1	0.0
46	1	7	0	0	1	0.0
47	1	7	0	0	1	0.0
48	1	8	0	0	1	0.0
49	1	7	0	0	1	0.0
50	1	5	0	0	1	0.0
51	1	5	0	0	1	0.0
52	1	4	0	0	1	0.0
53	1	4	0	0	1	0.0
54	1	4	0	0	1	0.0
55	1	6	0	0	1	0.0
56b	1	7	0	0	1	0.0
57	1	6	0	0	1	0.0
58	1	7	0	0	1	0.0
59	1	7	0	0	1	0.0
60	1	7	0	0	1	0.0
61	1	7	0	0	1	0.0
62	1	7	0	0	1	0.0
63a	1	7	0	0	1	0.0
162b	2	7	0	0	1	0.0

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
350	2	7	0	0	1	0.0
66	2	8	0	0	1	0.0
67	3	12	0	0	1	0.0
68	3	13	0	0	1	0.0
69b	3	13	0	0	1	0.0
69a	3	14	0	0	1	0.0
71	3	12	0	0	1	0.0
72	1	5	0	0	1	0.0
73	3	14	0	0	1	0.0
74	2	8	0	1	2	0.1
75	2	9	0	1	2	0.0
76	2	12	0	1	2	0.0
77	3	12	0	1	2	0.0
78	1	5	0	0	1	0.0
79	1	5	0	0	1	0.0
80	1	5	0	0	1	0.0
81	1	5	0	0	1	0.0
82	2	11	0	1	2	0.1
83	2	11	0	1	2	0.1
84a	2	10	0	1	2	0.1
85	2	11	0	1	2	0.1
86	2	15	0	1	3	0.1
87	2	12	0	1	3	0.1
88	2	15	0	1	3	0.1
89	3	22	0	1	4	0.1
91	3	23	0	1	4	0.1
92	3	22	0	2	6	0.2
93	4	30	0	2	5	0.1
94	3	18	0	1	4	0.1
95	3	16	0	1	4	0.1
96	2	14	0	1	4	0.1
97	2	15	0	1	4	0.1
98	3	21	0	1	3	0.1
99	2	15	0	1	4	0.1
100	3	15	0	2	5	0.1
101	3	14	0	2	5	0.1
102a	2	18	0	2	5	0.1
102b	2	17	0	2	6	0.2
105	6	48	1	6	20	0.5
111	3	20	0	2	6	0.1
112	6	32	1	4	12	0.4
114	7	43	1	7	24	0.7
116	6	49	1	7	23	0.6
122	5	28	1	4	13	0.2
127b	3	18	0	1	4	0.0
127a	2	12	0	1	3	0.0
133	7	25	0	2	6	0.1

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
134	10	37	0	2	4	0.1
135	9	36	0	1	4	0.1
136	7	29	0	1	4	0.1
137d	6	25	0	1	3	0.1
138	10	38	0	1	4	0.1
137c	8	31	0	1	3	0.0
137b	8	31	0	1	3	0.0
137a	8	30	0	1	3	0.0
142	9	36	0	1	3	0.0
143	2	13	0	1	3	0.0
144a	2	11	0	0	1	0.0
145	2	11	0	0	1	0.0
146	2	8	0	1	2	0.0
147	2	8	0	1	2	0.0
148	3	11	0	1	2	0.0
149	2	11	0	1	2	0.0
150	2	12	0	1	2	0.0
152	2	13	0	1	2	0.0
154	2	13	0	1	3	0.0
155	2	13	0	1	3	0.0
156	2	14	0	1	3	0.0
163	3	16	0	1	4	0.1
185	6	21	0	1	2	0.0
189a	4	18	0	0	1	0.0
189b	4	17	0	0	1	0.0
191	3	12	0	0	1	0.0
192	1	9	0	0	1	0.0
181	1	9	0	0	1	0.0
196	1	7	0	0	1	0.0
194a	1	5	0	0	1	0.0
195b	1	5	0	0	0	0.0
195a	1	5	0	0	0	0.0
194b	1	5	0	0	0	0.0
197a	1	5	0	0	0	0.0
197b	1	5	0	0	0	0.0
208	1	3	0	0	0	0.0
337	1	4	0	0	0	0.0
209	1	4	0	0	0	0.0
215	1	3	0	0	0	0.0
216	1	3	0	0	0	0.0
217	1	3	0	0	0	0.0
210	1	4	0	0	0	0.0
211	1	3	0	0	0	0.0
178	1	3	0	0	0	0.0
212	1	4	0	0	1	0.0
213	1	5	0	0	1	0.0
56a	1	7	0	0	1	0.0

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
44b	3	22	0	1	4	0.1
218	1	3	0	0	0	0.0
220	1	4	0	0	0	0.0
224	1	4	0	0	0	0.0
223c	1	4	0	0	0	0.0
223a	1	4	0	0	0	0.0
223b	1	5	0	0	0	0.0
214	1	5	0	0	1	0.0
226	1	5	0	0	1	0.0
228	2	7	0	0	1	0.0
227	1	6	0	0	1	0.0
229	2	7	0	0	1	0.0
230	2	8	0	0	1	0.0
221	2	7	0	0	1	0.0
248	3	10	0	0	1	0.0
232	3	11	0	0	1	0.0
249	3	10	0	0	1	0.0
233	3	11	0	0	1	0.0
234	3	9	0	0	1	0.0
235	2	8	0	0	1	0.0
236	2	7	0	0	1	0.0
245	2	6	0	0	1	0.0
241	1	5	0	0	0	0.0
237b	1	5	0	0	0	0.0
237a	1	5	0	0	0	0.0
240	1	3	0	0	0	0.0
242	1	4	0	0	1	0.0
244	1	4	0	0	1	0.0
243	1	6	0	0	1	0.0
246	2	8	0	0	1	0.0
347	2	9	0	0	1	0.0
247	3	12	0	0	1	0.0
250	3	11	0	0	1	0.0
251	3	12	0	0	1	0.0
252	3	11	0	0	1	0.0
253	2	9	0	0	1	0.0
348	1	7	0	0	1	0.0
254	1	7	0	0	1	0.0
255	1	6	0	0	1	0.0
277	1	10	0	1	2	0.1
287	1	9	0	1	3	0.1
285	1	6	0	1	2	0.1
283	1	8	0	1	2	0.1
274	2	13	0	1	2	0.1
272	1	8	0	1	3	0.1
270	2	10	0	1	3	0.1
279	2	13	0	1	4	0.1

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
281	2	15	0	1	4	0.1
280	1	6	0	0	1	0.0
282	3	21	0	2	7	0.2
290	2	18	0	2	6	0.2
164	4	27	0	3	8	0.2
292a	3	20	0	2	6	0.2
292b	3	20	0	2	7	0.2
289	2	14	0	2	5	0.1
288	2	13	0	2	5	0.1
294	3	21	0	2	6	0.1
293	4	28	0	2	7	0.1
295	4	29	0	2	6	0.1
296	4	29	0	2	5	0.1
297d	4	27	0	2	5	0.1
297a	2	15	0	1	4	0.1
297b	2	15	0	1	4	0.1
297c	2	15	0	1	4	0.1
299	2	15	0	1	3	0.1
300	2	15	0	1	3	0.0
302	2	13	0	1	3	0.0
303	3	23	0	1	4	0.1
349b	2	14	0	1	3	0.1
349a	2	14	0	1	3	0.1
305	2	16	0	1	3	0.1
298	2	13	0	2	4	0.1
304b	1	10	0	1	4	0.1
304a	1	10	0	1	4	0.1
306	2	14	0	1	3	0.0
307	2	14	0	1	3	0.0
308	2	14	0	1	3	0.0
309	2	14	0	1	3	0.0
310	2	13	0	1	3	0.0
311	2	13	0	1	3	0.0
312	2	12	0	1	2	0.0
319	3	21	0	2	7	0.2
320	2	13	0	1	3	0.0
321	2	11	0	1	2	0.0
318	2	11	0	1	2	0.0
322	2	10	0	1	2	0.0
317	1	10	0	1	2	0.0
316	1	9	0	1	2	0.0
323	1	9	0	1	2	0.0
324	1	10	0	1	2	0.0
315	1	9	0	1	2	0.0
314	1	8	0	1	2	0.0
330	2	10	0	1	2	0.0
329	1	5	0	0	1	0.0

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
328	1	9	0	1	2	0.0
327	1	9	0	1	2	0.0
326	1	9	0	1	2	0.0
325	1	9	0	1	2	0.0
144c	1	6	0	0	1	0.0
144b	1	7	0	0	1	0.0
278	1	7	0	1	2	0.1
84b	2	13	0	1	2	0.1
137e	7	26	0	1	2	0.0
259	3	17	0	1	2	0.1
260	3	17	0	1	2	0.1
127c	3	15	0	1	4	0.0
354	1	9	0	0	1	0.0
Mine Owned Receptors						
1	4	26	1	4	11	0.3
3	5	28	1	4	13	0.3
20	5	33	0	2	6	0.2
24	6	47	0	3	9	0.3
25	6	42	0	3	9	0.3
26	5	37	0	3	9	0.3
27	7	56	1	4	11	0.4
28	7	50	1	3	11	0.3
29	8	61	1	4	12	0.4
30	13	88	1	7	23	0.7
31	16	68	1	6	20	0.6
32	11	46	0	3	9	0.3
33	10	40	0	2	7	0.2
34	10	39	0	2	7	0.2
35	10	37	0	2	6	0.2
36	10	41	0	3	8	0.2
38	8	51	1	4	12	0.4
39	10	50	1	4	11	0.4
40	3	12	0	1	2	0.1
90	3	23	0	1	4	0.1
104	2	18	0	2	6	0.2
107	5	32	1	3	11	0.2
108	4	23	0	3	9	0.1
109	4	23	0	3	9	0.1
110	4	20	0	2	6	0.1
117	8	61	1	8	26	0.6
120	6	46	1	6	18	0.3
121	5	29	1	4	13	0.2
123	5	37	1	4	14	0.2
124	5	26	1	4	11	0.2
125	5	27	1	3	10	0.1
126	5	25	1	3	9	0.1
129	3	21	0	2	5	0.1

Receptor ID	24-hour Average		Annual Average			
	$PM_{2.5}$	PM_{10}	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Acquisition/Assessment Criterion					
	25 µg/m³	*50 µg/m³*	-	-	-	*2 g/m²/month*
130	3	20	0	1	4	0.0
131	8	53	1	3	11	0.2
151	2	12	0	1	2	0.0
351	2	13	0	1	3	0.0
157	4	22	0	2	8	0.1
158	2	12	0	0	1	0.0
159	2	10	0	1	2	0.0
160	2	11	0	1	1	0.0
162a	3	13	0	1	2	0.0
344	4	29	0	2	7	0.1
165	4	29	0	2	7	0.1
291	1	7	0	0	1	0.0
342	2	13	0	1	3	0.0
166	3	12	0	1	3	0.0
352	3	13	0	1	2	0.0
353	2	10	0	1	2	0.0

Table B2: Cumulative annual average predictions for Refined Project – Year 10 (shading indicates an exceedance of the relevant criterion)

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
Private Receptors (including those with acquisition rights)				
2	7	21	55	2.4
4	7	22	58	2.6
5	7	21	54	2.4
6	7	20	52	2.4
7a	7	20	52	2.4
7b	7	20	52	2.4
7c	7	19	49	2.3
10	7	19	47	2.3
11	7	18	46	2.3
12	7	19	46	2.3
13	6	18	43	2.2
14	6	17	43	2.1
15b	6	17	42	2.1
15a	6	17	42	2.1
17	6	17	42	2.1
19	7	18	46	2.3
21	7	19	47	2.3
22	7	19	47	2.3
23	7	19	48	2.4
41	6	16	39	2.0
42	6	16	39	2.0
43	6	16	39	2.0
44a	6	16	39	2.0
45	6	16	39	2.0
46	6	16	39	2.0
47	6	16	39	2.0
48	6	16	39	2.0
49	6	16	39	2.0
50	6	16	39	2.0
51	6	16	39	2.0
52	6	16	39	2.0
53	6	16	39	2.0
54	6	16	39	2.0
55	6	16	39	2.0
56b	6	16	39	2.0
57	6	16	39	2.0
58	6	16	39	2.0
59	6	16	39	2.0
60	6	16	39	2.0
61	6	16	39	2.0
62	6	16	39	2.0
63a	6	16	39	2.1
162b	6	16	39	2.1

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
350	6	16	39	2.1
66	6	16	39	2.1
67	6	16	39	2.0
68	6	16	40	2.1
69b	6	16	40	2.1
69a	6	16	40	2.1
71	6	16	40	2.1
72	6	16	40	2.1
73	6	16	40	2.1
74	6	17	41	2.1
75	6	16	40	2.1
76	6	16	40	2.1
77	6	16	40	2.1
78	6	16	40	2.1
79	6	16	40	2.1
80	6	16	40	2.1
81	6	16	40	2.1
82	6	17	41	2.1
83	6	17	41	2.1
84a	6	17	41	2.1
85	6	17	41	2.1
86	6	17	42	2.1
87	6	17	41	2.1
88	6	17	42	2.1
89	6	17	43	2.2
91	6	18	44	2.2
92	7	18	45	2.2
93	6	18	45	2.2
94	6	17	43	2.1
95	6	17	42	2.1
96	6	17	43	2.2
97	6	17	43	2.2
98	6	17	42	2.2
99	6	18	44	2.2
100	6	18	44	2.2
101	6	18	44	2.2
102a	7	18	45	2.2
102b	7	18	45	2.2
105	7	23	61	2.6
111	7	21	54	2.3
112	7	20	53	2.5
114	7	24	65	2.8
116	7	24	64	2.7
122	7	21	59	2.4
127b	7	19	47	2.2
127a	7	18	45	2.2
133	7	18	45	2.1

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
134	6	18	44	2.1
135	6	17	43	2.1
136	6	17	43	2.1
137d	6	17	42	2.1
138	6	17	43	2.1
137c	6	17	42	2.1
137b	6	17	42	2.1
137a	6	17	42	2.1
142	6	17	42	2.1
143	7	18	45	2.2
144a	7	22	48	2.4
145	7	20	46	2.3
146	7	18	44	2.2
147	7	18	43	2.2
148	7	18	44	2.2
149	7	19	44	2.2
150	7	19	45	2.2
152	7	19	45	2.2
154	7	19	45	2.1
155	7	18	44	2.1
156	7	19	45	2.1
163	6	17	42	2.1
185	6	16	40	2.1
189a	6	16	40	2.0
189b	6	16	40	2.0
191	6	16	39	2.0
192	6	16	39	2.0
181	6	16	39	2.0
196	6	16	39	2.0
194a	6	16	39	2.0
195b	6	16	38	2.0
195a	6	16	38	2.0
194b	6	16	38	2.0
197a	6	16	38	2.0
197b	6	16	38	2.0
208	6	15	38	2.0
337	6	16	38	2.0
209	6	16	38	2.0
215	6	16	38	2.0
216	6	16	38	2.0
217	6	16	38	2.0
210	6	16	38	2.0
211	6	16	39	2.0
178	6	16	38	2.0
212	6	16	39	2.0
213	6	16	39	2.0
56a	6	16	39	2.0

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
44b	6	17	43	2.2
218	6	16	38	2.0
220	6	16	38	2.0
224	6	16	38	2.0
223c	6	16	38	2.0
223a	6	16	38	2.0
223b	6	16	38	2.0
214	6	16	39	2.0
226	6	16	39	2.0
228	6	16	39	2.0
227	6	16	39	2.0
229	6	16	39	2.0
230	6	16	39	2.0
221	6	16	39	2.0
248	6	16	39	2.0
232	6	16	39	2.0
249	6	16	39	2.0
233	6	16	39	2.0
234	6	16	39	2.0
235	6	16	39	2.0
236	6	16	39	2.0
245	6	16	39	2.0
241	6	16	39	2.0
237b	6	16	38	2.0
237a	6	16	38	2.0
240	6	16	38	2.0
242	6	16	39	2.0
244	6	16	39	2.0
243	6	16	39	2.0
246	6	16	39	2.0
347	6	16	39	2.0
247	6	16	39	2.0
250	6	16	39	2.0
251	6	16	39	2.0
252	6	16	39	2.0
253	6	16	39	2.1
348	6	16	39	2.0
254	6	16	39	2.1
255	6	16	39	2.1
277	6	17	40	2.1
287	6	17	42	2.2
285	6	17	41	2.1
283	6	17	41	2.1
274	6	17	41	2.1
272	6	17	42	2.1
270	6	17	42	2.1
279	6	17	43	2.2

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
281	6	18	44	2.2
280	6	16	39	2.0
282	7	19	48	2.3
290	7	19	46	2.3
164	7	19	48	2.3
292a	7	19	47	2.3
292b	7	19	47	2.3
289	7	18	45	2.2
288	7	18	45	2.2
294	7	19	47	2.3
293	7	19	48	2.3
295	7	19	47	2.3
296	7	19	47	2.3
297d	7	19	46	2.3
297a	7	19	46	2.3
297b	7	19	46	2.3
297c	7	19	46	2.3
299	7	18	45	2.3
300	7	18	45	2.2
302	7	18	45	2.2
303	7	18	45	2.2
349b	7	18	44	2.2
349a	7	18	44	2.2
305	7	18	44	2.2
298	6	18	44	2.3
304b	6	18	43	2.2
304a	6	18	43	2.3
306	6	18	44	2.2
307	6	18	44	2.2
308	6	18	44	2.2
309	7	18	44	2.2
310	7	18	44	2.2
311	6	18	44	2.2
312	6	18	44	2.2
319	7	19	48	2.3
320	7	18	44	2.2
321	6	18	44	2.2
318	6	18	44	2.2
322	6	18	44	2.2
317	6	18	44	2.2
316	6	18	44	2.2
323	6	18	44	2.2
324	7	18	44	2.2
315	6	18	43	2.2
314	6	18	43	2.2
330	6	18	43	2.2
329	6	16	39	2.0

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
328	6	18	43	2.2
327	6	18	43	2.2
326	6	18	44	2.2
325	6	18	44	2.2
144c	7	21	48	2.3
144b	7	22	48	2.3
278	6	17	41	2.1
84b	6	17	41	2.1
137e	6	16	41	2.1
259	6	17	40	2.1
260	6	17	41	2.1
127c	7	18	46	2.2
354	7	18	42	2.2
Mine Owned Receptors				
1	7	20	51	2.4
3	7	20	53	2.4
20	7	18	45	2.2
24	7	19	48	2.4
25	7	19	48	2.4
26	7	19	48	2.3
27	7	20	51	2.4
28	7	20	50	2.4
29	7	20	52	2.5
30	7	24	63	2.8
31	7	23	60	2.7
32	7	19	48	2.3
33	7	19	46	2.3
34	7	18	46	2.2
35	7	18	45	2.2
36	7	19	47	2.3
38	7	20	51	2.5
39	7	20	50	2.4
40	6	17	41	2.1
90	6	17	43	2.2
104	7	18	45	2.2
107	7	21	58	2.4
108	7	21	56	2.4
109	7	20	56	2.4
110	7	21	56	2.4
117	7	25	68	2.8
120	7	22	61	2.5
121	7	21	59	2.4
123	7	22	58	2.4
124	7	21	58	2.4
125	7	20	57	2.4
126	7	20	56	2.4
129	7	19	49	2.2

Receptor ID	Annual Average			
	$PM_{2.5}$	PM_{10}	TSP	Dust Deposition
	Assessment Criterion			
	8 µg/m³	*30 µg/m³*	*90 µg/m³*	*2 g/m²/month*
130	7	19	48	2.2
131	7	19	52	2.3
151	7	19	44	2.1
351	7	19	44	2.1
157	7	20	55	2.3
158	7	20	45	2.2
159	7	19	44	2.2
160	7	19	44	2.2
162a	6	17	41	2.1
344	7	19	49	2.3
165	7	19	49	2.3
291	6	16	39	2.0
342	7	19	45	2.2
166	7	19	45	2.1
352	7	18	44	2.2
353	7	18	43	2.2

APPENDIX 3

Synopsis of Rehabilitation Research at Mount Owen

Appendix 3 - Rehabilitation Research Undertaken at Mount Owen by CSER Research/University of Newcastle

Research Synopsis 1996 - 2016

Research into rehabilitation techniques and processes has been undertaken at Mount Owen Mine since 1996, initially through The University of Newcastle and now *CSER RESEARCH*. Four key themes are present in this research that relate to sustainable rehabilitation issues important for the mine to achieve its consent conditions and relinquishment, some of these results have been made available to others in the industry through the "Establishment of Native Vegetation" document (Nussbaumer, Castor & Cole, 2012) available at (http://hdl.handle.net/1959.13/937756). The four themes are:

- Sustainable Plant Nutrition
- Topsoil Substitutes
- Reconstructing Soil Function
- Diversification and Success of Rehabilitation Areas

Theme 1: Sustainable Plant Nutrition (1996 to date)

Historically, mine rehabilitation practices followed those used by forestry and agriculture, not those that occur in nature. Thus, there was previously complete reliance on the use of fertilizer with the consequent downstream pollution of watercourses. This is understandable in that the soil had been heavily damaged through erosion following vegetation clearing and running hoofed animals over it. A key research theme has, therefore, been to minimize the use of fertilizer and encourage the use, and reintroduction, of natural nutrient acquisition and cycling processes. These require appropriate microbial life to be present in the topsoil or soil substitute, or that it be reintroduced.

Objectives:

- To reduce the dependency on fertilizer for plant growth
- To determine the capacity of topsoil (including stockpiles) to form root-microbe associations
- To determine if mycorrhizae and rhizobia can be reintroduced into rehabilitation areas

Synopsis of Key Outcomes:

- The capacity to form root-microbe associations in pasture and forest topsoil, including in stockpiles was very low or almost absent (Newman, 1996).
- Nitrogen was the most limiting nutrient (thus the need for nitrogen fixing rhizobia) and phosphorus the second most limiting nutrient (the need for mycorrhizal fungi), (Nussbaumer *et al.* 2016, Nussbaumer, 2005).
- The spoil amelioration experiment showed that we could grow forest on spoil with some amendments including gypsum and fertilizer as well as using forest soil (Nussbaumer, 2005).
- In Ravensworth State Forest (RSF) topsoil, in the mine path, it was found that 8% of locations contained endomycorrhizae. On the rehabilitation area where RSF topsoil had been used (in the monitoring transects) 67% of roots contained endomycorrhizal associations and when trap plants were used the soil had the capacity to infect all roots. Trapping on top of the spoil placement area showed that 78% of roots had these associations. In an old growth forest almost all feeding roots would be expected to be mycorrhizal. Soil decompaction appears to have allowed spores to germinate and infect roots. Nodulation capacity (with rhizobia) varied across the rehabilitation area but was present in all locations sampled (Nussbaumer *et al.* 2011, Cole *et al.* 2009).
- Early practices of using fertilizer on rehabilitated areas, where forest topsoil was used, ceased and natural plant nutrition replaced the use of fertilizer (recommendation adopted by mine operator).

- Mycorrhizal specificity was suggested when endomycorrhizal roots collected from *Themeda australis* were used to inoculate *Corymbia maculata* and *Angophora floribunda*, the latter failing to be infected (O'Keeffe, 1998). This was followed by apparent specificity of soil inoculum used in a field experiment containing *Acacia parvipinnula* (where all of the plants died) and *Acacia filicifolia* (where plants grew and reproduced) (Nussbaumer, 2005).

- An initial focus on microbial specificity was for rhizobia bacteria that fix nitrogen, because it is the most limiting nutrient for plant growth, and the presence of specificity was shown using DNA technology (Targett, 2001). This was further developed indicating a level of group specificity and demonstrated changes in growth efficiency for a range of species (Fisher, 2010).

- *Dodonaea viscosa* has been found to be an obligate endomycorrhizal species (Newman, unpublished) and can now act as an indicator species for the presence, and dispersal, of endomycorrhizae in rehabilitation sites. It has been one of the most successful species in the rehabilitation areas even during drought where its numbers continued to increase and it dispersed into the surrounds (Nussbaumer *et al.* 2011).

- RSF soils contain residual microbial capacity that will successfully establish natural root-microbe associations as noted above, however, most other soils or substitutes, following forestry and grazing practices will require that microbes will have to be reintroduced. This has been achieved through inoculation for mycorrhizae (O'Keeffe, 1998) rhizobia (Nussbaumber, 2005) specific native strains of rhizobia (Fisher, 2010) and mycorrhizae, rhizobia and endophytic fungi Newman (current PhD candidate).

Theme 2: Topsoil Substitutes (2005 - to date)

Most mines know that they will have a topsoil deficit during the life of the mine due to soil erosion whilst being used for forestry and grazing. Thus, we have been challenged by Mount Owen to conduct research linked to whether or not we can ameliorate spoil or use other topsoil substitute media. This included assessing residual microbial capacity and whether inoculation would succeed.

Objectives:

- To use readily available bulk materials to replace topsoil to construct woodland and forest.

- To trial the reintroduction of root-microbe associations depleted by past land uses.

Synopsis of Key Outcomes:

- The use of readily available bulk materials (ACARP C12033) showed success in constructing vegetation communities on a number of different media (Cole *et al.* 2006).

- After 10 years the soil chemistry in most of the treatments in ACARP Site 1 were very similar to those of the northern remnant of RSF. In addition, the carbon content of soil substitutes had increased showing carbon sequestration into the soil (Nussbaumer *et al.*, 2014).

- The different treatments in Site 2 were successfully inoculated with rhizobia (Fisher, 2010) although residual capacity was present in the subsoil used.

- It has been shown that all strata from canopy to grass can be grown in tailings, with or without organic matter added, as a potential soil substitute (Nussbaumer & Cole, unpublished).

Theme 3: Reconstructing Soil Function (2007 to date)

Plant root-microbe associations noted above are critical to the sustainability of plant growth and function, however, it is important that other components of soil function are present if these are to be maintained. These include the ability of soil to breathe and allow aerobic organisms, including the microbes and plant roots to gain oxygen supply. Thus soil structure is needed which would also assist with water penetration. A natural progression from reconstructing root-microbe associations was to begin to reconstruct other components of soil function by combining microbial mixes with organic matter and plants to sustain their establishment and growth.

Objectives:

- To demonstrate the role of plants, mycorrhizal fungi and organic matter in the formation of aggregates with spoil fines in the laboratory.

- To demonstrate the ability of a complement of microbes to assist with plant establishment and growth as well as aggregation of spoil in the field.

Synopsis of Key Outcomes:

- It was found the presence of plant roots, mycorrhizal fungi and organic matter was needed to achieve aggregation of spoil fines (Daynes *et al.* 2013, Daynes *et al.* 2010)

- The presence of a compliment of microbes with compost has increased survival and growth of four plant species in spoil (Newman, unpublished).

- Spoil aggregates are also being formed in the field experiment at Mount Owen (Newman, unpublished).

Theme 4: Diversification and Success of Rehabilitation Areas (1996 to date)

In rehabilitation areas the species that grow are generally very hardy, early succession species that can cope with poor physical and chemical soil conditions. Other species often fail. In forest topsoil many other species germinate and grow but some disappear, these may be incompatible with the soil or other conditions, or disappear into the seed bank; some species are absent and others fail to germinate. One of our key research questions has been why species fail to germinate, fail to establish and disperse, or disappear. As part of this the reintroduction of a number of species has occurred including those from the dry rainforest.

Objectives:

- To characterize dormancy mechanisms of species difficult to establish in mine rehabilitation areas.

- To evaluate dormancy breaking mechanisms, and methods of seeding with a particular focus on herbaceous, shrub, and rainforest species

- To trial the introduction of herbaceous and subshrub species using seed or seedlings.

- To determine if species of low abundance, or missing, could be reintroduced into the rehabilitation area and if soil amendments assist in doing so.

- To trial the introduction of dry rainforest species into the rehabilitation area.

Synopsis of Key Outcomes:

- Dormancy was characterized for a number of species and mechanisms for dormancy breaking investigated. The results (Milgate, 1996) were incorporated into the ACARP C7010 (Gillespie *et al*., 2001).

- Continued trials of dormancy breaking have been undertaken for species difficult to incorporate into the rehabilitation area and to improve methods used for seed preparation for use in the rehabilitation area. These include the use of Coopex at an appropriate concentration to deter, but not kill, ants that used to harvest well over 90% of the seed sown (Nussbaumer *et al.,* 2011). Contractors at the Mount Owen Complex now use the method that was selected.

- Herbaceous species have been experimentally introduced using seed or seedlings and a number of species have established well and are dispersing. Others are less obvious or cryptic. Thus, with good seed stocks for the hardy species the mine is now targeting less common species to develop (by seed or planting) sources that could be used for dispersal into other areas, or, as seed sources (Nussbaumer *et al.*, 2015).

- An addition to this is the experimental introduction of herbaceous species with the intent to begin to characterize their niche requirements and determine if soil ameliorants such as compost assist with their survival, recruitment and growth (Scanlon 2015, conducted at the neighbouring Ravensworth Operations).

- An objective of the dry rainforest experiment on the top of the spoil placement area at Mount Owen was not only to further diversify vegetation species but to also introduce more fruitivorous plant species. By increasing these species it is expected that birds and mammals would increasingly use fruit on the rehabilitation area rather than using fruit from weedy species such as *Lantana* and exotic olives. A byproduct is that support species such as *Melaleuca stypheloides,* are providing additional habitat opportunities as birds are nesting in them. Thus, this has been a successful diversification effort so far.

Relevant Publications:

2016: Nussbaumer, Y., Cole, M.A., Offler, C.E., & Patrick, J.W., “Identifying and ameliorating nutrient limitations to reconstructing a forest ecosystem on mined land”, *Restoration Ecology*, **24:2**, 202-211

2015 Scanlon, R., “Barriers to life cycling of Herbaceous Perennials on Restoration Sites”, Honours Thesis, The University of Newcastle

2014: Nussbaumer, Y., Castor, C., Newman, K., & Cole, M.A., “Establishing Native Vegetation” RSFVC Supplement: 2014 Edition

2013: Daynes, C.N., Field, D.J., Saleeba, J.A., Cole, M. A., and McGee, P. A., February 2013, “Development and stabilization of soil structure via interactions between organic matter, arbuscular mycorrhizal fungi and plant roots”, *Soil Biology and Biochemistry*, **57:** 683-694.

2012: Nussbaumer, Y., Castor, C., & Cole, M., “Establishing Native Vegetation, Principles and Interim Guidelines for Spoil Placement Areas and Restoration Lands”, Xstrata Coal and The University of Newcastle.

2011: Nussbaumer, Y., Castor, C., Cole, M., Fisher, N., Dyer, L., Kovacs, A., Schulz, S., Parsons, R., & Rainsford, F., “Ravensworth State Forest Vegetation Complex Research Program Report”, The University of Newcastle.

2010 Daynes, C.N., Field, D.J., Saleeba, J.A., Cole, M.A., McGee, P.A., “Restoration of soil function requires plants, arbuscular mycorrhizal fungi and organic matter” 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World 41 1 – 6 August 2010, Brisbane, Australia. Published on DVD.

2010 Fisher, N., “Sustainable Reintroduction of the Nitrogen Cycle Post Coal Mining Utilizing the Legume-Rhizobia Symbiosis”, PhD Thesis, The University of Newcastle.

2009: Cole, M., Nussbaumer, Y., Castor, C., Fisher, N., Dyer, L., Kovacs, A., Schulz, S., Parsons, R., & Rainsford, F., “Ravensworth State Forest Vegetation Complex Research Program Report”, The University of Newcastle.

2006: Cole, M., Nussbaumer, Castor, C., & Fisher, N., “Topsoil Substitutes and Sustainability of Reconstructed Native Forest in the Hunter Valley”, (ACARP C12033), Australian Coal Research Program, Brisbane.

2005: Nussbaumer Y., “Rebuilding Biodiversity and Microbial Associations in Native Forest Rehabilitation Following Open-Cut Coal Mining”, PhD Thesis, The University of Newcastle.

2001: Targett, K., “The Native Legume – Rhizobia Symbiosis in Sustainable Mine Rehabilitation, Honours Thesis, The University of Newcastle

2001: Gillespie, M., Baker, K.S., & Mulligan, D.R., “Native Understorey Species Regeneration at New South Wales Coalmines”, (ACARP C7010), Australian Coal Research Program, Brisbane.

1998: O’Keeffe, A., “Plant and Soil Nutrient Dynamics and Coal Mine Rehabilitation, Honours Thesis, The University of Newcastle

1996: Newman, K., “Mycorrhiza and Rhizobium in the Rehabilitation of Open-Cut Coal Mines in the Hunter Valley”, Honours Thesis, The University of Newcastle

1996: Milgate, A. W., 1996, “Aspects of Seed Dormancy in a Selection of Australian Native Flora, Honours Thesis, The University of Newcastle

Presentations and Posters by Kate Newman linked to her PhD Candidature:

2016: “Soil Biology in Rehabilitation: Mount Owen Case Study” in *Best Practice Ecological Rehabilitation of Mined Lands Conference 2016”*presented by the Tom Farrell Institute for the Environment. 7-8 April.

2015: “Organic Matter and Inoculum Amendment of Mine Spoil for Rehabilitation” in *School of Environmental and Life Sciences Research Higher Degree Candidates Conference 2015.”*4 Dec.

2015: Poster “Effects of Compost and Microbes on Rehabilitation of Bare Spoil” in *Best Practice Ecological Rehabilitation of Mined Lands Conference 2015”*presented by the Tom Farrell Institute for the Environment. 26-27 March 2015.

2014 “Can Inoculation with fungi improve mine rehabilitation?” Australian Mycological Society Meeting April 22-24.

2013: “Combining Compost and Microbes to Improve Spoil Rehabilitation” in special meeting of NSW, Office of Environment and Heritage Hunter Region. December.

2013: “The Importance of Functional Soil in Land Rehabilitation” in *Best Practice Ecological Rehabilitation of Mined Lands Conference 2013”*presented by the Tom Farrell Institute for the Environment. 12-13 September.

2013: “Mine Land Rehabilitation in the Hunter Valley, NSW.” in ordinary meeting of the Royal Mt George Yacht squadron.6 Dec.

2013: “Combining Compost and Microbes to Improve Spoil Rehabilitation” in special meeting of NSW, Department of Resources and Energy Hunter Region. July.

2012: “Investigation of Compost and Plant Associating Microbes for use in Mine Spoil rehabilitation” in *Best Practice Ecological Rehabilitation of Mined Lands Conference 2012”*presented by the Tom Farrell Institute for the Environment. 5 Sept.

2012: Poster “Investigation of Compost and Plant Associating Microbes for use in Mine Spoil rehabilitation” *Soil Solutions for Diverse Landscapes Conference 2012* conducted jointly by the Australian and New Zealand Soil Science Societies.

2012: Poster “Review of NSW Soil Policy” *Soil Solutions for Diverse Landscapes Conference 2012* conducted jointly by the Australian and New Zealand Soil Science Societies.

APPENDIX 4

Description of Key Vegetation Communities

Appendix 4 – Key Vegetation Communities found in the Mount Owen Continued Operations Project – Project Area and Immediate Surrounds

The following description of vegetation communities found in the immediate surrounds of the Project Area is taken from: *The Vegetation of the Central Hunter Valley, New South Wales. A Report on the Findings of the Hunter Remnant Vegetation Project (*Peake, 2006). These descriptions detail the key species observed in mature stands of these communities and show the structural variation present in the communities. Disturbed examples of these communities or regenerating examples of these communities may show different level of abundance or structural differences due to successional characteristics of these communities.

Central Hunter lronbark - Spotted Gum - Grey Box Forest

A woodland to open forest of 25-35% cover and 17-30 m height dominated by narrow-leaved ironbark *(Eucalyptus crebra),* spotted gum *(Corymbia maculata)* and grey box *(Eucalyptus moluccana).* Other tree species may be present and occasionally dominate or co-dominate, and include broad-leaved ironbark *(Eucalyptus fibrosa)* and forest red gum *(Eucalyptus tereticornis).* Slaty red gum *(Eucalyptus glaucina)* may be sub-dominant in the Belford district through to the Singleton Military Area. A sparse mid-understorey may be present in some areas, typically including bulloak *(Allocasuarina luehmannii)* or silver-stemmed wattle *(Acacia parvipinnula).*

The shrub layer of 1-3 m height can be sparse or absent in some cases, to moderately dense in others, although it is typically reasonably sparse (typically 5-10% cover). Common shrub species include gorse bitter pea *(Daviesia ulicifolia* subsp. *ulicifolia),* grey bush pea *(Pultenaea spinosa),* coffee bush *(Breynia oblongifolia),* bushy needlebush *(Hakea sericea),* native blackthorn *(Bursaria spinosa* subsp. *spinosa)* and hickory wattle *(Acacia falcata).*

The ground cover of <1 m height can be sparse to moderately dense (40-60% cover), and consists of numerous forbs, fewer grass species, and a limited number of ferns, sedges or other herbs. Common species include poison rock fern *(Cheilanthes sieberi* subsp. *sieberi),* barbed wire grass *(Cymbopogon refractus),* whiteroot *(Pratia purpurascens),* many-flowered mat-rush *(Lomandra multiflora* subsp. *multiflora),* pomax (Pomax *umbellata),* variable glycine *(Glycine tabacina),* blue flax lily *(Dianella revoluta),* slender wire lily *(Laxmannia gracilis),* weeping grass *(Microlaena stipoides* var. *stipoides), Vernonia cinerea* var. *cinerea,* peach heath *(Lissanthe strigosa),* blue trumpet *(Brunoniella australis),* variable tick-trefoil *(Desmodium varians),* kidney weed *(Dichondra repens),* winter apple *(Eremophila debilis),* purple burr-daisy *(Calotis cuneifolia),* small St John's wort *(Hypericum gramineum),* common everlasting *(Chrysocephalum apiculatum* and *Chrysocephalum apiculatum semipapposum* intergrade), stinkweed *(Opercularia diphylla), Paspalidium distans,* tufted hedgehog grass *(Echinopogon caespitosus* var. *caespitosus),* twining glycine *(Glycine clandestina),* wiry panic *(Entolasia stricta),* kangaroo grass *(Themeda australis),* slender stackhousia *(Stackhousia viminea)* and tufted bluebell *(Wahlenbergia communis).*

Barrington Footslopes Dry Spotted Gum Forest

A mid-high to tall (15-25 m) woodland to open forest (15-30% cover) clearly dominated by spotted gum *(Corymbia maculata)* with a number of other eucalypt species being locally abundant, including*/)* narrow-leaved ironbark *(Eucalyptus crebra)* and white mahogany *(Eucalyptus acmenoides),* while kurrajong *(Brachychiton populneus* subsp. *populneus)* is also relatively frequent. Rough-barked apple *(Angophora floribunda),* grey gum *(Eucalyptus punctata),* forest red gum *(Eucalyptus tereticornis),* grey ironbark *(Eucalyptus siderophloia) ,* grey box *(Eucalyptus moluccana),* thin-leaved stringybark *(Eucalyptus eugenioides)* and large-fruited grey gum *(Eucalyptus canaliculata)* can also be locally abundant.

A mid-understorey of 5-12 m height can be absent or present, and where present usually consists of forest oak *(Allocasuarina torulosa),* dogwood *(Jacksonia scoparia)* hickory wattle *(Acacia implexa)* or muttonwood *(Rapanea variabilis)* to 5-30% cover, although other species can be locally common. A sparse to mid-dense (10-30% cover) understorey of 1-3 m height is usually present, dominated by coffee bush *(Breynia oblongifolia),* large mock olive *(Notelaea longifolia),* narrow-leaved geebung *(Persoonia linearis),* narrow-leaved orangebark *(Maytenus silvestris)* and hairy clerodendrum *(Clerodendrum tomentosum).*

The ground cover is low (< 1 m), open to dense (40-90%) and dominated by grasses and herbs. Common species include blue flax lily *(Dianella caerulea),* whiteroot *(Pratia purpurascens),* kidney weed *(Dichondra repens),* poison rock fern *(Cheilanthes sieberi* subsp. *sieben),* weeping grass *(Microlaena stipoides* var. *stipoides),* slender tick-trefoil *(Desmodium varians),* barbed wire grass *(Cymbopogon refractus),* Indian weed *(Sigesbeckia orientalis* subsp. *orientalis),* blue trumpet *(Brunoniella australis),* many-flowered mat-rush *(Lomandra multiflora* subsp. *multiflora), Vernonia cinerea* var. *cinerea,* kangaroo grass *(Themeda australis),* blady grass *(lmperata cylindrica* var. *major),* basket grass *(Oplismenus aemulus),* small-flowered finger grass *(Oigitaria parviflora),* paddock lovegrass *(Eragrostis leptostachya)* and bordered panic *(Entolasia marginata)* . Small twiners such as slender tick-trefoil *(Desmodium varians)* , twining glycine *(Glycine clandestina),* variable glycine *(Glycine tabacina)* and false sarsaparilla *(Hardenbergia violacea)* are common.

Vines are relatively common, and include wombat berry *(Eustrephus latifolius),* traveller's joy *(Clematis glycinoides* var. *glycinoides),* wonga vine *(Pandorea pandorana* subsp. *pandorana),* small- leaved water vine *(Cissus opaca)* and scrambling lily *(Geitonoplesium cymosum).*

Central Hunter Swamp Oak Forest

A low to mid-high gallery forest of 12-18 m height with a closed canopy (30-80% cover) usually solely dominated by swamp oak *(Casuarina glauca),* but occasionally with forest red gum *(Eucalyptus tereticornis)* or rough-barked apple *(Angophora floribunda).* In the Belford district slaty red gum *(Eucalyptus glaucina),* or its intergrade with forest red gum *(Eucalyptus tereticornis - glaucina)* , may occur. River oak *(Casuarina cunninghamiana* subsp. *cunninghamiana)* can occur at the edges of the community, as well as the intergrade *(Casuarina cunninghamiana- glauca).* An understorey is very rarely present due to the density of the tree canopy.

The ground cover of <0.5 m height is usually sparse to mid-dense (35-50% cover), but can be dense in places where breaks in the canopy allow a higher solar radiation penetration. The groundcover typically consists of the following dominant species: kidney weed *(Dichondra repens),* weeping grass *(Microlaena stipoides* var. *stipoides),* slender bamboo grass *(Austrostipa verticillata),* common couch *(Cynodon dactylon),* whiteroot *(Pratia purpurascens),* variable glycine *(Glycine tabacina),* scurvy weed *(Commelina cyanea),* slender tick-trefoil *(Desmodium varians),* blue trumpet *(Brunoniella australis),* forest nightshade *(Solanum prinophyllum),* pennywort *(Centella asiatica),* poison rock fern *(Cheilanthes sieberi* subsp. *sieberi)* and traveller's joy *(Clematis glycinoides* var. *glycinoides).*

Hunter Lowlands Red Gum Forest

A mid-high to tall (18-30 m) woodland to open forest of 25-40% cover dominated by a number of tree species, in particular forest red gum *(Eucalyptus tereticornis),* grey gum *(Eucalyptus punctata),* narrow-leaved ironbark *(Eucalyptus crebra)* and rough-barked apple *(Angophora floribunda).* The NPWS (2000) diagnostic species list includes spotted gum *(Corymbia maculata)* as a positive diagnostic species, however this is likely to be an artefact of sampling that included ecotones within their survey areas. Grey box *(Eucalyptus moluccana)* is an important tree species, particularly in the western and central parts of its range, and even in the western parts of Maitland and Cessnock LGAs. In places, *Eucalyptus punctata* may be replaced by large-fruited grey gum *(Eucalyptus canaliculata),* or by the intergrade between the two species.

At some sites, ball honeymyrtle *(Melaleuca nodosa)* is present and forms relatively dense thickets. A new analysis of this form of the vegetation community is necessary to determine its relationship to other less shrubby forms. It is possible that these sites reflect past clearing.

A shrub stratum of 1-5 m height is sometimes present and is usually sparse but may be mid-dense at times, with 30-65% cover. It may consist of coffee bush *(Breynia oblongifolia),* prickly beard-heath *(Leucopogon juniperinus)* , gorse bitter pea *(Daviesia ulicifolia* subsp. *ulicifolia),* narrow-leaved geebung *(Persoonia linearis)* and dogwood *(Jacksonia scoparia).* Forest nightshade *(Solanum prinophyllum)* is a common sub-shrub.

Generally, the vegetation community is characterised by a grassy understorey of less than 1 m height and 70-90% cover; whether this is through natural circumstances or as a result of previous modification is not entirely clear. Common and dominant species include weeping grass *(Microlaena stipoides* var. *stipoides),* whiteroot *(Pratia* *purpurascens),* many-flowered mat-rush *(Lomandra multiflora* subsp. *multiflora),* barbed wire grass *(Cymbopogon refractus),* pomax *(Pomax umbellata),* kidney weed *(Dichondra repens), Vernonia cinerea* var. *cinerea* and tufted hedgehog grass *(Echinopogon caespitosus* var. *caespitosus).* Poison rock fern *(Cheilanthes sieberi* subsp. *sieberi)* occurs at all sites, and variable glycine *(Glycine clandestina)* is also frequent. Although not recorded on the NPWS (2000) diagnostic species list, common couch *(Cynodon dactylon)* is typically abundant and frequently dominant at sites in the study area.

References

Peake, T, C, (2006) *The Vegetation of the Central Hunter Valley, New South Wales. A Report on the Findings of the Hunter Remnant Vegetation Project.* Hunter – Central Rivers Catchment Management Authority, Paterson.

APPENDIX 5

Central Hunter Ironbark-Spotted Gum-Grey Box-Ironbark Forest Species in Ravensworth State Forest and their Functional Roles

Appendix 5 - Central Hunter Ironbark-Spotted Gum-Grey Box-Ironbark Forest Species in Ravensworth State Forest and Their Functional Roles

Table A-1 provides details of the presence and abundance of species identified in the NSW Scientific Committee final determination for the listing of the Central Hunter Ironbark-Spotted Gum-Grey Box-Ironbark Forest EEC(NSW Scientific Committee 2010) in both Ravensworth State Forest (RSF) and rehabilitation areas at Mount Owen. The Table also provides a summary of life form of the species, and the current understanding of the physiological activity associated with the species and ecological role (ecological services) that the species plays in the community and broader environment.

This information has been provided by CSER Research and is based on the research work undertaken at the Mount Owen Complex by the University of Newcastle and CSER Research.

Species	Presence		Functional Groups / Attributes							COMMENTS
	RSF-NF	MO Rehab	Life Form		Physiological Activity			Ecosystem Role/Services		
			Morphology	Redundancy and Resilience	Reported Root Associations	Role	Redundancy and Resilience	Pollination/ Dispersal/ Habitat Value	Likely Redundancy and Resilience	
Acacia falcata	YES	YES	tall shrub	not redundant - one phyllode form species	N fixing bacteria, endo- and ectomycorrhizal	provide organic nitrogen, phosphorus, other nutrients, drought and pathogen resistance	Reasonable N fixing and mycorrhizal redundancy with other Acacia, Fabaceae & Casuarinaceae species.	insects / gravity-animals/some large birds are known to feed on pods	Seed form will assist with resilience to drought and fire.	Known as a 'disturbance' species it occurs in small patches in RSF and can be found in many locations in the rehabilitation area.
Acacia parvipinnula	YES	YES	tall shrub	not redundant - one bipinnate species	N fixing bacteria, endo- and ectomycorrhizal	provide organic nitrogen, phosphorus, other nutrients, drought and pathogen resistance	Reasonable N fixing and mycorrhizal redundancy with other Acacia, Fabaceae & Casuarinaceae species.	insects / gravity-animals/some large birds are known to feed on pods	Seed form will assist with resilience to drought and fire.	Probably the most dominant shrub species in RSF and very abundant on the rehab where forest soil has been used.
Allocasuarina luehmanii	YES	YES	tree	not redundant - one species.	N fixing fungi ecto- and endomycorrhizal	provide organic nitrogen, phosphorus, other nutrients, drought and pathogen resistance	Reasonable N fixing and mycorrhizal redundancy with other Acacia, Fabaceae & Casuarinaceae species.	wind/ gravity/food, substrate for epiphytic orchids and mistletoes	Seed form will assist with resilience to drought and fire.	Common in the lower slopes community on sodic soils especially in the SE corridor offset. Not present in RSF. Difficult to grow from local seed.
Brachyscome multifida	YES	YES	herb	A number of herbaceous Asteraceae are present and may provide some level of redundancy, but it may be low.	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects/wind/?	fleshy roots confer drought resistance	Fairly abundant in RSF. Has been recorded in Rehab.
Breynia oblongifolia	YES	YES	shrub	shrub form unique	?		unknown	insects/fruit eating birds/ host to " little yellow" butterfly	not redundant	Found in a number of locations across the complex. Present but not abundant on Rehab.
Brunoniella australis	YES	YES	herb	fleshy roots confer resilience to drought	?		unknown	insects/ gravity/unknown	not redundant	Common in RSF. Present in small numbers in Rehab. Can spread if population large enough.
Bursaria spinosa subsp. spinosa	YES	YES	shrub	one of a small number of prickly shrubs	?		unknown	insects/ gravity?/prickly hide for birds and animals	unknown	Present in parts of RSF. One of the species often encountered in land cleared for grazing. Present but not abundant in Rehab.
Calotis cuneifolia	YES	YES	herbaceous sub-shrub	A number of herbaceous Asteraceae are present and may provide some level of redundancy, but it may be low.	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects/animals/?	unknown	Present in low numbers. *Calotis lappulacea* is the common species both in the forest and on the rehabilitation area.

Species	Presence		Functional Groups / Attributes							COMMENTS
	RSF-NF	MO Rehab	Life Form		Physiological Activity			Ecosystem Role/Services		
			Morphology	Redundancy and Resilience	Reported Root Associations	Role	Redundancy and Resilience	Pollination/ Dispersal/ Habitat Value	Likely Redundancy and Resilience	
Cheilanthes sieberi subsp. seiberi	YES	YES	fern	not redundant	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	haplodiplontic - water & wind/may aid in soil stability as species is clonal and resistant to drought	not redundant	Common in RSF. Present in Rehab.
Chrysocephalum apiculatum	YES	YES	herbaceous sub-shrub	A number of herbaceous Asteraceae are present and may provide some level of redundancy, but it may be low.	?		unknown	insects/wind/?	unknown	As for *Calotis* but is more common in open areas
Corymbia maculata	YES	YES	tree	Highly successful species, will contribute to redundancy of similar tree species	ecto- and endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	potential to provide some redundancy for root associations, specificity unknown	gliders and some birds use as food source, nesting in hollows, flowers in winter May-Sept	possibly redundant with other eucalyptus	Common and successful species in both RSF and Rehab.
Cymbopogon refractus	YES	YES	grass	Likely to be resilient to drought and fire and contribute to redundancy in native grasses	?		unknown	wind/gravity/possible hide, kangaroo and wallaby feed	Similar to Themeda	Common in some parts of complex, present on rehab. Include in seed mix where possible
Daviesia ulicifolia subsp. ulicifolia	YES	YES	shrub	one of a small number of prickly shrubs	N fixing bacteria, possibly endo- and ectomycorrhizal	nutrient acquisition & cycling	Reasonable N fixing and mycorrhizal? redundancy with other Acacia, Fabaceae & Casuarinaceae species.	insects/gravity/prickly hide for birds and animals	Seed likely forms a long term seed bank conferring resilience	Fairly common in RSF, is present in offsets in a patchy way. Some success on rehab from seed. Difficult to grow from seedlings.
Desmodium varians	YES	YES	herb	one of several small herbs	N fixing bacteria, endomycorrhizal	nutrient acquisition & cycling	Reasonable N fixing and mycorrhizal redundancy with other Acacia, Fabaceae & Casuarinaceae species.	insects?/ epizochory/unknown	good dispersal capacity could confer resilience	
Dianella revoluta var. revoluta	YES	YES	graminoid	clonal, thick rooted plant, not redundant	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	Reasonable mycorrhizal redundancy with other species, specificity unknown.	insects / birds - mammals/clonal habit could confer site stability	not redundant	Common in RSF with a number of other *Dianella* species. Has appeared in rehab from transferred root stock or rhizomes.
Dichondra repens	YES	YES	herb	clonal	?		unknown	insect/gravity/clonal habit could confer soil stability	not redundant	Common in RSF and rehab

Species	Presence		Functional Groups / Attributes							COMMENTS
	RSF-NF	MO Rehab	Life Form		Physiological Activity			Ecosystem Role/Services		
			Morphology	Redundancy and Resilience	Reported Root Associations	Role	Redundancy and Resilience	Pollination/ Dispersal/ Habitat Value	Likely Redundancy and Resilience	
Echinopogon caespitosus var. caespitosus	?	?	grass	small tussock forming grass, common redundant form for native grasses	?		unknown	wind/wind/erect tussock habit could confer hides for small ground dwelling animals	probably redundant with other similar grasses	Small tussock forming grasses are a common native grass habit. Whilst redundant species exist, different flowering times may provide food for animals through the year and the redundant species help to fill the area with species thus outcompeting weeds.
Entolasia stricta	?	?	grass	small tussock forming grass, common redundant form for native grasses	?		unknown	wind/wind/erect tussock habit could confer hides for small ground dwelling animals	probably redundant with other similar grasses	As for *Echinopogon caespitosus*
Eremophila debilis	YES	YES	sub-shrub	not redundant	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects/ wallabies and birds/?	not redundant	Common in RSF and rehab
Eucalyptus crebra	YES	YES	tree	redundant with other Eucalyptus	ecto- and endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects and animals/wind/ rough bark, hollows, flowers April, Sept-Nov.	possibly redundant with *E. fibrosa* except for flowering period	Most abundant on the better soils in RSF. Present in the rehab but thought to need more mature soil conditions. Expect its presence may improve as the system ages. Thought to be host for squirrel gliders
Eucalyptus fibrosa	YES	YES	tree	redundant with other Eucalyptus	ecto- and endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects and animals/wind/ rough bark, hollows, flowers March to Aug.	possibly redundant with *E. crebra* except for flowering period	Tends to replace *E. crebra* in the lower slopes especially in the more sodic soils where it is found with *A. luehmannii*
Eucalyptus glaucina	NO	NO	-	redundant with other Eucalyptus	ecto- and endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects and animals/wind/ Secondary food tree for Koala; squirrel gliders feed on some Eucalyptus flowers	possibly redundant with other eucalypts	Threatened species - Not present in RSF or Rehab.
Eucalyptus moluccana	YES	YES	tree	redundant with other Eucalyptus	ecto- and endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects and animals/wind/ Secondary food tree for Koala; squirrel gliders feed on some Eucalyptus flowers, flowering Mar-Jun	possibly redundant with other eucalypts	Present in RSF on the lower slopes. Thought to be present in the Rehab however juveniles can be difficult to identify

Species	Presence		Functional Groups / Attributes							COMMENTS
	RSF-NF	MO Rehab	Life Form		Physiological Activity			Ecosystem Role/Services		
			Morphology	Redundancy and Resilience	Reported Root Associations	Role	Redundancy and Resilience	Pollination/ Dispersal/ Habitat Value	Likely Redundancy and Resilience	
Eucalyptus tereticornis	YES	YES	tree	redundant with other Eucalyptus	ecto- and endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects and animals/wind/ Primary food tree for Koala; squirrel gliders feed on some Eucalyptus flowers, flowering Jun-Nov	possibly redundant with other eucalypts except for flowering period	A few present along Betty's Creek in RSF. Present in New Forest and also successfully planted. Successfully planted into parts of the offsets. Present in rehab.
Glycine clandestina	YES	YES	twiner	not redundant	N fixing bacteria & ?	nutrient acquisition & cycling	unknown	insects/gravity/?	possibly redundant with *Desmodium* species	Present in RSF and Rehab on forest soil
Glycine tabacina	YES	YES	twiner	clonal	N fixing bacteria & ?	nutrient acquisition & cycling	unknown	insects/gravity/ may confer soil stability through clonal habit	resistance conferred by long term seed banks, not redundant	Present in both RSF and rehab in large numbers if not limited by weedy grasses
Hakea sericea	NO	YES	shrub	one of a small number of prickly shrubs	occasional colonization of roots	unknown	unknown	insects/gravity/ prickly hide for birds and animals	probably serves different pollinators than other similar prickly bushes	Only present in Kate Newman's research site on the Rehab.
Hypericum gramineum	YES	YES	herb	not redundant	?		unknown	insects/gravity/?	possibly redundant with other small herbs	Present, but not abundant, across complex including rehab.
Laxmannia gracilis	YES	YES	herb	not redundant	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects/gravity/ contributes to ground cover structure	possibly redundant with other small herbs	Present, but not abundant, across complex including rehab.
Lissanthe strigosa	YES	NO	shrub	redundant with Melichrus urceolatus, clonal	ericoid mycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	specialised insects?/animals? /prickly hide for small animals	redundant with *Melichrus urceolatus*, but pollinators may be different	Old plants present in RSF and offsets. Flowers abundantly but not seen viable seed on them. A species that needs study before any attempts to introduce it into rehab.
Lomandra multiflora subsp. multiflora	YES	YES	graminoid	resilience conferred by drought resistant roots, not redundant	non mycorrhizal		unknown	insects?/gravity/ contributes to ground cover structure	not redundant	Present with a number of other *Lomandra* species in RSF. Present in rehab.
Melichrus urceolatus	YES	NO	shrub	redundant with *Lissanth strigosa*	ericoid mycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	specialised insects?/animals? /prickly hide for small animals	redundant with *Lissanth strigosa*, possibly different pollinators	Old plants present in RSF and offsets. Flowers abundantly but not seen viable seed on them. A species that needs study before any attempts to put into rehab.
Microlaena stipoides var. stipoides	YES	YES	grass	small grass which can form lawns	?		unknown	wind/animals/?	not redundant	Common in RSF, and transferred in small amounts to the rehabilitation area

Species	Presence		Functional Groups / Attributes							COMMENTS
	RSF-NF	MO Rehab	Life Form		Physiological Activity			Ecosystem Role/Services		
			Morphology	Redundancy and Resilience	Reported Root Associations	Role	Redundancy and Resilience	Pollination/ Dispersal/ Habitat Value	Likely Redundancy and Resilience	
Opercularia diphylla	YES	YES	herb	small herb, thick roots probably confer drought resistance	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	?/gravity/?	probably forms seed bank, not redundant	Very inconspicuous herb, present in both forest and rehab.
Paspalidium distans	YES	YES	grass	small flat tussock	?		unknown	wind/gravity/?	probably resilient through a seed bank and production of large amounts of seed. Not redundant	Another important grass component of the RSF understorey. Recorded in the rehab.
Pomax umbellata	YES	YES	herb	small shrub-like herb, similar to a small number of other plants	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects/gravity/ contributes to ground cover structure	probably not redundant as pollinators may be specific	Recorded in both RSF and rehab.
Pratia purpurascens	YES	YES	herb	small clonal herb with thick roots that confer drought resistance.	?		unknown	insects/explosive/ contributes to soil stability through clonal habit	not redundant	Common in RSF and rehab
Pultenaea spinosa	YES	YES	shrub	one of a small number of prickly shrubs	N fixing bacteria, ecto- and endomycorrhizal	Associates with N fixing bacteria and mycorrhizal???	unknown	insects/gravity/ prickly hide for birds and animals	Seed likely forms a long term seed bank conferring resilience	Present in RSF and Rehab on forest soil
Solanum prinophyllum	YES	YES	herb	one of a small number of prickly shrubs	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	insects/animals/ prickly hide for animals	not redundant	Present in RSF and Rehab
Stackhousia viminea	YES	YES	herb	very small herb	?		unknown	insects?/gravity/ contributes to ground cover structure	possibly redundant with other small herbs	Present in RSF & Rehab.
Themeda australis	YES	YES	grass	tussock forming grass redundant with Cymbopogon refractus	endomycorrhizal	provide phosphorus, other nutrients, drought and pathogen resistance	unknown	wind/animals?/ tussock shape provides hides for animals	possibly redundant with *Cymbopogon refractus*	Present in RSF and offsets in patches. Recorded in rehab.
Vemonia cinerea var. cinerea	YES	YES	herb	tall erect herb	?		unknown	insects/wind/?	not redundant	

Species	Presence		Functional Groups / Attributes							COMMENTS
	RSF-NF	MO Rehab	Life Form		Physiological Activity			Ecosystem Role/Services		
			Morphology	Redundancy and Resilience	Reported Root Associations	Role	Redundancy and Resilience	Pollination/ Dispersal/ Habitat Value	Likely Redundancy and Resilience	
Wahlenbergia communis	YES	YES	herb	small tussock shaped herbs	?		unknown	insects/gravity/?	resilience through seed bank, probably redundant with other Wahlenbergia species	A number of *Wahlenbergia* species occur throughout the forest and rehab. Can be very abundant early in rehabilitation and falls off. Never disappears so possibly in seed bank for when a disturbance occurs; numbers may be reduced by competition as part of natural succession processes.
Wahlenbergia gracilis	YES	YES	herb	small tussock shaped herbs	?		unknown	insects/gravity/?	resilience through seed bank, probably redundant with other Wahlenbergia species	As per *Wahlenbergia communis*

NOTES:
Life form is based on observations and information provided in the Flora of NSW
Role and Physiological information is based on research undertaken as part of ongoing research work at Mount Owen (unpublished) and published or 'internet' information.
Redundancy evaluation is based on this species list and doesn't consider other possible native species present in the rehabilitation area or the forest
? or unknown - requires further literature searching or research

References:

NSW Scientific Committee (2010*) Central Hunter Ironbark-Spotted Gum-Grey Box Forest in the NSW North Coast and Sydney Basin Bioregions - endangered ecological community listing: NSW Scientific Committee - final determination, http://www.environment.nsw.gov.au/determinations/centralhunterironbarkFD.htm*

APPENDIX 6

Updated Water Resources Assessment

Inspired people | Dedicated team
Quality outcomes

GLENCORE

UPDATED WATER RESOURCES ASSESSMENT

Mt Owen Continued Operations Refined Project

FINAL

May 2016

GLENCORE

UPDATED WATER RESOURCES ASSESSMENT

Mt Owen Continued Operations Refined Project

FINAL

Prepared by

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Report No.	3109/R21/FINAL
Date:	May 2016

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1.0 Introduction

Mount Owen Pty Limited (Mount Owen) is proposing to refine the Mount Owen Continued Operations Project (the Project) compared to that detailed in the Environmental Impact Statement (EIS) completed in January 2015, to take account of the Planning Assessment Commission (PAC) Review Report issued in February 2016. Mount Owen has undertaken a review of the final landform focussing on the issues raised by the PAC in relation to final void management and also the incorporation of micro relief into the conceptual mine plan for the Project. This review has identified refinements to the design of the Project as originally outlined in the EIS to meet the objectives of not creating additional voids (relative to current approved Mount Owen operations) and incorporating additional micro relief into the final landform for the Project.

This report discusses the water resources impacts associated with the Refined Project compared to the Project assessed as part of the EIS (Umwelt, 2015).

1.1 Report Structure

The key components of the Water Resources Assessment for the Refined Project are included in the following sections:

- Conceptual WMS for the Refined Project; **Section 2.1.**
- Water balance; **Section 2.2.**
- Potential impacts of the Refined Project and proposed surface water management strategies; **Section 2.3.**
- Monitoring, licensing and reporting; **Section 2.4.**
- Potential impact of Refined Project on groundwater resources; **Section 3.0**.

2.0 Surface Water

2.1 Surface Water Context

A comprehensive assessment of potential surface water impacts was completed for the Project and included in the EIS as Appendix 9.

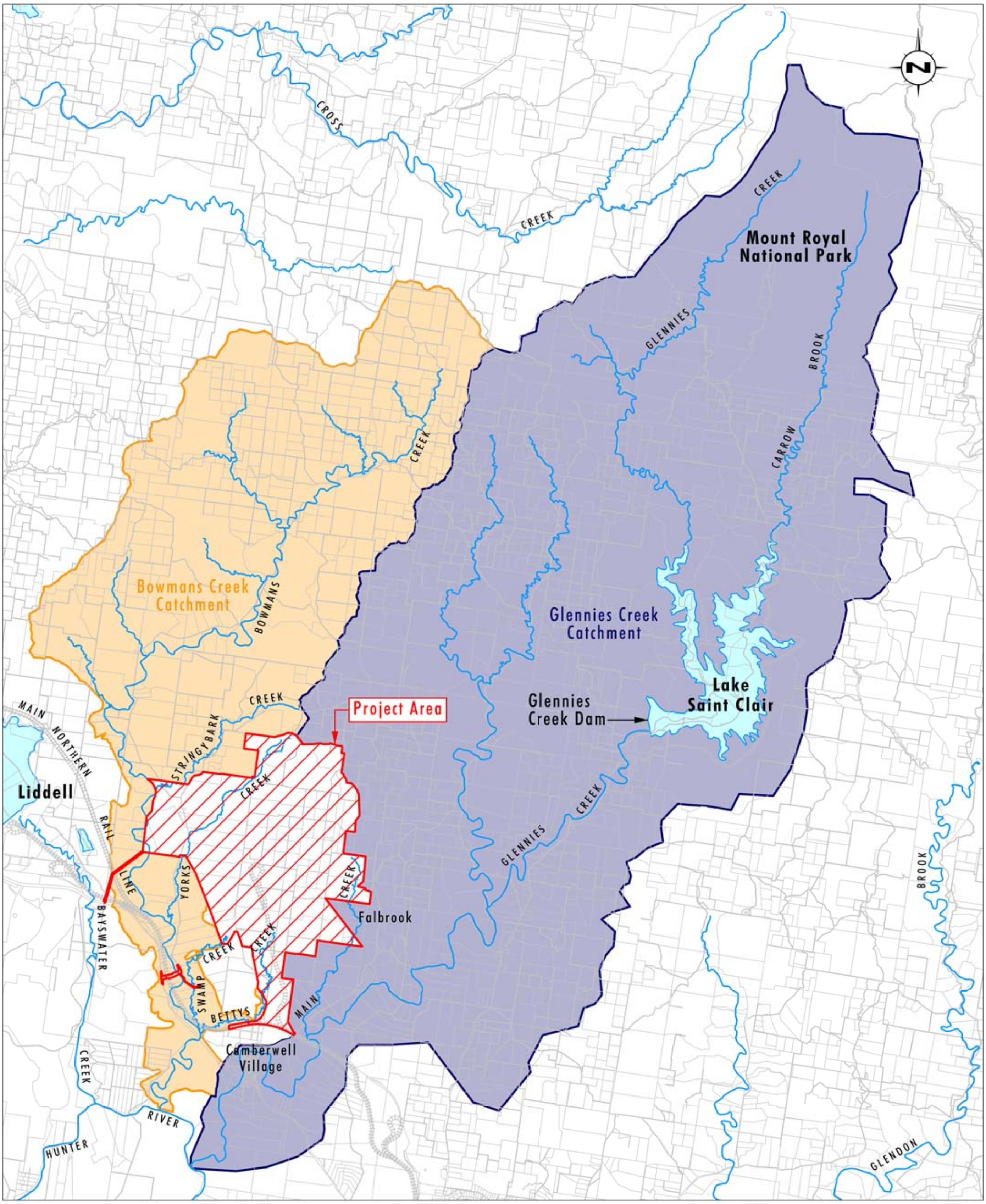
The following changes associated with the Refined Project have the potential to impact on surface water:

- minor reshaping associated with incorporation of micro-relief in the southern portion of the North Pit Overburden Emplacement Area
- minor reshaping of the Ravensworth East Overburden Emplacement Area associated with placement of tailings within the West Pit Void and reshaping of the Bayswater North Pit Final Void
- no mining within the RERR mining area with the existing TP2 void used instead as a water storage during Years 1 and 5 of the Project, prior to being rehabilitated
- ongoing use of the Bayswater North Pit (BNP) as a water storage area following completion of coal mining in BNP from Year 10 of the Project
- changes to the tailings management strategy for the Project associated with the receival and emplacement of tailings from Ravensworth Operations and Liddell coal handling and preparation plants and return of tailings reclaim water to those sources, as approved under Ravensworth East DA52-03-99 MOD 6.

The Project Area is located within the catchments of Bowmans Creek and Glennies Creek. Both Bowmans Creek and Glennies Creek flow into the Hunter River to the south of the Project Area. In vicinity of the Project Area, the Bowmans Creek catchment includes the sub catchments of Stringybark Creek, Yorks Creek, Swamp Creek and Bettys Creek. Glennies Creek catchment includes the sub catchment of Main Creek (refer to **Figure 2.1**).

In comparing the Refined Project to the Project described in the EIS it is considered that the Refined Project will result in:

- no changes to the assessed surface water impacts on Stringybark Creek, Yorks Creek, Swamp Creek, Bettys Creek or Main Creek during the Project life
- no changes to the assessed surface water impacts on Yorks Creek associated with the final landform
- no changes in overall impacts to the assessed surface water impacts (i.e. flooding) on Swamp Creek, Bettys Creek and Main Creek as a result of minor changes to the final landform, including removal of the RERR final void
- minor changes to the Project water balance associated with changes to the tailings strategy associated with the Project
- Changes to the final void water recovery levels and salinity associated with minor changes to the final void catchment areas and reshaping of the North Pit and Bayswater North Pit. The final voids will remain self-contained and not spill.



Data Source: Mount Owen (2014), Geoscience Australia (2006), Department of Lands (2009)

0 2.5 5.0 10.0km
1:200 000

Legend

- Project Area
- Glennies Creek Catchment Area
- Bowmans Creek Catchment Area
- Cadastre
- Railway
- Drainage Line

FIGURE 2.1

Catchment Context

File Name (A4): R21/3109_1134.dgn
20140901 9.59

2.2 Water Management System

The water management system manages water of three distinct types: clean, dirty and mine water. Each type of water requires different management measures to minimise the risk of contamination of downstream drainage systems by construction and mining activities. There are no changes to the Water Management Strategy presented in the EIS assessment associated with the Refined Project.

The layout of the key components of the WMS for the Refined Project is shown on **Figures 2.2** to **2.4**.

It is important to note that the stage plans presented in **Figures 2.2** to **2.4** are conceptual, being determined by current construction and mining schedules. The WMS will be constructed and modified as and when required so as to support the infrastructure and mine development. Further, the stage plans indicate only the components of the WMS which are required for a particular stage of the mine, and do not preclude the construction of some components over the life of the Project.

Similarly, the conceptual storage capacities required for the various water management dams are provided to indicate the quantum of the proposed dams. Refinement of the design criteria and capacities will be undertaken during detailed design stages of the Project, as well as the ongoing operational stages.

The changes to the WMS with the Refined Project compared to the EIS Project include:

- minor drainage changes associated with the reshaping of the Ravensworth East Overburden Emplacement resulting in minor changes to catchment boundaries within the WMS and associated sediment dam requirements

- changes to drainage around the TP2 area with removal of mining of the RERR mining area and use of the TP2 area as a water storage for Years 1 and 5 of the Refined Project

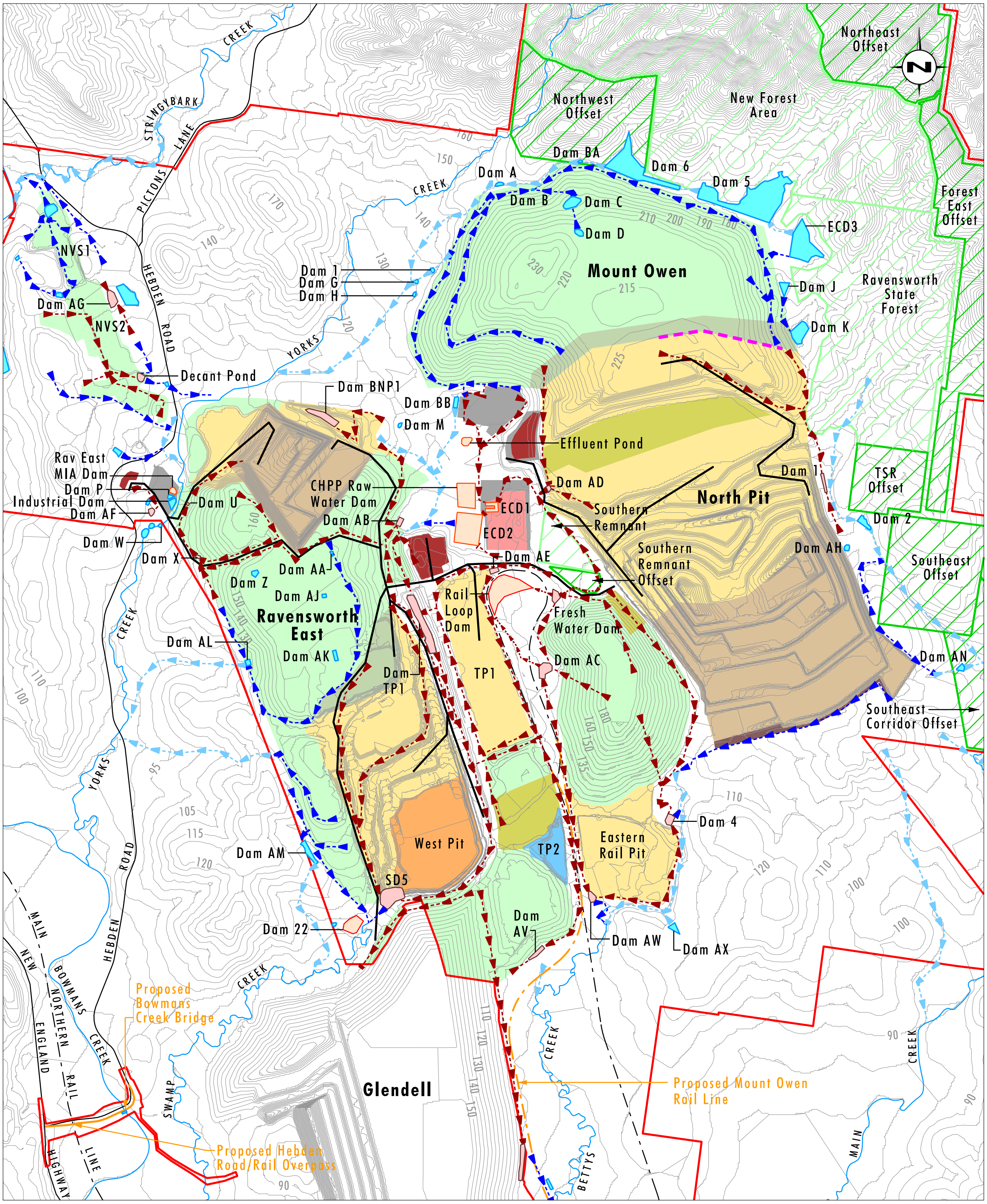
- minor drainage changes associated with the reshaping of the North Pit Overburden Emplacement Area, resulting in minor changes to required sediment dam sizes and locations

- use of the BNP as a water storage at the cessation of mining(around Year 7 of the Project).

The proposed WMS for the final landform is shown in **Figure 2.5**.

When the final landform is achieved, all operations will be complete and the Project Area will be completely rehabilitated. The proposed final landform will result in two final voids, one in the southern area of the North Pit Continuation, and one in the former BNP in the north of the Ravensworth East Mine. It is proposed that at the end of the Project, the BNP void will be decommissioned as an operational water storage with overburden emplacement batter angles flattened and high-walls stabilised. The North Pit Continuation void high-walls will also be stabilised following the cessation of mining. Drains will be constructed upslope of the final voids in order to direct upstream catchment runoff away from the final voids to downstream watercourses.

Groundwater flows into and out of the final voids were estimated using relationships provided by Jacobs (2014). If the final voids remain as water bodies in the final landform, the water balance indicates the final voids are not likely to spill and will reach an equilibrium level below the spill level. The predicted equilibrium water levels within the North Pit final void and BNP final void are 20 mAHD and 10 mAHD respectively.



Data Source: Mount Owen (2014)

Note: Contour Interval 5m(AHD). Subject to refinement as part of WMP process

0 0.5 1.0 2.0km

1:40 000

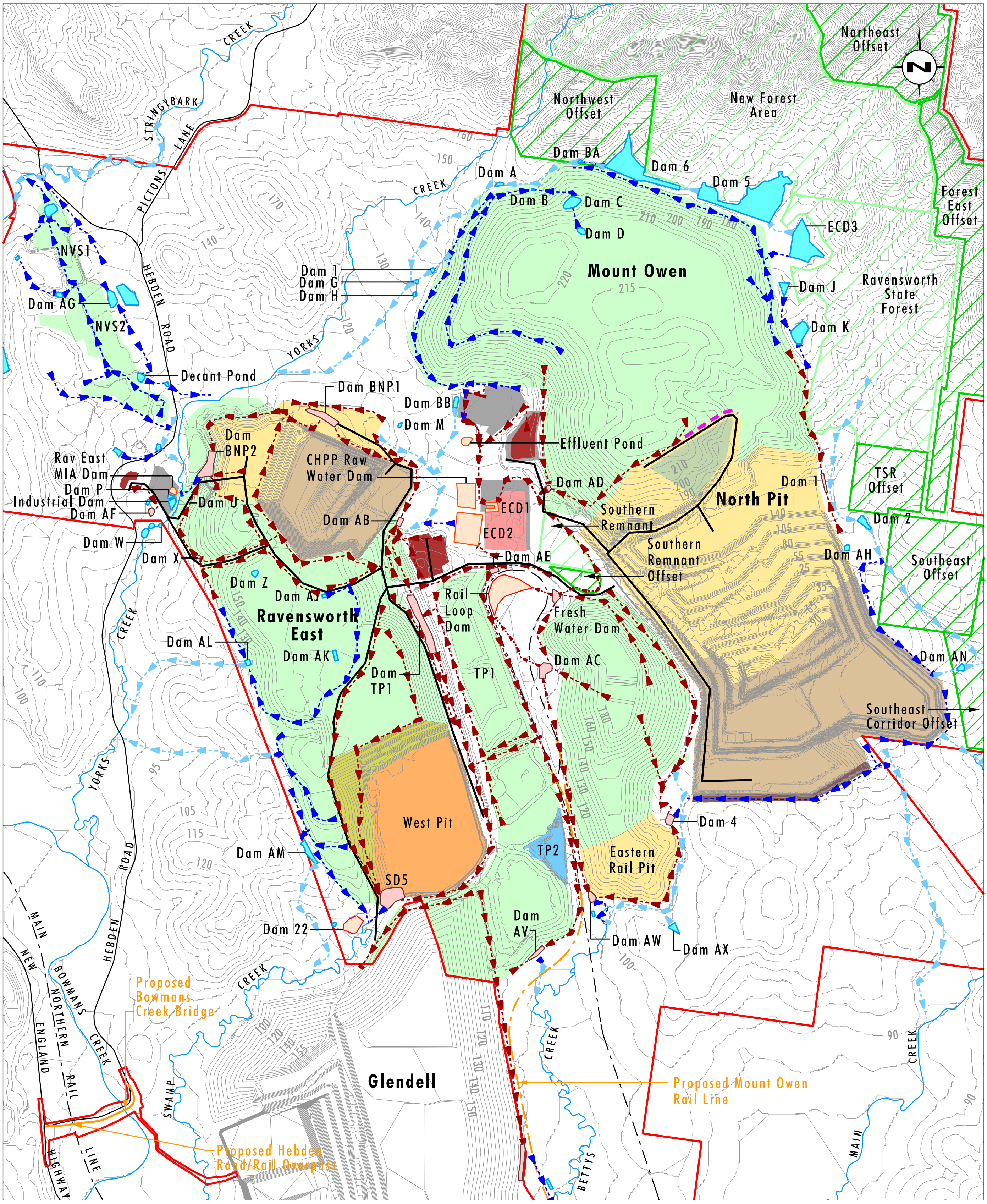
Legend

- Project Area
- Existing Biodiversity Offset Areas
- Ravensworth State Forest
- Existing Railway
- Proposed Rail Upgrade Works
- Proposed Hebden Road Upgrade Works
- Clean Water Dam
- Sediment Dam
- Mine Water Dam
- Existing Flow Path
- Clean Water Diversion Drain
- Dirty Water Drain
- Windrow
- Drainage Line
- Haul Road
- Active Mining Area
- Active Overburden Emplacement Area
- Topsoil Removal
- Coal Stockpile - Product
- Coal Stockpile - ROM
- Infrastructure
- Rehabilitation - Complete
- Rehabilitation - Temporary
- Shaped Not Seeded
- Tailings Placement
- Water Storage Area

FIGURE 2.2

Conceptual Surface Water Management Year 1

File Name (A4): R21/3109_1130.dgn
20160513 8.31



Data Source: Mount Owen (2014)
Note: Contour Interval 5m(AHD). Subject to refinement as part of WMP process

0 0.5 1.0 2.0km
1:40 000

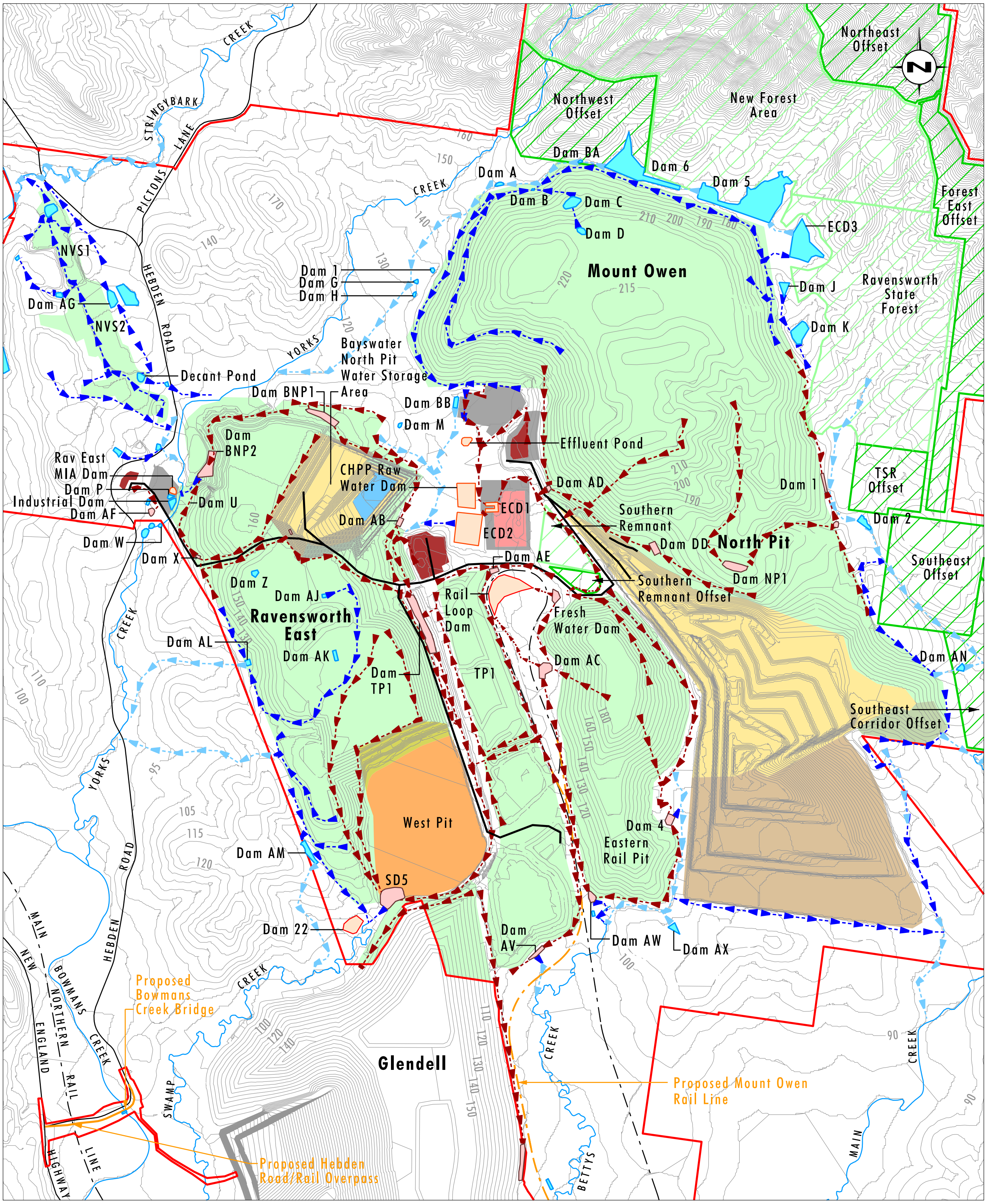
Legend

- Project Area
- Existing Biodiversity Offset Areas
- Ravensworth State Forest
- Existing Railway
- Proposed Rail Upgrade Works
- Proposed Hebden Road Upgrade Works
- Clean Water Dam
- Sediment Dam
- Mine Water Dam
- Existing Flow Path
- Clean Water Diversion Drain
- Dirty Water Drain
- Windrow
- Drainage Line
- Haul Road
- Active Mining Area
- Active Overburden Emplacement Area
- Topsoil Removal
- Coal Stockpile - Product
- Coal Stockpile - ROM
- Infrastructure
- Rehabilitation - Complete
- Rehabilitation - Temporary
- Shaped Not Seeded
- Tailings Placement
- Water Storage Area

FIGURE 2.3

Conceptual Surface Water Management Year 5

File Name (A4): R21/3109_1131.dgn
20160513 8.32



Data Source: Mount Owen (2014)
Note: Contour Interval 5m(AHD). Subject to refinement as part of WMP process

Legend

- Project Area
- Existing Biodiversity Offset Areas
- Ravensworth State Forest
- Existing Railway
- Proposed Rail Upgrade Works
- Proposed Hebden Road Upgrade Works
- Clean Water Dam
- Sediment Dam
- Mine Water Dam
- Existing Flow Path
- Clean Water Diversion Drain
- Dirty Water Drain
- Drainage Line
- Haul Road
- Active Mining Area
- Active Overburden Emplacement Area
- Coal Stockpile - Product
- Coal Stockpile - ROM
- Infrastructure
- Rehabilitation - Complete
- Rehabilitation - Temporary
- Shaped Not Seeded
- Tailings Placement
- Water Storage Area

FIGURE 2.4

Conceptual Surface Water Management Year 10

File Name (A4): R21/3109_1132.dgn
20160513 8.33

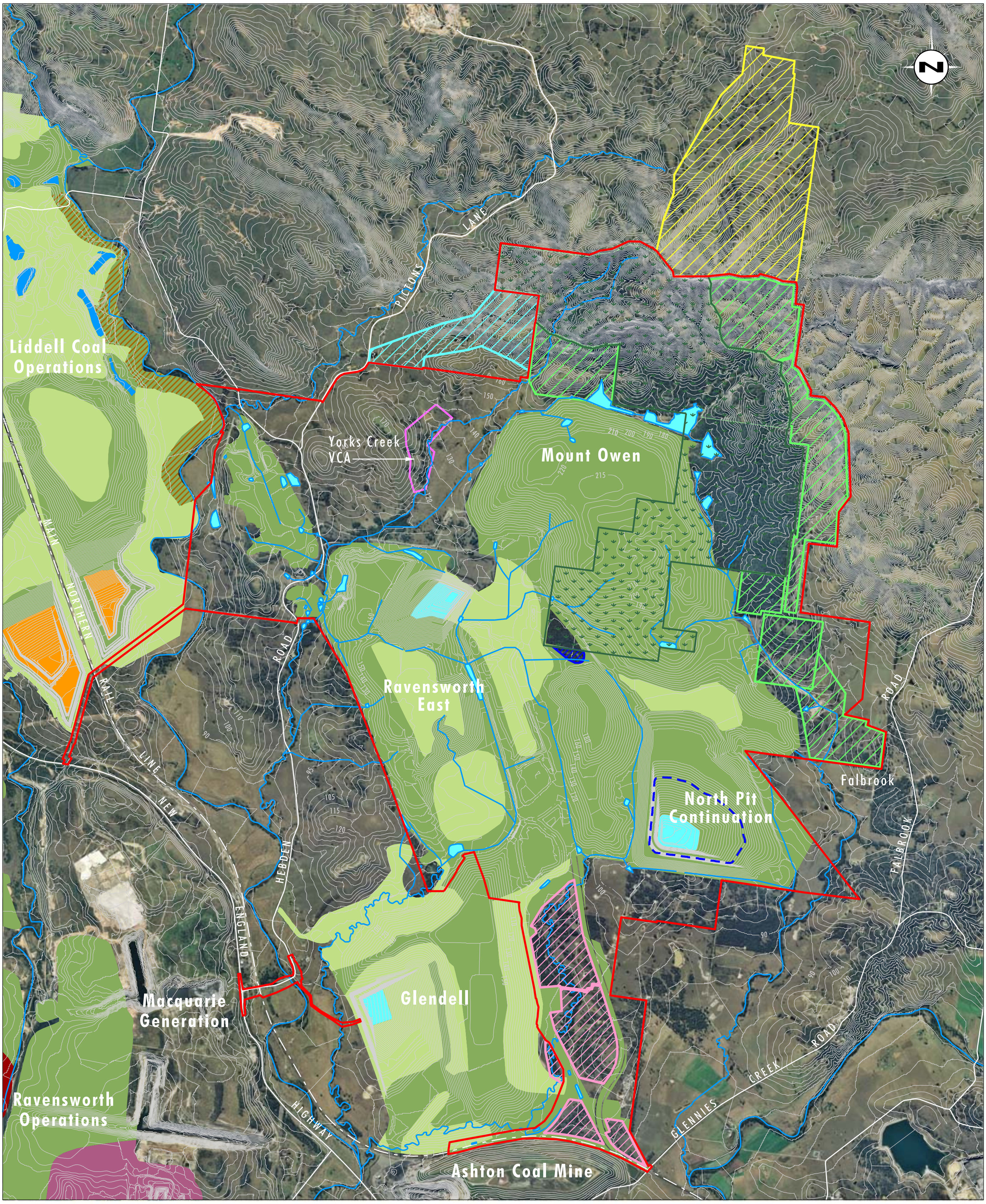


Image Source: Mount Owen (2012-2013)
Data Source: Mount Owen (2014), Ravensworth Operation Vegetation: Umwelt (2010),
Liddell Coal Operations Vegetation: Umwelt (2016)
Note: Contour Interval 5m(AHD)

0 1.0 2.0 3.0km
1:65 000

Legend

- Project Area
- Yorks Creek VCA
- Pit Lake
- Native Woodland
- Open Grassland (Potential grazing areas) with pockets of Native Vegetation
- Grassland for Stabilisation (Liddell)
- Ravensworth State Forest
- Proposed Corridor Habitat Enhancement on Non-Mined land (Liddell Coal Operations)
- Existing Biodiversity Offset Area
- Proposed Cross Creek Biodiversity Offset Area
- Bettys Creek Habitat Management Area
- Southern Remnant Biodiversity Offset Area
- Stringybark Creek Habitat Corridor
- Final Landform Water Dam - Clean
- Maximum Pit Lake Water Level
- Grazing
- Riparian / Wetland
- Drainage Line

FIGURE 2.5

Mount Owen Continued Operations Project Conceptual Final Landform

File Name (A4): R21/3109_1133.dgn
20160518 14.25

2.2.1 Proposed Additional Dams

The proposed changes to the WMS for the Refined Project result in modification to the proposed additional dams, in terms of volume and location, that were presented for the WMS for the Project detailed in the EIS. The additional dams required to manage dirty and clean runoff from disturbance areas and rehabilitated areas for the Refined Project, in addition to existing dams are listed in **Table 2.1**.

Table 2.1 Changes to Dams with Refined Project

Dam	Approximate Volume (ML)[1]	Year 1	Year 5	Year 10	Final Landform
Dam 1	24 (70)	Dirty Water	Dirty Water	Dirty Water	Clean Water
Dam 4	50	Dirty Water	Dirty Water	Clean Water	Clean Water
Dam AD	50	Dirty Water	Dirty Water	Clean Water	Clean Water
Dam DD	6 (45)	-	-	Dirty Water	-
Dam AE	5	Dirty Water	Dirty Water	Dirty Water	Clean Water
Dam AW	35	Dirty Water	Dirty Water	Clean Water	Clean Water
Dam AH	25 (10)	Clean Water	Clean Water	Dirty Water	-
Dam TP1	57	Dirty Water	Dirty Water	Clean Water	Clean Water
BNP1	13	Dirty Water	Dirty Water	Dirty Water	Clean Water
BNP2	64 (35)	-	Dirty Water	Dirty Water	Clean Water
Ravensworth East MIA Dam	4	Mine Water	Mine Water	Mine Water	Clean Water
NP1	68 (-)	-	-	Dirty Water	Clean Water

Notes: 1) Includes sediment zone volume

Shading indicates changes to dam or additional dam (i.e. NP1) compared to EIS project. Dam WP is not required with the Refined Project and has been removed from the table above. EIS Project dam volumes, where different to the Refined Project, are shown in brackets.

2.3 Water Balance

As discussed in **Section 2.2**, the WMS at the Mount Owen Complex is an integrated system, that is, the water from the Mount Owen, Ravensworth East and Glendell Mines are managed together within an integrated WMS. In addition, the Mount Owen Complex is an integral part of the Greater Ravensworth Water Sharing System (GRWSS) with the Cumnock, Ravensworth Surface Operations, Narama, Ravensworth Underground and Liddell mining operations and associated coal handling and preparation plants. The GRWSS allows greater flexibility in the mine water management by the Mount Owen Complex.

The use and management of water within the Glendell Mine does not form part of the Project and will continue to be managed pursuant to the existing Development Consent. However, due to the integrated nature of the Mount Owen Complex WMS, the overall water balance of the Mount Owen Complex (which includes water make and use at the Glendell Mine) and the changes to the water balance associated with the Refined Project are detailed in this document.

Inflows to the water balance include site rainfall runoff, tailings decant water, groundwater inflows to open cut pits, transfers from other mines within the GRWSS and water extracted under licence from Glennies Creek.

An updated Site Water Balance considering the removal of the RERR mining area and the updated tailings management strategy has been completed for the Refined Project. A summary of the water balance findings are included in the remainder of this section.

2.3.1 Overview of Models

The water balance models are based in Microsoft Excel and utilise Palisade @Risk software to undertake a Monte Carlo analysis to calculate the probability of different water balance outcomes based on the variability of the model input data.

Daily time step water balance models have been used to assess the gross water balance for the existing operations and the Project, the frequency and volume of water transfers to and from the Mount Owen Complex, the frequency and volume of spills, and final void water levels for the Project.

Water is supplied to the Mount Owen Complex from both the GRWSS and Glennies Creek. Mount Owen currently holds 1,056 ML per year of High Security Entitlement and 861 ML per year of General Security Entitlement Water Access Licences for extraction of water from Glennies Creek.

Surplus water at the Mount Owen Complex is managed by offsite transfer as part of the GRWSS.

2.3.2 Potential Impacts with the Project

Table 2.2 presents a summary of the gross water balance results for Year 1, Year 5 and Year 10 of the Refined Project in isolation from the GRWSS. The Project gross water balance results reported in the EIS are also presented in parentheses for Years 5 and 10 to allow comparison with the Refined Project. The water balance for the Refined Project incorporates the water associated with additional tailings emplacement as part of the approved Ravensworth East DA52-03-99 MOD 6. The gross water balance for Year 1 of the Refined Project is unchanged from the Project.

Table 2.2 Refined Project Gross Water Balance (ML)

Scenario	10th Percentile	50th Percentile	90th Percentile
Year 1	-2,325	-810	1,660
Year 5	-1,760 (-2,200)	-230 (-665)	2,250 (1,810)
Year 10	-835 (-800)	310 (340)	2,280 (2,310)

Note: EIS Project Water, where different to Refined Project, included in brackets.

The 50th percentile gross water balance results show that the Refined Project is estimated to remain in water deficit in Year 1 and Year 5. At Year 10 the Project, in isolation from the GRWSS, is predicted to operate at a surplus (i.e. water exporter to the GRWSS) as a result of lower ROM production and therefore lower CHPP demands and losses to tailings. The Refined Project 50th percentile gross water balance deficit for Year 5 is lower than that predicted for the Project in the EIS as a result of the additional water imported with tailings from the Ravensworth and Liddell CHPPs. In Year 10 of the Refined Project there will be approximately 1.3 Mt per year less production without the RERR mining area and a reduction of groundwater inflow of approximately 235 ML per year without the RERR mining area. The lower water usage associated with reduced production in Year 10 is offset by a moderately greater degree by the reduction in groundwater inflows to the WMS. As a result the 50th percentile gross water balance excess for Year 10 of the Refined Project is marginally lower than the gross water balance excess for the Project in the EIS.

While the gross water balance model assesses the gross site water surplus or deficit for a given year without importing or exporting water to site, the likely import and export volumes to meet daily operational requirements also needs to be understood. As there is limited water storage capacity at the Mount Owen Complex, water is transferred to the Mount Owen Complex to meet water demands during dry periods and transferred from the complex to manage water surplus during wet periods.

Water is imported to the Mount Owen Complex from the GRWSS and from Glennies Creek under water access licences. **Table 2.3** presents the modelled annual mine complex import volumes for the Refined Project stage plans Year 1, Year 5 and Year 10. Project import volume results from the EIS are also presented in parentheses for Years 5 and 10 to allow comparison with the Refined Project. The import volumes for Year 1 of the Refined Project are unchanged from the Project.

Table 2.3 Refined Project Annual Raw Water Import Volumes (ML)

Scenario	10th Percentile	50th Percentile	90th Percentile
Year 1	2,325	1,450	1,840
Year 5	1,750 (2,210)	935 (1,320)	1,400 (1,745)
Year 10	705 (670)	305 (280)	530 (505)

Note: EIS Project Water, where different to Refined Project, included in brackets.

Note: water is also imported to site with tailings imports. This water is not considered a raw water import and as such is not reported in the table above.

Year 5 raw water import volumes are lower for the Refined Project as a result of the additional water transferred to the site with tailings from the Ravensworth and Liddell CHPPs. As with the gross water balance, the impacts of lower production are offset by reduced groundwater inflow resulting in marginally higher import demands for the Refined Project compared to the Project.

Exports from the Mount Owen Complex include water transfers to the GRWSS, and spills from sediment dams during extreme weather events, when the water management system design criteria are exceeded. **Table 2.4** presents the modelled annual export volumes for Year 1, Year 5 and Year 10 of the Refined Project.

Table 2.4 Refined Annual Export Volumes (ML)

Scenario	10th Percentile	50th Percentile	90th Percentile
Year 1	190	640	3,790
Year 5	205 (195)	700 (650)	3,915 (3,840)
Year 10	105 (105)	520 (530)	2,945 (2,950)

Note: EIS Project Water, where different to Refined Project, included in brackets.

Year 5 export volumes are moderately higher for the Refined Project as a result of the return of additional water transferred to the site with tailings from the Ravensworth and Liddell CHPPs. As with the gross water balance, the impacts of lower production are offset by reduced groundwater inflow resulting in marginally lower export demands for the Refined Project compared to the EIS Project.

Since the lodgement of the EIS, Glencore has constructed a new water storage, known as Reservoir North, at Liddell. Reservoir North will form an integral component of the GRWSS and be the primary off-site water storage for the Mount Owen Complex with a proposed storage capacity of 2 GL. The pipeline connecting the Mount Owen Complex with Reservoir North is subject to a separate approvals process. In addition, the BNP will be used as an operational water storage for the Mount Owen CHPP after the completion of mining in in the BNP pit, in approximately 2022.

As indicated in **Section 2.2**, export of surplus water at the Mount Owen Complex is possible via transfers to the GRWSS. Mount Owen proposes to continue to share water within the GRWSS, including the use of existing water storages and, where necessary, utilise existing approved discharge points under the HRSTS for the Project at Ravensworth Operations and Liddell Coal Mines. The GRWSS includes a number of large water storages used to manage water from the various operations. Surplus water transferred from Mount Owen to the GRWSS will be stored in these water storages and reused within the GRWSS in preference to being discharged.

2.4 Surface Water Impacts and Management

Surface water impacts that will change as a result of the Refined Project are detailed below.

2.4.1 Catchment Areas and Annual Flow Volumes

The potential impacts on catchment areas with the Refined Project, compared to the Project as presented in the EIS and the Current Approved Final Landform are presented in **Table 2.5**.

Table 2.5 Predicted Impacts on Catchment Areas

Catchment	Pre-Mining (ha)	Current Approved Final Landform (ha)	Project			Refined Project		
			Year 5 (ha)[1]	Proposed Final Landform[2]		Year 5 (ha)[1]	Proposed Final Landform[2]	
				Area (ha)	%[4]		Area (ha)	%[4]
Bowmans Creek[3]	**25,055**	**20,390**	**21,590**	**20,520**	**101**	**21,590**	**20,510**	**101**
- Stringybark Creek	1,290	1,300	1,300	1,300	100	1,300	1,300	100
- Yorks Creek	1,230	1,660	1,800	1,920	116	1800	1910	115
- Swamp Creek	2,380	1,440	390	1,230	85	390	1160	81
- Bettys Creek	1,810	960	700	780	81	700	850	89
Glennies Creek[3]	**52,335**	**50,405**	**50,215**	**50,255**	**100**	**50,275**	**50,335**	**100**
- Main Creek	2,000	2,620[5]	2,430	2,470	94	2,430	2,530	97

Notes: 1) Excluding WMS

2) Final Landform is when both the decommissioning of infrastructure and the rehabilitation of the post mining landform are completed.

3) Catchment areas modified to reflect changes due to the Project and approved and proposed Liddell Operations. This does not include impacts from other modifications (such as other mining operations) downstream of the Project Area.

4) Project final landform catchment area as a percentage of the current approved final landform.

5) Catchment area updated and larger than identified in Mount Owen Operations EIS, 2003 (previously 1,750 ha), as more accurate terrain data is now available (LiDAR) over entire catchment

The Refined Project will not change the catchment impacts assessed for the Project for Year 5 as detailed in the EIS.

The Refined Project will have negligible impacts on the catchment area and as such annual flow volumes of Bowmans Creek with the final landform compared to the Project as detailed in the EIS. Similarly there are negligible impacts on the catchment area and as such annual flow volumes for Glennies Creek when comparing the Refined Project to the Project presented in the EIS.

With the Refined Project there are minor predicted changes when compared to the Project for the catchment areas of Swamp Creek and Bettys Creek. Similarly the catchment area of Main Creek is predicted to increase relative to that detailed in the EIS, but will remain less than the Current Approved Final Landform catchment area.

As per the EIS assessment the predicted changes in annual flow volumes associated with the Refined Project are considered to be small within the context of ephemeral streams. That is, the change in flows is less than the seasonal and annual variations in flow volumes.

2.4.2 Flooding

With the Refined Project, it is considered that there will be no changes to the impacts on flooding in the Yorks Creek, Swamp Creek or Bettys Creek catchment areas compared to the EIS assessment.

Similarly it is predicted that, although the catchment area of Main Creek is increasing compared to the Project detailed in EIS, the catchment area remains less than the catchment area associated with the Current Approved Landform. The flood model used in the EIS Project assessment was updated with the changes to the Main Creek catchment for the final landform associated with the Refined Project, with peak flood model results presented in **Table 2.6**.

Table 2.6 Peak Flood Model Results for Main Creek

Scenario	10% AEP Event			5% AEP Event			1% AEP Event		
	Depth (m)	Velocity (m/s)	Flow (m^3/s)	Depth (m)	Velocity (m/s)	Flow (m^3/s)	Depth (m)	Velocity (m/s)	Flow (m^3/s)
Approved Final Landform	1.15	1.16	45.9	1.29	1.16	58.1	1.53	1.15	80.4
Current Landform	1.08	1.12	45.1	1.19	1.12	54.6	-	-	-
EIS Project (final landform)	1.12	1.16	42.5	1.28	1.16	56.1	1.48	1.16	74.5
Refined Project (final landform)	1.13	1.15	44.3	1.29	1.16	57.3	1.51	1.14	77.4

The modelling indicates that although the peak flows and depths are marginally greater than those presented in the EIS for the Refined Project they remain below or the same as the peak flows, velocities and depths for the Current Approved Final Landform. As such it is considered that the Refined Project will have no greater impact on downstream flooding than that with the Current Approved Landform.

2.4.3 Other Impacts

The EIS detailed potential impacts on water, quality base flows, downstream water users, riparian and ecological values of the watercourses, environmental flows, erosion and sediment control measures and cumulative impacts.

The Refined Project is not predicted to increase any of the potential impacts on the abovementioned surface water features relative to the Project as detailed in the EIS. The predicted changes with the Refined Project relative to the EIS Project are unchanged.

2.5 Monitoring, Licensing and Reporting

2.5.1 Monitoring

The surface water assessment undertaken for the EIS discussed monitoring requirements for the Project with specific reference to:

- erosion and sediment control measures
- water balance monitoring
- watercourse stability monitoring and management
- surface water quality monitoring
- flow monitoring
- contingency measures
- decommissioning of the water management system.

Monitoring requirements are unchanged for the Refined Project. If the Refined Project is approved, the *Mount Owen Complex Water Management Plan* and associated sub plans will be updated to include monitoring and reporting aspects of the Project, as discussed in the Project EIS.

2.5.2 Licensing

2.5.2.1 Protection of the Environment Operations Act 1997

Licensing requirements for the Project under the *Protection of the Environment Operations Act 1997* are unchanged for the Refined Project.

2.5.2.2 Water Act 1912 and Water Management Act 2000

The *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* continues to apply to watercourses and alluvial groundwater in the vicinity of the Project Area and their use continues to be governed by the *Water Management Act 2000*.

In response to issues raised by DPI Water subsequent to the PAC Review Report, a refined method for calculating the water licensing requirements for the Refined Project has been developed in consultation with DPI Water and in accordance with Harvestable Rights Orders (gazetted 31 March 2006 http://www.nsw.gov.au/sites/default/files/pdfs/2006/31st_March.pdf#page=36) and Water Access Licensing requirements (see http://www.water.nsw.gov.au/water-licensing/about-licences/new-access-licences), and is presented in **Figure 2.6**.

Using the above method for calculating licensing requirements, the water allocation volumes for both Harvestable Rights and the available Water Access Licences were calculated and results are shown in **Table** 2.7. It is important to note that the water licensing regime may further evolve between now and mine closure, and obviously the licensing would need to adapt accordingly. That said, the details provided below indicate that the proposed final landform can be appropriately accommodated in the current water licence regime.

Table 2.7 Water Licensing Requirements, Final Landform (ML)

	Harvestable Rights		Water Access Licences	
	Mount Owen	**Forestry Corporation**	**Jerrys Water Source**	**Glennies Water Source**
Water Allocation Volumes Available				
MHRDC	344	62	-	-
WAL	-	-	200	450
Licensable Water Take				
Dams	149	154	191	-
Final Voids	-	-	56	330
Remaining Allocation	195	-92	-47	120

The results indicate that water take for several of the dams (i.e. there is 92 ML of dam volume in excess of the MHRDC for the Forestry Corporation, **refer to Table 2.7**) within land owned by the Forestry Corporation will need to be accounted for with Water Access Licences. Similarly Water Access Licences will need to be sought to manage the water take within the Jerrys Water Source (i.e. **Table 2.7** indicates that the allocation within the Jerrys Water Source is exceeded by 47 ML). It is considered that transfer of Water Access Licences from Mount Owen in the Glennies Water Source will be transferred to Forestry Corporation to account for the water take from the 92 ML of dam volume unable to be accounted for under Harvestable Rights Provisions.

2.5.3 Reporting

Reporting requirements for the Refined Project are unchanged from those detailed in the Project EIS.

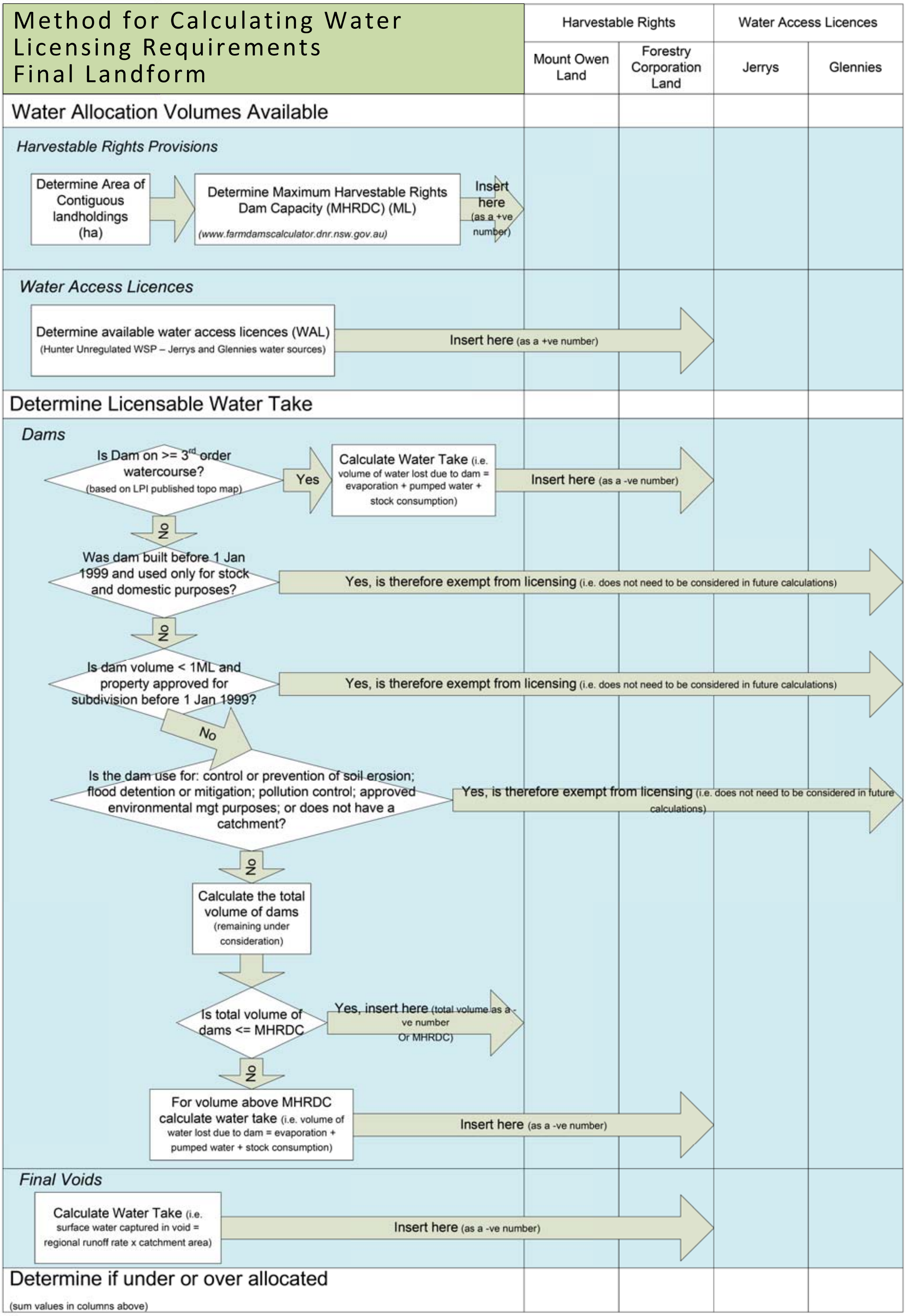


FIGURE 2.6

Conceptual Final Landform Water Licensing and Accounting Framework

3.0 Groundwater Impacts

A comprehensive assessment of potential groundwater impacts was completed for the Project and included in the EIS as Appendix 10. The Refined Project will not alter the proposed mining operations in North Pit as described and assessed in the EIS, and accordingly the overall outcomes of the groundwater impact assessment remain unchanged to that presented in the EIS.

In general terms, the exclusion of the RERR from mining would result in the predicted groundwater sink and cone of depression associated with this area not occurring. Therefore, any impacts arising from the proposed changes as compared with the Project in the EIS would be less than predicted in the EIS.

Likewise, impacts to alluvial aquifers are not predicted to be exacerbated by the Refined Project. The original modelling predicted negligible incremental changes to groundwater flow into Glennies Creek and Bowmans Creek. Bettys Creek is most proximal to RERR and Yorks Creek to BNP. The EIS predicted that Bettys Creek would experience the greatest potential impact from the mining of the RERR; this impact would be reduced as a result of the removal of RERR mining area as part of the Refined Project.

The extent of the drawdown within hard rock aquifers as modelled for the EIS is limited to within the Project area. No existing groundwater users are predicted to be impacted. The Refined Project would not alter this outcome.

The changes to the long-term hydrologic and hydrogeological regimes following cessation of mining was assessed as part of the EIS. It was found that post-mining equilibrium levels within the hard rock aquifer would be influenced by the final voids associated with the Project. However, these long-term, groundwater levels would be greatly impacted by the other concurrent mining activities in the local area. Since the Refined Project includes the removal of one final void (associated with the RERR), the impact of the Project on the long-term steady state groundwater levels in comparison with the original Project is likely to be similar or less than that detailed in the EIS.

3.1 Assessment Against Aquifer Interference Policy

Tables 3.1 to **3.3** describe the changes resulting from the Refined Project assessed against the NSW Aquifer Interference Policy's (AIP) water licence information requirements, minimal impact consideration requirements and additional requirements for aquifer interference activities.

Table 3.1 Water Licence Information Requirements Specified in the AIP

AIP Requirement	Response for EIS Project	Changes Resulting from Project Refinements
Described the water source(s) the activity will take water from?	The Project will take water primarily from the hard rock aquifer associated with the Wittingham Coal Measures through dewatering to ensure safe resource recovery from the target coal seams and interburden. In addition, numerical modelling predicts the Project will draw limited quantities of water from alluvial aquifers associated with tributaries of Bowmans Creek and Glennies Creek. Groundwater in the alluvial aquifers associated with Bowmans Creek and its tributaries is accounted for in the Jerrys Water Source under the Hunter Unregulated and Alluvial WSP (2009), and groundwater associated with Glennies Creek and its tributaries is accounted for under the Hunter Regulated River WSP (2003).	No change to water sources.
Predicted the total amount of water that will be taken from each connected groundwater or surface water source on an annual basis as a result of the activity?	Predicted water take from each water source, as determined through numerical modelling, are provided in Section 3.5 of Groundwater Impact Assessment. Peak median of 15 ML/year from Main Creek (Glennies Water Source) and 6 ML/year from Bettys Creek (Jerrys Water Source) are predicted. Negligible take (<1 ML/year) is predicted from either the Glennies Creek or Bowmans Creek alluvium aquifers. Estimates of groundwater extraction rates required to accommodate the Project are generally less than 500 ML/year, with a broad peak from 2022 through 2026 up to 750 ML/year.	The Refined Project will result in similar or less volumes than those specified here and in the Groundwater Impact Assessment.
Predicted total amount of water that will be taken from each connected groundwater or surface water source after the closure of the activity?	Post-mining simulations predict that the North Pit and RERR final voids will act as groundwater sinks while the BNP final void will act as a groundwater sink until the water level in that pit exceeds 37 m AHD, above which point water movement will be back into the hard rock aquifers and thence flow naturally into the RERR void. Long-term, steady-state fluxes into North Pit and RERR voids are predicted to be 55 and 110 ML/year, respectively, with BNP locally providing 40 ML/year of high quality water to the hard rock aquifer.	RERR will not be a void and therefore not act as a groundwater sink. The revised assessment (refer to Surface Water Assessment) indicates that the BNP final void will, with the proposed reshaping associated with the Refined Project, act as a sink with the long term water level predicted at 10 mAHD.

AIP Requirement	Response for EIS Project	Changes Resulting from Project Refinements
Made these predictions in accordance with Section 3.2.3 of the AIP?	Predictions have been made using a regional scale numerical groundwater model that was developed, constructed, calibrated and analysed in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012), as prescribed in Section 3.2.3 of the AIP.	Predictions made using the EIS numerical model have been used for the Refined Project whilst noting the minor, beneficial changes as a result of the Refined Project.
Described how and in what proportions this take will be assigned to the affected aquifers and connected surface water sources?	The numerical groundwater model allows the proportion of water take from affected aquifers to be distinguished. Detailed description of the proportions of water take from the affected aquifers is provided in Section 3.5 of the Groundwater Impact Assessment.	Negligible changes to aquifer take are predicted with the Refined Project relative to that predicted in the EIS
Described how any licence exemptions might apply?	Mount Owen has sufficient licensing allocations to account for the predicted water take from the affected aquifers, comprising the alluvial and hard rock water sources. No exemptions apply.	No change to the requirement for licensing exemptions.
Described the characteristics of the water requirements?	Water requirements are described in Umwelt's Water Balance Assessment (2014).	No change to the characteristics of the water requirements (refer to Surface Water Assessment for the Refined Project).
Determined if there are sufficient water entitlements and water allocations that are able to be obtained for the activity?	Mount Owen has sufficient existing licensing allocations to account for the predicted water take from the affected aquifers, comprising the alluvial and hard rock water sources.	No change to licensing requirements.
Considered the rules of the relevant water sharing plan and if it can meet these rules?	The rules and requirements of the relevant WSPs are outlined in Section 1.4 of the Groundwater Impact Assessment. Through licence allocations and management procedures (including monitoring and on-going assessment) the Project has demonstrated that it meets these rules.	No change to the ability of the Project to meet the rules of the WSPs.

AIP Requirement	Response for EIS Project	Changes Resulting from Project Refinements
Determined how it will obtain the required water?	No additional water will be required.	No change to requirement for additional water.
Considered the effect that activation of existing entitlement may have on future available water determinations?	The proposed mining period extends to 2030. Beyond this, the aquifer systems are predicted to recover with no adverse impacts on future available water determinations.	No change to predicted recovery or adverse impacts on future water determinations.
Considered actions required both during and post-closure to minimise the risk of inflows to a mine void as a result of flooding?	Management and action requirements to minimise inflows to mine voids as a result of flooding are provided in the Surface Water Assessment (Umwelt, 2014).	No conceptual changes to management and action requirements to minimise inflows to voids, however in practice any such requirements applicable to RERR are not applicable to the Refined Project.
Developed a strategy to account for any water taken beyond the life of the operation of the Project?	No additional water to that already licensed is predicted to be taken beyond the life of the operation. Details of predicted groundwater conditions post-mining are provided in Section 4.1.1 of the Groundwater Impact Assessment.	No increases to predicted post-mining water take. Due to the exclusion of the RERR void, post-mining water take will be reduced with the Refined Project.
Will uncertainty in the predicted inflows have a significant impact on the environment or other authorised water users?	Uncertainties associated with the predicted inflows are provided in the predictive model results shown in Figure 3-29 through Figure 3-33 of the Groundwater Impact Assessment. These uncertainties are not predicted to have a significant impact on the environment or other authorised water users.	No change to potential for uncertainties in the predicted inflows to have a significant impact on the environment or other water users. Impacts detailed in the EIS are predicted to remain within the extent of the Project area. No change to this prediction is likely as a result of the Refined Project.

Note: All figure and section references refer to Appendix 10 of the EIS

Table 3.2 Requirements for Minimal Impact Considerations

AIP Requirement	Response for Original Project	Changes Resulting from Refined Project
Establishment of baseline groundwater conditions?	Baseline groundwater conditions are reported in the Groundwater Impact Assessment in Section 2.6.4 for groundwater levels and flow patterns and in Section 4.1.2 for groundwater quality. Details of the current groundwater monitoring network and program are provided in Section 2.6.4.	No change to baseline conditions.
A strategy for complying with any water access rules?	Water meters are being progressively installed at all pumping locations to provide accurate information for annual water balance modelling reported through the Annual Reviews.	No change to strategy for complying with water access rules.
Potential water level, quality or pressure drawdown impacts on nearby basic landholder rights water users?	The estimated extent of impacts resulting from the Project is largely limited to the Project area and there are no registered groundwater users or basic landholder rights within this extent.	No increase in the extent of impacts resulting from the Refined Project. No increase to the potential for the Refined Project to impact on nearby basic landholder rights.
Potential water level, quality or pressure drawdown impacts on nearby licensed water users in connected groundwater and surface water sources?	The estimated areal extent of impacts resulting from the Project is largely limited to the Project area. There are no registered groundwater users or basic landholder rights within this extent.	No increase in the extent of impacts resulting from the Refined Project. No increase to the potential for the Refined Project to impact on nearby licensed water users.
Potential water level, quality or pressure drawdown impacts on groundwater dependent ecosystems?	There are no identified GDEs within the Project area or area potentially impacted by the Project.	No change to potential for GDEs to be impacted by the Refined Project.

AIP Requirement	Response for Original Project	Changes Resulting from Refined Project
Potential for increased saline or contaminated water inflows to aquifers and highly connected river systems?	Post-mining equilibrium simulations undertaken by Umwelt predict the North Pit and RERR final voids will act as groundwater sinks. The Bayswater North void will ultimately act as a source, but will not discharge to the alluvial aquifers and adversely impact groundwater quality. Rather, it will discharge to the hard rock aquifer and thence to the RERR void. The Water Balance Assessment (Umwelt, 2014) predicts salinity in the North Pit final void will increase continuously over time, resulting in the potential for long term impacts to groundwater quality in the hard rock aquifer due to discharge of increasingly saline water to the surrounding aquifer. However salinity modelling indicates that adverse impacts, which would occur when salinity levels in the final void are greater than the salinity of groundwater in the surrounding hard rock aquifer, are unlikely to occur for at least 200 years after end of mining. Salinity levels in the hard rock aquifer are currently brackish at best and do not provide a viable water resource.	RERR no longer acts as a sink in the Refined Project. The Bayswater North Pit void, with the reshaping, will become a groundwater sink.
Potential to cause or enhance hydraulic connection between aquifers?	Enhanced connection between aquifers has been modelled as part of this assessment. Consideration has been made of activities extending over underground mining operations that may result in changed (enhanced) hydraulic connection. No adverse impacts are predicted to occur.	The Refined Project is unlikely to alter the potential for enhanced hydraulic connectivity.
Potential for river bank instability, or high wall instability or failure to occur?	The mining limit has been designed to be greater than 200 m (approximately450 m) from the high bank of Main Creek and will not pose an instability risk.	No change to the potential for bank instability or failure.

AIP Requirement	Response for Original Project	Changes Resulting from Refined Project
Details of the method for disposing of extracted activities (for coal seam gas activities)?	Not applicable.	Not applicable

Note: All figure and section references refer to Appendix 10 of the EIS

Table 3.3 Additional Requirements for Aquifer Interference Activities

AIP Requirement	Response for Original Project	Changes Resulting from Refined Project
For the Gateway process, is the estimate based on a simple modelling platform, using suitable baseline data, that is, fit-for-purpose?	Not applicable.	Not applicable
For State Significant Development or mining or coal seam gas production, is the estimate based on a complex modelling platform that is: • Calibrated against suitable baseline data, and in the case of a reliable water source, over at least two years? • Consistent with the Australian Modelling Guidelines? • Independently reviewed, robust and reliable, and deemed fit-for-purpose?	The predictive scenarios have been modelled using a complex numerical groundwater model based on the MODFLOW-SURFACT modelling platform. Full details of the modelling framework, calibration and results are provided in Section 3 of the Groundwater Impact Assessment. All modelling has been undertaken in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et al., 2012). The numerical model has undergone an independent peer review specific to this Project. This peer review found the groundwater model to be *fit for purpose* and concluded that this Groundwater Impact Assessment addresses the requirements of the DGRs and NOW. Specifically, the reviewer concluded the model has: • acceptable global calibration performance statistics • reliable anticipated mine inflows • reasonable quantitative estimates of water take for licensing purposes.	The changes resulting from the Refined Project were qualitatively assessed using the model detailed in the EIS as the base case. The Refined Project is deemed to be unlikely to result in materially detrimental changes to groundwater impacts. This is a result of: The relative magnitude of the Project changes; The Project changes resulting in a lower level of disturbance to existing groundwater systems; The extant conditions of the local groundwater systems as a result of the Project and concurrent mining operations; The predicted future conditions of the local groundwater systems as a result of the Project and concurrent mining

AIP Requirement	Response for Original Project	Changes Resulting from Refined Project
	A copy of the peer review report has been provided to DP&E.	operations; and The absence of sensitive receptors and other users. In addition, any changes to groundwater impacts resulting from the Refined Project are likely to be similar to or less than the impacts detailed in the EIS. Accordingly the original peer reviewed groundwater impact assessment presented in the EIS remains unchanged.
In all other processes, estimate based on a desk-top analysis that is: • Developed using the available baseline data that have been collected at an appropriate frequency and scale; and • Fit-for-purpose?	Not applicable.	Not applicable

Note: All figure and section references refer to Appendix 10 of the EIS

4.0 Conclusion

The proposed refinements to the Project will either reduce the surface water impacts or have no change on the surface water impacts. Updated conceptual layouts to the WMS have been prepared for the Refined Project.

In response to issues raised by DPI Water subsequent to the PAC Review Report, a conceptual water licensing and accounting framework has been developed in accordance with Harvestable Rights Orders (gazetted 31 March 2006 http://www.nsw.gov.au/sites/default/files/pdfs/2006/31st_March.pdf#page=36) and Water Access Licensing requirements (see http://www.water.nsw.gov.au/water-licensing/about-licences/new-access-licences). This conceptual framework will be utilised as part of the water management plan for the Refined Project.

The Refined Project was assessed against the requirements of the NSW AIP and found to remain consistent with these requirements and the Project detailed in the EIS. The Refined Project is also considered to have consistent or less groundwater impacts compared to the original Project assessed in the EIS.

5.0 References

Department of Environment and Climate Change (DECC), 2008. *Managing Urban Stormwater – Soils and Construction, Volume 2*.

Jacobs Group (Australia) Pty Limited, 2014. *Mount Owen Continued Operations Project: Groundwater Impact Assessment*.

Landcom, 2004. *Managing Urban Stormwater – Soils and Construction, Volume 1 4th Edition*.

Mount Owen Operations Environmental Impact Statement, 2003

NSW Government, 2009. *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009.*

Umwelt, 2015. *Mount Owen Continued Operations Project, Environmental Impact Statement*.

Xstrata Coal 2012. *Mount Owen Complex Water Management Plan.*

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APPENDIX 7

Updated Cost Benefit Analysis

Deloitte Access Economics

Cost Benefit Analysis and Economic Impact Analysis of the Mount Owen Continued Operations Project

Umwelt (Australia) Pty Limited

May 2016

Deloitte.

Contents

Charts

Tables

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Glossary

ABS	Australian Bureau of Statistics
ACHA	Aboriginal Cultural Heritage Assessment
ACHMP	Aboriginal Cultural Heritage Management Plan
AIS	Agricultural Impact Statement
ANZECC	Australian and New Zealand Environment Conservation Council
AUD	Australian dollar
BCR	Benefit Cost Ratio
BNP	Bayswater North Pit
BSAL	Biophysical Strategic Agricultural Land
CBA	Cost Benefit Analysis
CDE	Constant Differences of Elasticities
CGE	Computable General Equilibrium
CHPP	Coal Handling and Preparation Plant
CRESH	Constant Ratio of Elasticities Substitution, Homothetic
DAE	Deloitte Access Economics
DALY	Disability Adjusted Life Year
DEC	Department of Environment and Conservation
DGRs	Director General's Requirements
DP&E	Department of Planning and Environment
ECX EUA	European Climate Exchange European Union Allowance
EEC	Endangered Ecological Community
EIA	Economic Impact Analysis
EIS	Environmental Impact Statement
EPA	Environment Protection Authority
EP&A	Environmental Planning and Assessment Act
EVRI	Environmental Valuation Reference Inventory
FOB	Free on board
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GRP	Gross Regional Product
GSP	Gross State Product
ICE	Intercontinental Exchange
IO	Input Output
IRR	Internal Rate of Return
LGA	Local Government Area
LSC	Land and Soil Capability
MIA	Mining Infrastructure Area

NPV	Net Present Value
NSW	New South Wales
PM	Particulate Matter
RAP	Registered Aboriginal Party
RCT	Ravensworth Coal Terminal
RGEM	Regional General Equilibrium Model
ROM	Run-of-mine
RUM	Random Utility Maximisation
SIOA	Social Impact & Opportunities Assessment
SLA	Statistical Local Area
SUA	Significant Urban Area
TSP	Total Suspended Particulate Matter
UK	United Kingdom
USD	United States dollar
VCA	Voluntary Conservation Area
VPA	Voluntary Planning Agreement
VSL	Value of Statistical Life
WACC	Weighted Average Cost of Capital
WTP	Willingness to pay

Executive Summary

Deloitte Access Economics was commissioned by Umwelt (Australia) Pty Limited (Umwelt) to undertake a Cost Benefit Analysis and Economic Impact Analysis of the proposed Mount Owen Continued Operations Project ('the 2014 Project') in 2014. The purpose of this report is to assist Mt Owen Pty Limited and its contractor Umwelt to produce a response to the Planning Assessment Commission report dated February 2016 (PAC report) and further feedback provided by the Department of Planning and Environment which includes an updated economic analysis of the refined Mount Owen Continued Operations Project.

The Mount Owen Complex is located within the Hunter Coalfields in NSW. The Complex encompasses three open cut mining operations: the Mount Owen, Ravensworth East and Glendell Mines. Through the Mount Owen Continued Operations Project, Mount Owen Pty Limited (Mount Owen) is seeking to extend mining operations at the Mount Owen Mine beyond 2018 out to 2030, and consolidate the Mount Owen and Ravensworth East Operations through a single development consent.

Mount Owen has refined elements of the 2014 Project that include the removal of the Ravensworth East Resource Recovery (RERR) mining area from the 2014 Project in response to a number of recommendations in the PAC report. The Refined Project, along with the resultant changes to impacts, mitigation and management measures, have been assessed as part of this updated Cost Benefit Analysis.

In order to provide for the direct comparison between the 2014 Project presented in the 2014 CBA and this CBA for the Refined Project, many of the underlying assumptions have been maintained, aside from updating to 2016 values, to ensure that this updated assessment provides a comparison of refinements to the 2014 Project and associated updated impacts, mitigation and management measures.

This report presents a detailed assessment of the incremental costs and benefits of the Refined Project relative to a baseline, 'business as usual' case, as well as an analysis of whether the project would result in a net benefit for the NSW community. These assessments have been made in reference to the Director General's Requirements (DGRs), the recommendations of the PAC report and further feedback provided by DP&E. It should be noted that the analysis has drawn on information provided by Mount Owen, the findings of the EIS and further information provided by Umwelt.

Overall the Refined Project is expected to generate net benefits for the NSW community. It is important to note that the analysis of flow on economic impacts of the project has not been updated as part of this report. The results have not been updated as current Guidelines (NSW Government 2015) do not require the use of Computable General Equilibrium (CGE) analysis. Accordingly, updated CGE analysis of the project has not been undertaken.

The main findings of this report can be summarised as follows:

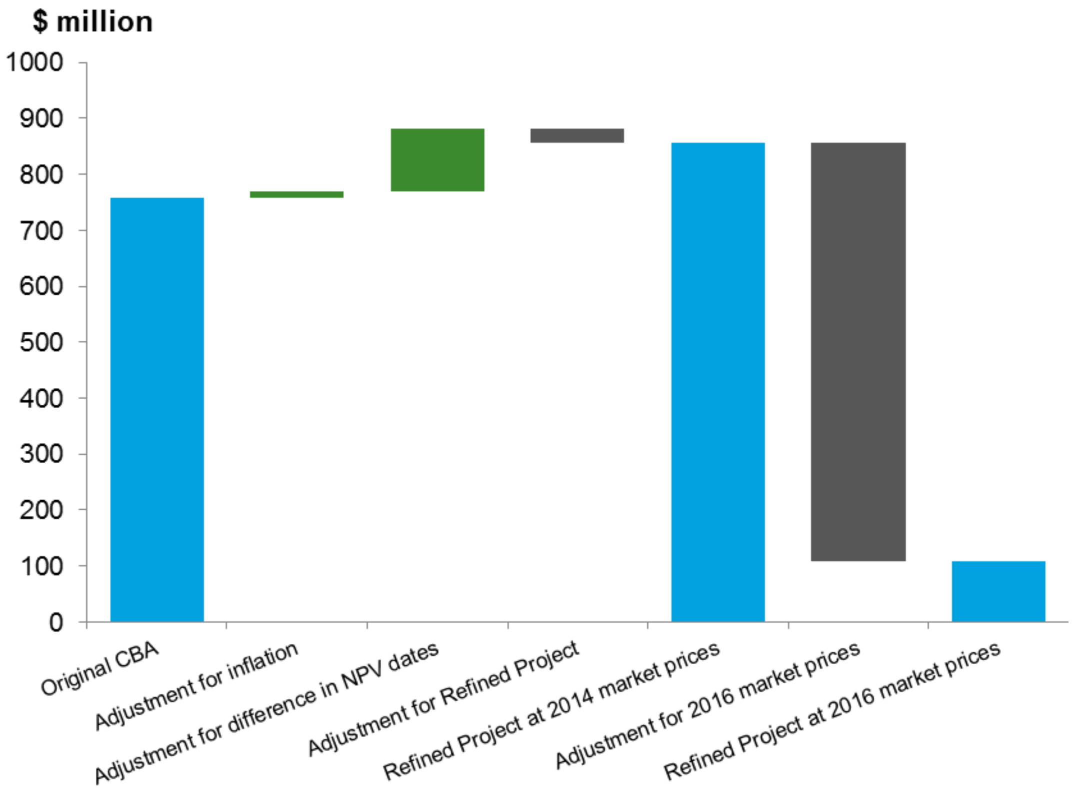
- Adjusting the original CBA analysis for changes relating to the Refined Project indicates that the Refined Project delivers net benefits of around $857 million over its life. After accounting for the difference in timing, this is slightly lower than the benefits estimated in the previous economic assessment.

    - Further adjustments to take into account changes in market prices indicate that the Refined Project delivers net benefits of around $108 million over its life.

- Adjusting the original CBA analysis for changes relating to the Refined Project indicates that Royalties generated by the Refined Project, relative to the baseline, are estimated to be worth around $259 million in NPV terms to the NSW Government. These royalties are the largest component of benefits generated by the Refined Project for NSW. The net benefits for the NSW community are estimated at $312 million.
    - Further adjustments to take into account changes in market prices indicate that the Refined Project delivers net benefits to the NSW Community of around $186 million.

A summary of how the estimated benefits of the project have changed between the original CBA and the current CBA is presented in the chart below.

Chart i: Waterfall chart showing the effect of modelling changes



Source: Deloitte Access Economics

Project level cost benefit analysis

Consideration of the costs and benefits of the project as a whole is primarily done through a cost benefit analysis (CBA). The CBA compares the Refined Project case to a baseline case which involves mining activity at the Mount Owen North Pit out to 2018, followed by land rehabilitation.

The overall finding of the CBA is that the Refined Project as a whole is likely to deliver net economic benefits. Adjusting the original CBA analysis for changes relating to the Refined Project indicates that, in the central case, the Refined Project delivers net benefits of around $857 million over its life. Further adjustments to take into account changes in market prices indicate that the Refined Project delivers net benefits of around $108 million over its life.

In undertaking the cost benefit analysis we have had regard to the costs and benefits listed in Table ii. These items have been drawn from the DGRs and a number of guidelines for cost benefit analysis published by the NSW Government. As recommended in CBA guidelines such as NSW Treasury (2007), where it is difficult to place a value on a particular cost or benefit of the project, a qualitative analysis has been undertaken. We consider that all of the potentially large negative externalities of the project have been valued in quantitative terms. The remaining negative externalities which have been considered qualitatively, such as visual amenity, are identified in the table below and discussed thoroughly in Section 5.

Table ii: Costs and Benefits – Mount Owen Continued Operations Project

	Costs	Benefits
Production	Other onsite revenue forgone	Gross mining revenue
	Exploration costs	Residual value of capital
	Capital investment costs	Residual value of land
	Operating costs excluding taxes	
	Rehabilitation costs	
	Decommissioning costs	
Externalities	Offsite agricultural revenue*	Net traffic impacts
	Related public expenditure*	Conservation*
	Groundwater quality*	
	Surface water quality*	
	Carbon emissions	
	Air quality impacts – particulate matter	
	Air quality impacts – other pollutants*	
	Noise impacts	
	Visual amenity*	
	Biodiversity – flora and fauna	
	Quality of open space*	
	Rural amenity and culture	
	Aboriginal heritage*	
	Historic heritage*	
	Health*	

* Item has been considered qualitatively

Table iii, below, presents the overall CBA results using the price assumptions from the previous CBA. This allows this figure to be compared to the results in the previous CBA. To make this comparison, the difference in timing between the two assessments must be accounted for (this assessment calculates the NPV in 2016 while the previous report calculated the NPV in 2014). The net present value in the previous CBA was estimated at $758 million, this increases to $769 million in 2015 dollars and then to $880 million after accounting for the difference in NPV dates. This shows that the net benefits estimated in this report are somewhat lower than those provided in the previous economic assessment which reflects the reduction in value due to the changes between the 2014 Project and the Refined Project.

Table iii: Overall Project level CBA results

Discount rate	Total net benefits ($m)
4%	1,077.63
7%	857.18
10%	689.36

Note: the results in this table only adjust for changes to the Refined Project, not for updated market conditions. Results that include updated market conditions are reported in Section 7.3

Benefits to NSW

While a CBA provides a clear picture of the overall benefits and costs of the Refined Project, it is not well suited to show how those costs and benefits are distributed between the different stakeholders. An analysis of the share of each cost and benefit that is attributable to NSW has also been undertaken. This analysis has been undertaken in response to the PAC recommendations and is in line with approaches set out in the Guidelines for the Use of Cost Benefit Analysis in mining and Coal Seam Gas Proposals (NSW Government 2012) and the Guidelines for the economic assessment of mining and coal seam gas proposals (NSW Government 2015).

The benefits to NSW have been identified as:

- Net producer surplus
- Royalties
- Company income tax
- Economic benefit to existing landholders
- Economic benefit to workers
- Economic benefit to suppliers
- Net environmental, social and transport-related costs
- Net public infrastructure costs

Adjusting the original CBA analysis for changes relating to the Refined Project indicates that Royalties generated by the Refined Project, relative to the baseline, are estimated to be worth around $259 million in NPV terms to the NSW Government. The net benefits for the NSW community are estimated at $312 million. Further adjustments to take into account changes in market prices indicate that the Refined Project delivers net benefits to the NSW

Community of around $186 million. The additional royalties to the NSW Government is the main incremental benefit to NSW of the Refined Project in relation to the base case. The key incremental costs of the Refined Project (within the NSW community) are the additional external costs, such as the cost of greenhouse gas emissions.

The results presented in Table iv are when the original CBA analysis is only updated for changes relating to the Refined Project.

Table iv: Breakdown of state level benefits results by item

Item	Incremental ($m, NPV)	NSW community share (%)	Net benefit to NSW ($m, NPV)	Net cost to NSW ($m, NPV)
Royalties	259	100%	259	
Company income tax	221	32%	71	
Net environmental, social and transport costs	47	See Table 6.3	-	18
Total			**330**	**18**

Note: the results in this table only adjust for changes to the Refined Project, not for updated market conditions. Results that include updated market conditions are reported in Section 7.3

1 Introduction

The Mount Owen Complex is located within the Hunter Coalfields in the Upper Hunter Valley of New South Wales (NSW), approximately 20 kilometres north-west of Singleton, 24 kilometres south-east of Muswellbrook and to the north of Camberwell village.

Mount Owen Pty Limited (Mount Owen), a subsidiary of Glencore Coal Pty Limited (formerly Xstrata Coal Pty Limited), currently owns the three open cut operations in the Mount Owen Complex. These three operations are: Mount Owen (North Pit), Ravensworth East (West Pit and Bayswater North Pit (BNP)) and Glendell (Barrett Pit). This relationship is shown in Figure 1.1.

The Mount Owen North Pit and associated infrastructure is owned by Mt Owen Pty Limited and is currently operated under contract by Thiess Pty Limited (Thiess). All operations at Glendell and Ravensworth are managed and operated by Mount Owen.

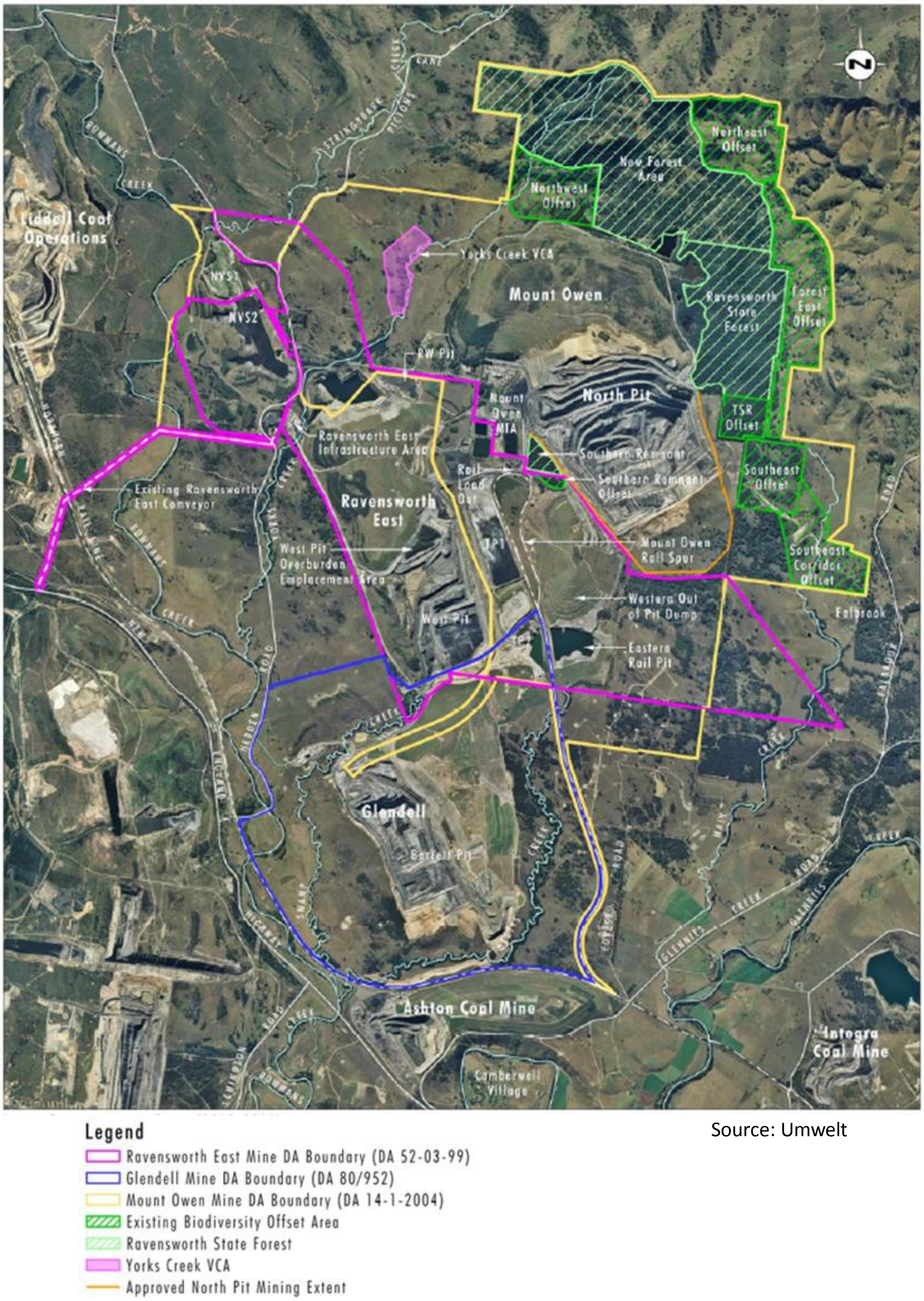
Figure 1.1: Schematic of operations at the Mount Owen Complex

The mining operations at the Mount Owen Complex include the integrated use of the Mount Owen coal handling and preparation plant (CHPP), coal stockpiles and the rail load-out facility.

As part of the Refined Project, Mount Owen proposes to extend mining operations at the Mount Owen Mine beyond 2018 out to 2030 to extract additional coal resources south of the currently approved North Pit mining limit (the North Pit Continuation) and to undertake mining operations within the BNP.

The project does not include any changes to operations at the Glendell Mine, which will continue to operate in accordance with its current development consent.

Figure 1.2: Current operations at the Mount Owen Complex



Source: Umwelt

In accordance with the EP&A Act, an Environmental Impact Statement (EIS) is required for the project. The objective of the environmental assessment is to ensure that approval bodies, government authorities (including local councils), the applicant and the broader public have sufficient material to properly consider the potential environmental consequences of a proposal (NSW Government, 2000).

As such, an EIS has been prepared for to accompany a Project Application following Department of Planning and Environment (DP&E) issuing Director-General's Requirements (DGRs).

A required component of the EIS is an analysis of economic issues. Specifically, the DGRs include the need for an assessment of the costs and benefits of the development of as well as an analysis of whether the project would result in a net benefit for the NSW community.

This report therefore undertakes an assessment of the impacts of the Refined Project within a cost benefit analysis (CBA) framework to address the costs and benefits of the proposed continued operations, relative to a baseline, 'business as usual' scenario. This baseline case involves mining activity at the Mount Owen North Pit out to 2018 followed by land rehabilitation.

The CBA in this report is an update of the CBA presented in the EIS. The analysis in this report reflects the fact that Mount Owen has refined elements of the 2014 Project that include the removal of the RERR mining area from the 2014 Project in response to a number of recommendations in the PAC report. The Refined Project, along with the resultant changes to impacts, mitigation and management measures, have been assessed as part of this updated Cost Benefit Analysis. The CBA also addresses further feedback provided by the Department of Planning and Environment (DP&E).

In order to provide for the direct comparison between the 2014 Project presented in the 2014 CBA and this CBA for the Refined Project, many of the underlying assumptions have been maintained, aside from updating to 2016 values.

It is noted that, should the Refined Project not proceed, additional mining would be undertaken at the Ravensworth Mine, subject to the existing approvals. However, this approach has been adopted to allow for the measurement of the incremental costs and benefits of the Refined Project when operating as a consolidated project. This aligns with the requirements of the Department of Planning and Environment for the proposal to cover a consolidated development consent.

1.2 Report structure

The structure of this report is as follows:

- Chapter 2 outlines the methodology employed in this report, including how the approach used aligns to the NSW CBA guidelines.
- Chapter 3 provides a background on the Singleton LGA, presenting a brief demographic and employment profile of the region.
- Chapter 4 details the Refined Project and defines the base case and the expected scenario under the Refined Project case.
- Chapter 5 presents the results of the cost benefit analysis.
- Chapter 6 presents an analysis of the benefits and costs of the Refined Project to the NSW community.
- Chapter 7 provides sensitivity analysis of the results of Chapter 5 and Chapter 6.
- Chapter 8 notes that the results of the CGE analysis have not been updated for this revised CBA.
- Appendix A provides a checklist illustrating how this report has met the requirements of various guidelines.
- Appendix B outlines relevant valuation techniques that are often employed in CBA.
- Appendix C discusses the variety of approaches that may be used to value specific costs and benefits.

2 Methodology

DAE have established a methodology for undertaking this CBA which relies on the range of guidelines and requirements set out by the NSW Department of Urban Affairs and Planning (2002), NSW Treasury (2007) and NSW Government (2012 and 2015). This chapter reviews the guidelines and requirements before discussing how these have been applied to develop the specific methodology for the Refined Project.

2.1 CBA guidelines

There are a large number of CBA guidelines available for both reference and compliance purposes. These guidelines cover conceptual issues such as how environmental consequences should be treated as well as practical issues, such as what discount rates should be used in what circumstances. The following documents have been used as the most relevant guidelines for this CBA:

- NSW Treasury (2007), "NSW Government Guidelines for Economic Appraisal";
- NSW Department of Urban Affairs and Planning (2002), "Guideline for economic effects and evaluation in EIA"; and
- NSW Government (2012) "Guidelines for the Use of Cost Benefit Analysis in mining and Coal Seam Gas Proposals"
- NSW Government (2015), "Guidelines for the economic assessment of mining and coal seam gas proposals"

These four documents move from high level issues around CBA through to how CBA should be applied to an EIA and then also cover the application of CBA to coal mines in particular. A full account of the requirements of these guidelines is given in Appendix A and the requirements are cross referenced to sections of this report.

It is important to note that NSW Government (2015) is the final version of the draft set of guidelines proposed by NSW Government (2012). References to NSW Government (2012) has been retained as this guideline is specifically referred to in the PAC report.

2.2 Director General's requirements

In addition to the CBA focused guidelines listed above, for this project there are also specific requirements set out in the Director General's Requirements (DGRs). The DGRs were issued in March 2013 and set out specific issues that the EIS must cover. As noted in Section 1, this report addresses the requirement for a detailed assessment of the costs and benefits of the development as a whole and whether it would result in a net benefit for the NSW community. The results in this report also allow consideration of potential direct and indirect economic benefits of the development for local and regional communities and the State.

While the remainder of the requirements cover topics beyond the scope of an economic assessment, there are particular areas which are relevant to our methodology. These areas of relevance are summarised and cross referenced in Appendix A.

2.3 Implications of these guidelines

Together, these four documents set the baseline requirements for this economic assessment. While Appendix A contains an item by item reconciliation of how these guidelines have been addressed, it is worth considering their implications qualitatively here. Overall, the guidelines require that the CBA should be carried out using a set of standard approaches and also must include consideration of certain topics.

Looking first at the standard approach, the guidelines suggest that the CBA should involve:

- identification of the characteristics of the proposal and any alternatives;
- defining the spatial boundaries of analysis (e.g. local, regional, state, national);
- identification of the environmental impacts of the project;
- identification of costs and benefits, including:
  - economic resource costs (e.g. capital expenditure);
  - negative externalities; and
  - base case benefits given up.
- quantification of costs and benefits, using market prices where available, otherwise using imputed prices or a qualitative assessment;
- consolidation of values by applying a discount rate; and
- applying decision criteria such as a benefit cost ratio.

This standard approach will be applied throughout this report. The definition of the proposal and spatial boundaries of analysis is covered in Section 4. Section 5 then covers the identification, discussion, quantification and consolidation of costs and benefits of the Refined Project.

Moreover, the guidelines suggest that the CBA must contain analysis of a broad range of issues, costs, benefits and distributional matters. Beyond the costs and benefits of the Refined Project itself (such as revenue, capital investment and operating expenditure), the issues broadly fall into two main categories:

- **Externalities:** these externalities cover areas where the Refined Project will create costs or benefits, which cannot be captured in current market transactions, for third parties not involved in the production, sale or purchase of coal. These are mostly relevant in areas where property rights are non-existent or difficult to enforce. Key externalities here include effects on agricultural productivity; bodies of water and water quality; carbon emissions; air quality impacts; noise impacts; visual amenity; traffic; biodiversity and ecosystem conservation; quality of open space; rural amenity and culture; and heritage.
- **Regional and industry flow-on economic effects:** as with the externalities, flow-on effects involve parties who are not directly transacting in the production or consumption of coal, and encompass any market based responses to the presence of the Refined Project. Flow-on effects are indirect impacts due to adjustments in the

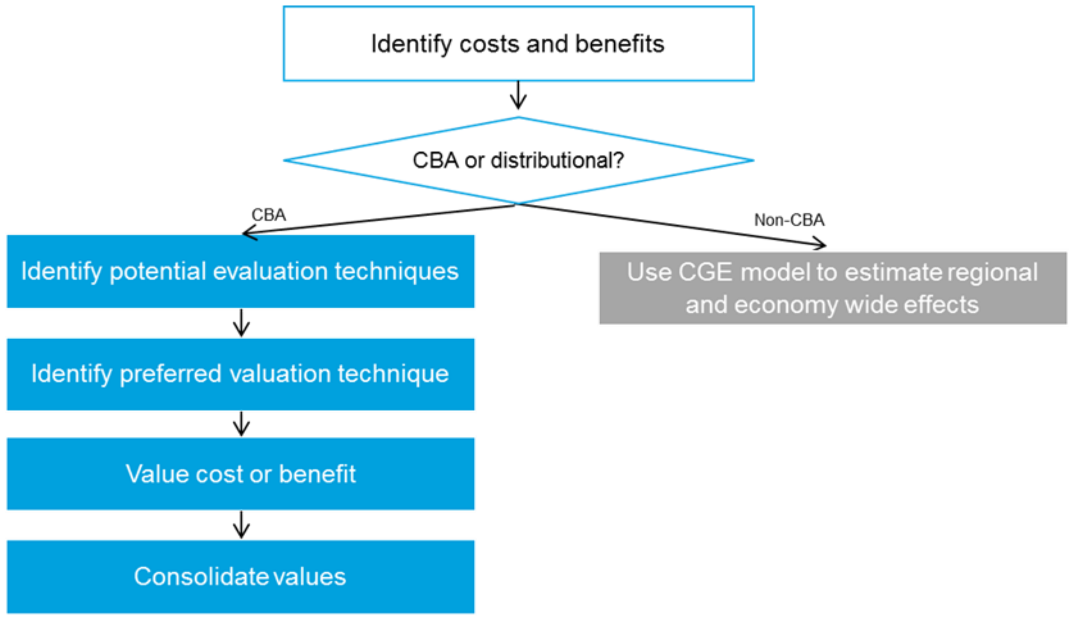
economy, such as price movements, that depend upon initial market based responses or direct impact which occur first. For example, if the Refined Project increases demand for a certain type of labour this may affect the price of labour in the region which will have flow-on consequences for other local industries. These are not externalities, but are rather seen as the mechanisms by which the economy re-adjusts in response to changed patterns of supply and demand. Key effects here include: increases in mine worker wages; profits of mine suppliers; impacts on the agricultural industry; impacts on labour supply and local tourism effects.

A traditional CBA, which focuses mainly on the project itself and then incorporates any quantifiable externalities, may not be able to provide sufficient analysis of the diversity of this range of issues. For example, a CBA, by its nature, does not take into account the general equilibrium flow-on effects described above as these are essentially benefits to some parts of the economy which are offset by costs elsewhere. The following section sets out our approach for ensuring that all the requirements are covered within this economic analysis.

2.4 Our Methodology

Taking the above guidelines together creates a complex set of requirements which encompass topics that are handled well by a traditional CBA as well as other issues which do not fit neatly into a CBA framework. To address this we have developed a methodology which first analyses items amenable to CBA modelling within a CBA framework. We then apply CGE modelling to look at further issues, such as a circumstance where wages may increase in response to increased demand for labour or distributional effects, whereby the impact on wages differs across subregions or industries of the local economy.

Figure 2.1: Outline of methodology



The methodology has been designed to clearly separate the issues identified in the guidelines and requirements based on how they can be analysed from an economic point of view. For example, the issues covered under externalities are amenable to modelling within a CBA framework. These will therefore pass through the stages of having evaluation techniques identified, selecting one particular technique, valuing the externality and adding it into the consolidated value of the CBA (such as a NPV or cost benefit ratio).

This approach can be contrasted with an issue such as impacts on local labour supply. This issue is not amenable to a CBA framework, as it involves transfers of costs and benefits between groups within the economy which cancel each other out. As a result, issues like this will pass down the other arm of the methodology. The CGE modelling is used to determine the economy wide effects of a project and provides a clear picture of benefits for NSW, especially the Hunter economy.

CGE modelling can be seen as an addition and extension of the CBA but with a particular focus. That is, the CBA focuses on the Refined Project and its immediate external effects. The CGE model is then used to trace these immediate effects through the economy more broadly. For example, increased capital expenditure may lead to increased demand for steel and fuel as inputs. This, in turn, can increase demand for labour in iron mines and oil refineries. This chain of events will create complex interactions between supply and demand in each market which will ultimately be resolved by changes in prices and outputs across the economy. The CGE model provides a way to trace this chain of events through to its final resolution. It should be noted that the CGE model is, fundamentally, built on the national accounting system and so focuses on outputs that are traded in markets and contribute to GDP – it does not capture environmental and other externality costs that are captured as part of the CBA.

It should also be noted that CGE modelling is a substitute for Input-Output (IO) modelling. Both approaches can provide estimates of increases in economic output, value added and employment in the broader economy flowing from a project. CGE modelling uses a more complex set of techniques and involves different assumptions about the state of the economy. One central difference between the two approaches is that IO modelling generally assumes that there is a large pool of resources available in the economy to meet increases in demand. In contrast, CGE modelling generally assumes that the economy and sectors within the economy are competing for the use of resources. This means that increases in demand from a project may result in effects such as increased prices in other markets and crowding out effects (rather than just increased output).

2.5 Specific considerations for this report

The above discussion covers a general methodology for completing economic assessments in line with relevant guidelines. For this report a number of additional considerations must be taken into account.

This is a revision of an existing CBA in order to reflect that Mount Owen has refined elements of the 2014 Project that include the removal of the RERR mining area from the 2014 Project in response to a number of recommendations in the PAC report. The Refined Project, along with the resultant changes to impacts, mitigation and management measures, have been assessed as part of this updated Cost Benefit Analysis. The CBA also addresses further feedback provided by the Department of Planning and Environment (DP&E).

Specifically, this updated CBA:

- Reflects changes to the physical aspects of the 2014 Project;
- includes information on current market conditions;
- provides additional analysis of the costs associated with particulate matter emissions;
- updates and expands analysis of benefits to NSW;
- provides additional sensitivity analysis of carbon prices;
- provides additional explanation of ranges used in the sensitivity analysis
- provide additional explanation of the likely relationship between different scenarios in the sensitivity analysis

Addressing the updated issues above creates a challenge in conveying the results of the CBA. Altering the physical aspects of the 2014 Project and updating the results to current market conditions at the same time makes it difficult to isolate the effects of each change. Therefore, for the purpose of this update, the results in Section 5 and 6 isolate the effect of changes to the physical aspects of the 2014 Project while maintaining market prices from the previous analysis. This allows for the results of these sections to be directly compared to the results from the previous CBA. Section 7 then demonstrates how these results change when current market prices are also accounted for.

This report does not provide an update of the modelling of the flow on effects of the Refined Project. The results have not been updated as, according to the most recent Guidelines (NSW Government 2015), they are not used as part of the decision making process of the NSW Government.

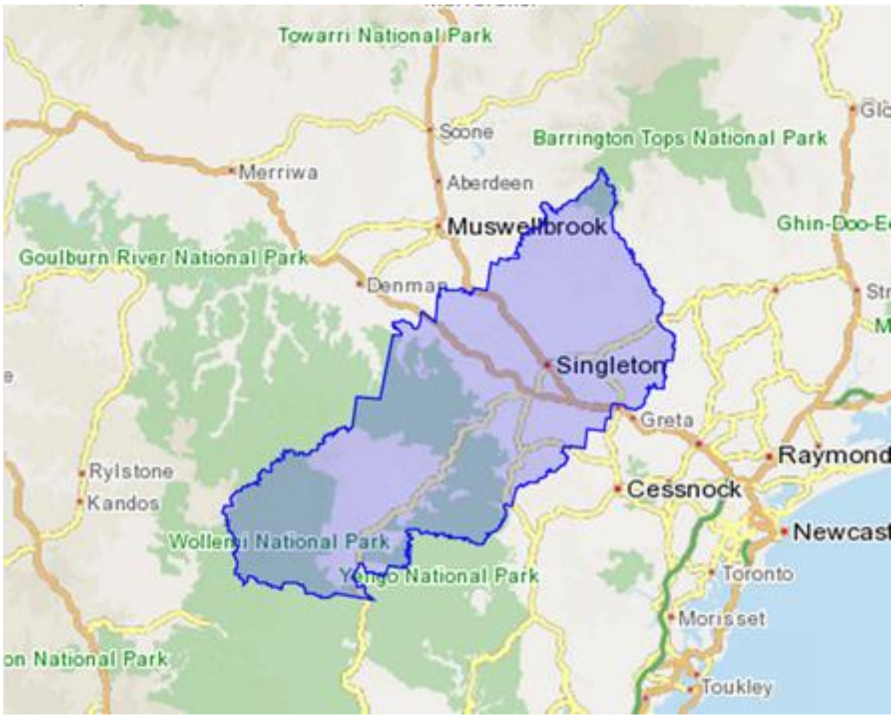
3 Background on Project Area location

This chapter provides an overview of the economic and demographic characteristics of the location of the Refined Project. The Singleton Local Government Area (LGA) is used as the unit of analysis in this chapter as it provides an appropriate scale on which to give a picture of local social and economic conditions. Later chapters of the report include detailed analysis on the broader Hunter region.

Singleton LGA is located in the Hunter region of New South Wales, approximately 200 km northwest of Sydney and 80km inland from Newcastle. The LGA consists of a number of townships and villages, including Singleton, Broke, Camberwell and Jerrys Plains, as well as numerous surrounding smaller localities.

The LGA is bounded by the LGAs of Muswellbrook to the west, Upper Hunter Shire to the north, Dungog, Maitland and Cessnock to the east and Lithgow and Hawkesbury to the south.

Figure 3.1: Singleton LGA



Source: ABS (2013)

3.1 People

At the time of the 2011 Census, the population of Singleton LGA was 22,694; this represents a 10.7% increase in population from 2001. This is higher than the population increase state wide which was 9.2%. The population is evenly split across sexes, with 51% of the population being male. The average age across the LGA is approximately 35 years, which is slightly lower than the New South Wales average of 38 years.

Table 3.1: Population characteristics of Singleton

	2001	2006	2011	2001-2011 change
Population (usual residence)	20,509	21,939	22,694	10.7%
Population (enumeration)	20,384	22,071	23,019	12.9%
Mean household size	2.8	2.8	2.7	-3.70%
Median age	33	34	35	6.1%
Total occupied private dwellings	6,983	7,640	8,163	16.9%
Median mortgage repayment ($/month)	1345	1675	2073	54.1%
Median rent ($/week)	179	215	269	50.3%
Median household income ($/week) - Singleton	1322	1511	1748	32.2%
Median household income ($/week) - NSW	1140	1243	1278	12.1%

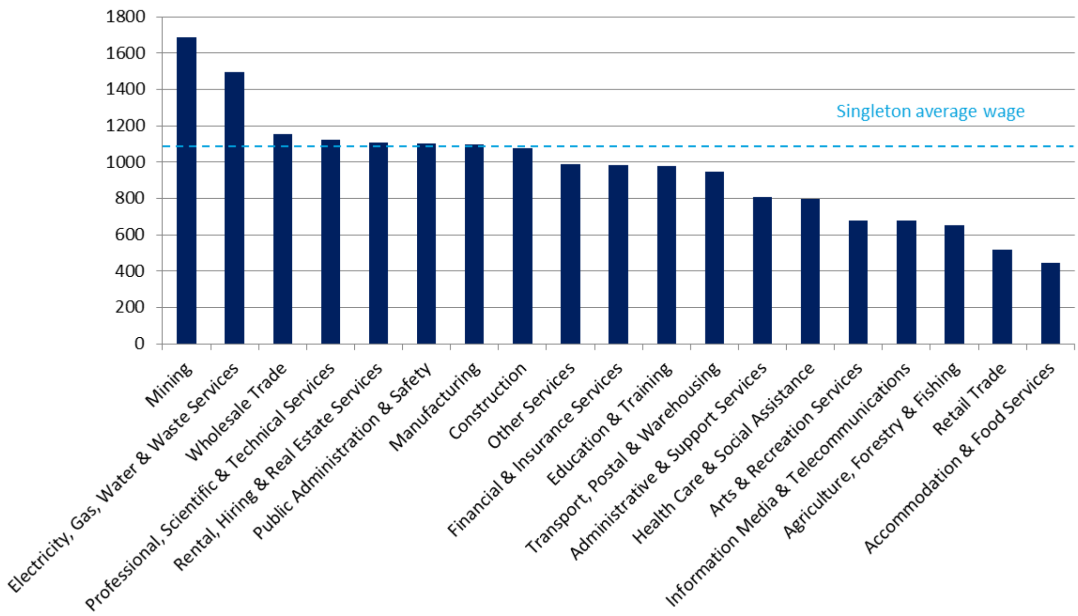
Source: ABS, 2011 Census Time Series Profile Cat. 2003.0
Note: All dollar values reflect real figures adjusted using ABS CPI to June 2013 dollars.

The number of occupied private dwellings in the Singleton LGA has increased by 16.9% over the ten years from 2001 to 2011, an average annual growth rate of 1.6%. Approximately 1,200 additional dwellings were established in Singleton LGA over the period from 2001 to 2011. This trend is a reflection of both the population growth in the region and the decline in average household size observed between 2001 and 2011.

In the 2014-15 financial year, there were 65 new residential dwellings approved in Singleton LGA, including 55 new houses. The value of residential building approvals over the financial year was $ 21.7 million and the value of total building approvals was $39.5 million (ABS Building Approvals, 2016).

The 2011 census, still the most reliable piece of information on household income, indicates that the median weekly household income in Singleton in 2011 was $1,748, considerably higher than the NSW median of $1,278. Given anecdotal reports, it may be that this gap has since narrowed. A breakdown of the average wage by industry is provided in Chart 3.2 below. As illustrated, mining is the highest paying industry in the Singleton LGA.

Chart 3.1: Singleton average weekly personal income by industry – 2011



Source: ABS (2012a)

3.2 Education

The average educational attainment in Singleton is lower than the NSW average, as evidenced by Table 3.2 below. For example, in the 2011 Census, only 12.4% of the population indicated they held a tertiary level qualification, compared with 22.8% of the NSW population.

Table 3.2: Highest level of education attained

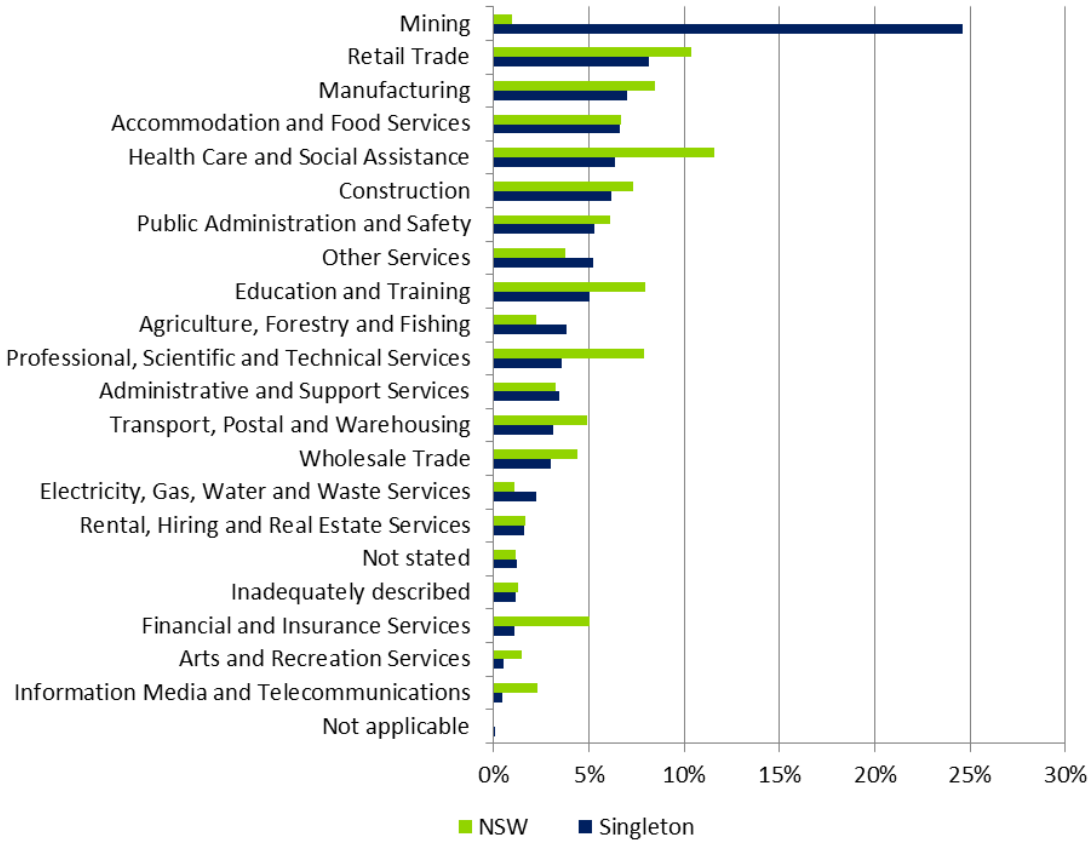
Highest level of education	Singleton	NSW
Tertiary level		
Postgraduate degree level	0.9%	3.5%
Graduate diploma and graduate certificate level	0.6%	1.2%
Bachelor degree level	5.9%	11.4%
Advanced diploma and diploma level	5.0%	6.7%
Certificate level		
Year 12 or equivalent	24.8%	38.4%
Year 11 or equivalent	6.7%	4.8%
Year 10 or equivalent	28.7%	19.5%
Year 9 or equivalent	7.8%	5.9%
Year 8 or equivalent	4.2%	4.5%
Did not go to school	0.3%	0.8%
Highest year of school not stated	5.3%	6.9%

Source: ABS, 2011 Census (2012a)

3.3 Industries of employment

Mining is the major industry of employment in the Singleton LGA, employing 24.6% of the employed population. This is much higher than in NSW, where just 1.0% of the employed population work in the mining sector. The retail and manufacturing industries are the next highest employers, at 8.2% and 7.0% respectively.

Chart 3.2: Industry of employment in Singleton LGA and New South Wales



Source: ABS (2012a)

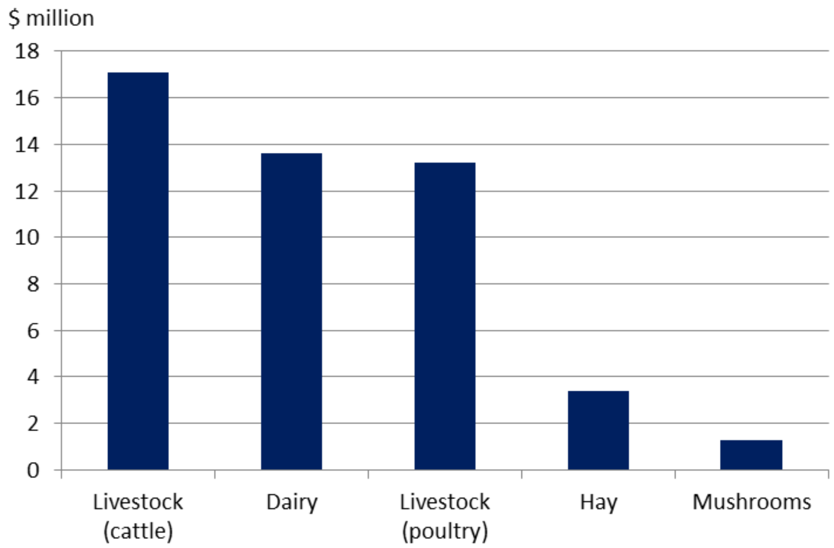
3.3.2 Mining

As at the 2011 Census, the mining industry employed 2,808 people in the Singleton LGA. The vast majority of these jobs are in Coal Mining (89.4%), with the next highest sub-industry employment in Exploration (5.8%). Given anecdotal reports, particularly in the exploration and mining services industry, it may be that this figure has since declined. The major mines and operations in the local area are Mount Owen, Integra, Liddell, Ashton and Ravensworth Operations, as well as a number of other mines.

3.3.3 Agriculture

In the year ended June 2011, the Singleton LGA produced agricultural produce of a gross value of $50.9 million from 454 businesses. The major contributing commodities were livestock, dairy and hay, as illustrated in Chart 3.3 below.

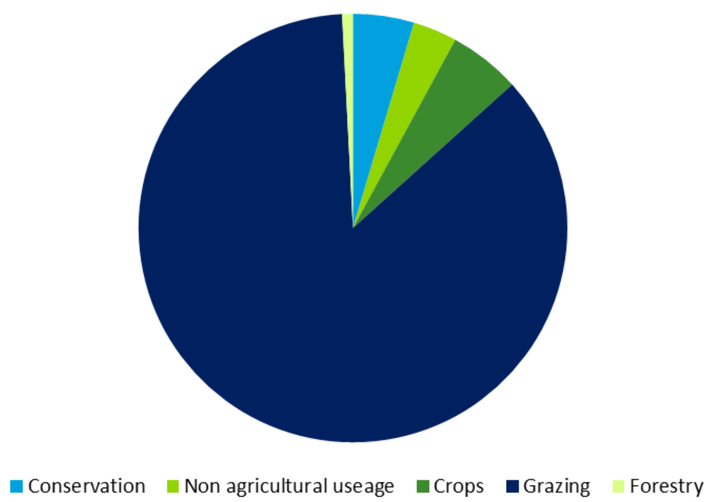
Chart 3.3: Gross value of primary agricultural commodities – Singleton 2010-11



Source: ABS, Agricultural Commodities, 2010-11, Cat. 7121.0

91% (135,545 ha) of land in the Singleton LGA is used for agricultural purposes, as evidenced in Chart 3.4 below. The vast majority of this agricultural land is dedicated to grazing (94% of agricultural land).

Chart 3.4: Use of agricultural land in Singleton and Singleton region SLAs – 2011



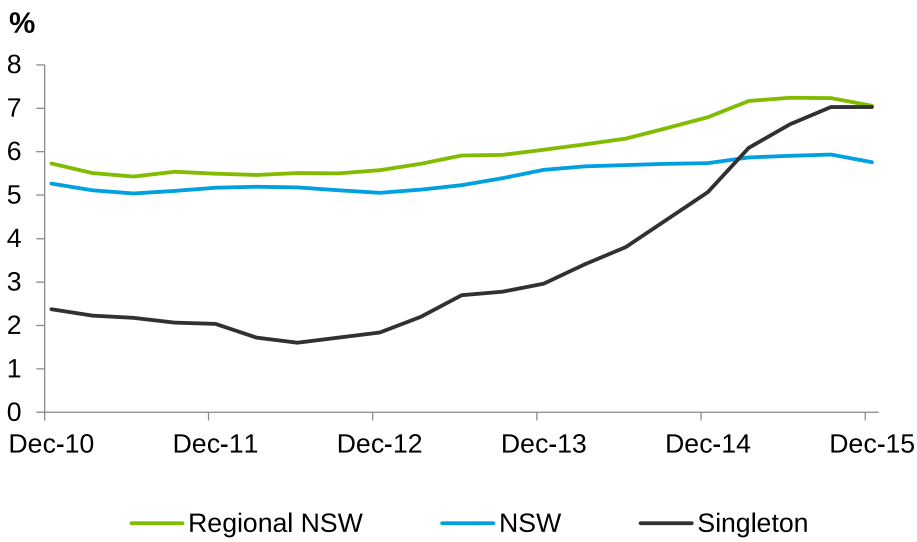
Source: ABS, Agricultural Commodities, 2010-11, Cat. 7121.0 (Note that this is has different boundaries to the Singleton LGA shown in Figure 3.1 due to ABS region definitions. Land is also only that covered by the Agricultural Resource Management Survey and so will not include non-agricultural uses such as state forests.)

3.4 Unemployment

According to Department of Employment small area labour markets data, the unemployment rate for the quarter preceding December 2015 in Singleton was 7.0%, a rise from 5.1% in the December quarter of the previous year. Singleton has experienced a steadily rising unemployment rate over the past three years. In December 2015, the unemployment rate in Singleton was greater than NSW (5.8%) and equal to regional NSW (7.0%). In contrast, from December 2012 to December 2013 the unemployment rate in Singleton was significantly lower than both regional NSW and NSW.

Chart 3.5, below, illustrates a general trend towards rising unemployment in Singleton LGA[1].

Chart 3.5: Unemployment rate in Singleton and NSW



Source: Department of Employment 2016, Small Area Labour Markets Data

[1] The Department of Employment unemployment estimate is constructed by apportioning the ABS' Upper Hunter Region employment statistics based on the size of the labour market in the Singleton region. This methodology has the potential to overestimate the Singleton unemployment rate due to movements in other small area labour markets. As a point of comparison, the 2011 Census indicated that the unemployment rate of usual Singleton residents was 3.4%. At the same time, the state-wide unemployment rate, as indicated by the Census, was 5.9%. This is broadly in line with the trends displayed through the Department of Employment estimates, and suggests that while a margin for error applies, the rates displayed in Chart 3.5 is a plausible account of the unemployment pattern in Singleton over the past year.

4 The Mount Owen Continued Operations Project

As described above, the purpose of a CBA is to provide a structured approach to assessing whether or not a project is likely to result in overall benefits to the economy (including benefits to the NSW community). To carry out this economic assessment, the costs and benefits associated with the Refined Project are compared to those under a baseline, 'business as usual' case. This comparison allows for an incremental analysis, to reach a clear conclusion on the net benefits of the Refined Project. Accordingly, for the purposes of the CBA, it is important to clearly define the baseline case and the Refined Project case.

As described in Section 1, the Mount Owen Complex consists of three open-cut mining operations: the Mount Owen, Ravensworth East and Glendell Mines. In both the baseline case and the Refined Project case, the Glendell Mine will continue in accordance with its development consent. It is anticipated that operations will conclude at Glendell in 2021.

The baseline case and Refined Project case are defined in turn below.

4.1 Baseline case

The North Pit has an approved production rate of 10 million tonnes per annum (Mtpa) of run of mine (ROM) coal, and blended with Ravensworth East (4 Mtpa) and Glendell (4.5 Mtpa) ROM coal, feed the Mount Owen CHPP and associated infrastructure which has a total approved processing capacity of 17 Mtpa of ROM coal. Processed coal, both semi soft and thermal coals, is transported via the Main Northern Rail Line to Port Waratah in Newcastle for export, or by rail or conveyor for domestic use.

Mount Owen expect, subject to market conditions, that mining will be completed within the currently approved area of the North Pit by 2018. Accordingly, the baseline case assumes that 24 Mt of ROM coal will be extracted from the North Pit at Mount Owen between 2016 and 2018. This extraction profile is within the extraction limit of 10 Mt ROM coal per annum.

It is noted that should the Refined Project not receive approval, mining operations at the BNP will continue according to existing approvals. However, in order to estimate the incremental costs and benefits of the Refined Project under a single development consent as requested by the DP&E, the assumption that mining will conclude at Ravensworth East after 2015 has been adopted for the baseline case.

An alternative approach for the base case would be to include the mining activity at Ravensworth East between 2015 and 2022. This approach is not feasible due to the scope of the Environmental Impact Statement (EIS). Specifically, Mount Owen Pty Limited (Mount Owen) has been instructed by the Department of Planning and Environment (DPE) that the EIS should allow for consideration of granting a consolidated consent following the surrender of the existing Mount Owen and Ravensworth East consents. On this basis, analysis of externalities must reflect the combined impacts of mining activity at both Mount Owen (the North Pit) and Ravensworth East. This means that the data available for use in the CBA treats activity at Mount Owen and Ravensworth East as occurring under the Refined Project case without the ability to separately identify the effects from each location. To ensure that the CBA is consistent with other parts of the EIS this requires that the full benefits and costs of mining activity at Ravensworth East from 2016 onwards are included under the Refined Project case.

From 2019, the cessation of mining activities at the North Pit in Ravensworth East will require rehabilitation activities in the mine area. The current consent stipulates that rehabilitated land will be primarily used for native vegetation conservation to redevelop forest and woodland, with some other areas used for grazing. The exact allocation process and proportion of future land use is still to be confirmed and agreed by stakeholders. More broadly, rehabilitated land at Ravensworth East will be allocated to approximately 70% low level agriculture and 30% rehabilitated forest. The current consent for the Ravensworth Mine lapses in 2021.

Further details on activities approved under the baseline case, relative to the Refined Project case, are summarised in Section 4.3.

4.2 Refined Project case

Mount Owen is seeking development consent for the Mount Owen Continued Operations Project, to extract additional mineable coal tonnes through continued open cut mining methods. This involves:

- continuation of mining activity at the Mount Owen North Pit beyond 2018 to 2030, extracting an additional 74 Mt of ROM coal; and
- continuation of mining activity at the BNP, Ravensworth East, beyond 2015 to 2022, extracting 12 Mt of ROM coal;

The Refined Project differs from the 2014 Project analysed in the EIS as Mount Owen has refined elements of the 2014 Project that include the removal of the RERR mining area from the 2014 Project in response to a number of recommendations in the PAC report.

To improve operational efficiencies, should the proposal be successful, Mount Owen will surrender the existing consent for Ravensworth East operations, to take up a single consolidated development consent covering continued Mount Owen operations and the operations at Ravensworth East. As such, the EIS studies, including this economic assessment, measure the impacts of consolidated continued operations.

As illustrated in Figure 4.1, the operations under the Refined Project case will be accommodated by a continuation of the North Pit by an additional disturbance area. In the remainder of the report, this area is described as the North Pit Continuation Area. There is no additional disturbance from the Ravensworth East mining pits, as they are located in areas that have been previously disturbed.

The Refined Project would seek to maintain the current approved extraction rates of 10 Mtpa of ROM coal and 4 Mtpa for the North Pit and Ravensworth East operations respectively. The extraction of additional mineable coal tonnes would continue the North Pit life to approximately 2030.

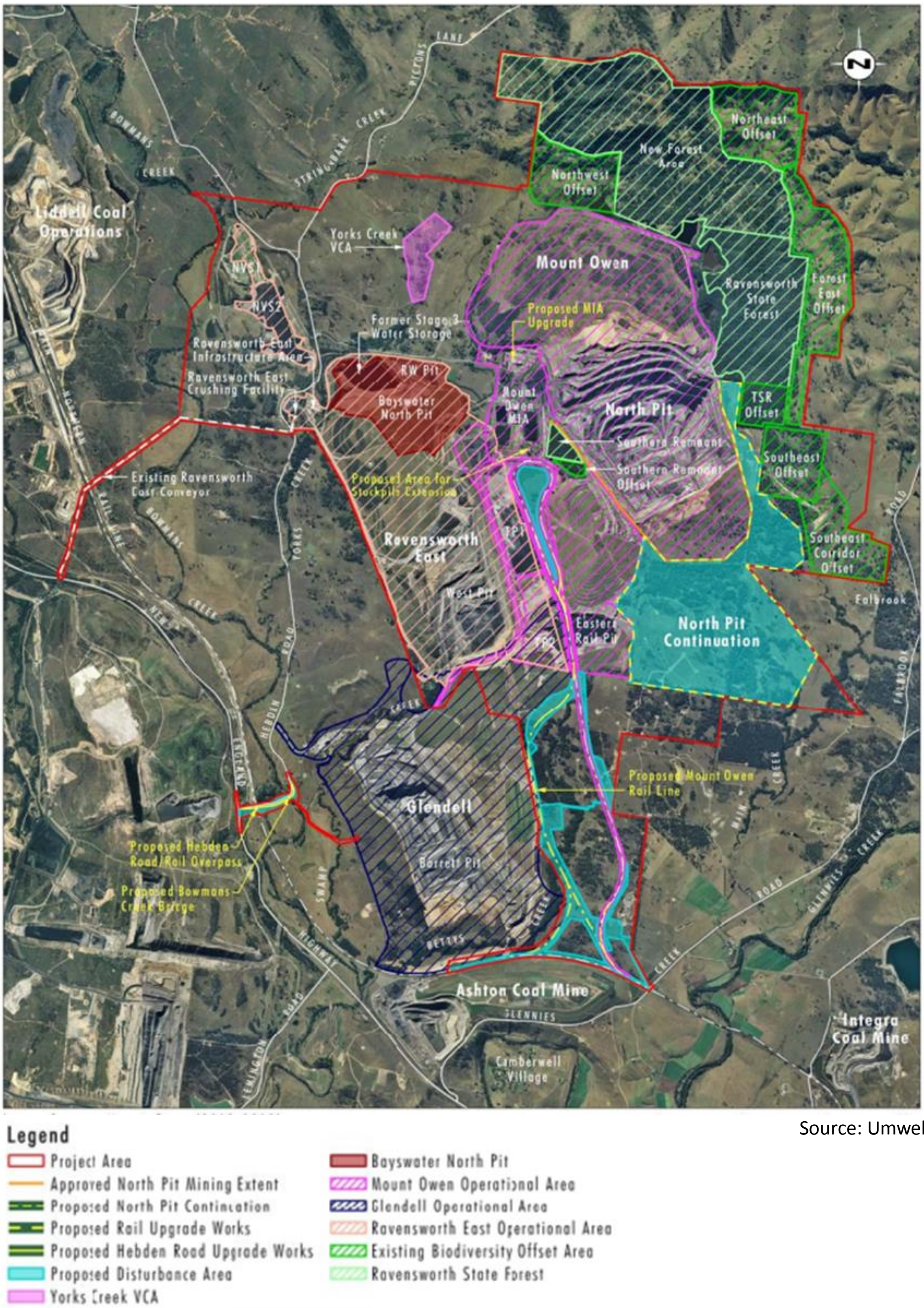
In addition, the Refined Project case involves a number of infrastructure upgrades, including:

- expansion of the existing product stockpile to manage additional product types;
- upgrade and extension of the Mount Owen mine infrastructure area (within existing operational areas);
- provision of an additional rail line and northern-turn out, to the west of the existing Mount Owen rail spur, with use of the existing rail spur as a park-up area for Glencore trains that are not in service;
- construction of a rail overpass, and removal of the existing level crossing on Hebden Road to improve traffic flow and reduce traffic hazards; and
- construction of a new bridge on Hebden Road to allow for two-way traffic movements over Bowmans Creek.

The rail and road infrastructure upgrades noted here are planned to affect an additional parcel of land. Together with the North Pit Continuation Area, the Proposed Disturbance Area is 485 hectares in total. Mount Owen proposes to commence construction within one year of the commencement of mining beyond the currently approved mine life. For the purpose of this analysis, it is assumed that this construction phase will begin in 2016.

Upon commencement of the Refined Project, it is estimated that employment at Mount Owen will range between 510 and 660 FTEs from 2016 to 2027. At Ravensworth East, employment will be around 240 FTE to 2022 These will be augmented with a peak construction phase employment of approximately 330 FTEs for 18 months following commencement of the Refined Project.

Figure 4.1: Proposed operations within the Project Area



Source: Umwelt

4.3 Summary

Table 4.1 below summarises the key elements of the baseline case and Refined Project case.

Table 4.1: Comparison of Baseline and Refined Project case

Key Features	Proposed Operations
Mine Life	Consent will be sought for 21 years (from date of Project Approval) to provide for mining at the North Pit until approximately 2030 and contingency for other activities such as rehabilitation and capping of tailings emplacement areas. Proposed mining operations at BNP in Ravensworth East from 2016 to 2022
Limits on Extraction	No change in approved extraction rates. • North Pit – up to 10 Mtpa ROM. • Ravensworth East – up to 4 Mtpa ROM.
Mine Extent	• Continuation of the North Pit footprint to the south of current approved North Pit mining limit. • Mining within the approved BNP within the Ravensworth East Mine. • Mining depths to approximately 300 m. • Total additional mineable coal tonnes of approximately 74 Mt ROM for North Pit Continuation, 12 Mt ROM at BNP.
Operating Hours	No change proposed. 24 hours per day, 7 days per week.
Workforce Numbers	• No significant change to workforce numbers is required. Current workforce required to operate North Pit and CHPP fluctuates and peaks at about 660 and the Ravensworth East development consent allows for a workforce of up to 260 to operate Ravensworth East operations. • Ravensworth East workforce of 240 FTE will continue until 2022, • Addition of approximately 330 personnel for construction phase for proposed infrastructure works (approximately 18 months).
Mining Methods	No change to mining methods proposed.
Existing Mine Infrastructure	Continued utilisation of all existing mining infrastructure, including the existing crushing plant for the crushing of overburden.

<table>
<tr><th>Key Features</th><th>Proposed Operations</th></tr>
<tr><td>Construction Activities</td><td>Infrastructure upgrades including:
provision for a northern rail line turn-out and additional Mount Owen rail line;
product stockpile extension;
MIA extensions and improvements;
Hebden Road overpass over Main Northern Rail Line; and
New Hebden Road bridge crossing over Bowmans Creek.
CHPP improvements (including operational efficiencies) to increase processing capacity and tailings management.</td></tr>
<tr><td>Tailings Emplacement</td><td>Continued use of the Ravensworth East West Pit void for tailings emplacement and co-disposal of coarse reject and overburden within the North Pit Continuation and the West Pit / BNP as mining progresses
Tailings cells may be constructed and filled within the North Pit Continuation area as required.
Allowance for the receipt of tailings from other mines in accordance with relevant approvals including Ravensworth East DA52-03-99 MOD 6.</td></tr>
<tr><td>Coal Transportation</td><td>No change to current export coal transportation with the exception of the use of the proposed additional rail line.
Use of existing rail line for train park up.
Transportation of up to 2 Mtpa ROM coal and crushed gravel on an as required basis via the existing overland conveyor to Liddell Coal Operations and the RCT in addition to maintaining the current approval to transport ROM coal to Bayswater and Liddell power stations.</td></tr>
</table>

Source: Mount Owen; Umwelt

4.4 Project options and scope of CBA

In addition to clearly defining the baseline case and the Refined Project case, completion of the CBA also requires a consideration of other project options and the geographic scope of the analysis.

In terms of considering other Project options, the following three alternatives were considered, but were not considered feasible and therefore were not identified as the preferred case. Accordingly, these options were not incorporated in the CBA.

- **Underground Mining (including highwall mining):** economic extraction through underground mining is not possible due to steep seam dips and complex geology;
- **Eastern Extension of Mining Area:** not considered to avoid damage to the Biodiversity Offset areas committed to by Mount Owen in the 2004 approval; and,
- **Western Extension of Mining Area:** not considered to maintain the integrity of the remnant State forest area (committed to by Mount Owen in 2004) and because of economic constraints associated with mining through the existing Western Out-of-pit Dump and the adjacent Eastern Rail Pit tailings emplacement area.

The second issue that must be clarified is the geographic scope of the CBA. This is important as it draws a line for which benefits and costs are included in the analysis and which are excluded. For example, if the scope of the CBA is defined as the State of NSW, rates payable to Singleton Council, and royalties payable to the NSW Government should not be included in the analysis in Chapter 5. As the cost to Mount Owen is offset by the benefits to the government, these transfer payments cancel out.

As the CBA is being developed for compliance with NSW Government processes, the scope of the CBA will generally be the State of NSW. However, the fact that the guidelines and requirements discussed in Section 2 do not fit neatly into a traditional CBA framework means that the analysis will sometimes require consideration of effects for particular groups within the scope. For example, Chapter 6 mostly focusses on transfer payments within the state. Whenever this is the case we will attempt to clearly identify which parties are being analysed and where they are likely to be located.

5 Cost benefit analysis – Project level

This section presents the first stage of our methodology, consisting of a CBA of the Refined Project. This involves identifying the incremental costs and benefits of the Refined Project relative to the baseline case and quantifying these items wherever possible to obtain a consolidated estimate of the net economic value of the Refined Project. Overall, adjusting the original CBA analysis for changes relating to the Refined Project indicates that, in the central case, the Refined Project delivers net benefits of around $857 million over its life (in 2016 NPV terms). The steps involved in this analysis are described in this section.

5.1 Identifying costs and benefits

The economic, environmental and social costs and benefits considered in this analysis are set out in Table 5.1 below.

Table 5.1: Direct Costs and Benefits – Mount Owen Continued Operations Project

	Costs	Benefits
Production	Other onsite revenue forgone	Gross mining revenue
	Exploration costs	Residual value of capital
	Capital investment costs	Residual value of land forgone
	Operating costs excluding taxes	
	Rehabilitation costs	
	Decommissioning costs	
Externalities	Offsite agricultural revenue*	Net traffic impacts
	Related public expenditure*	Conservation*
	Groundwater quality*	
	Surface water quality*	
	Carbon emissions	
	Air quality impacts – particulate matter	
	Air quality impacts – other pollutants*	
	Noise impacts	
	Visual amenity*	
	Biodiversity – flora and fauna	
	Quality of open space*	
	Rural amenity and culture	
	Aboriginal heritage*	
	Historic heritage*	
	Health*	

* Item has been considered qualitatively

Note: As the Refined Project involves open-cut mining activity, there are no subsidence impacts which need to be valued in this analysis. Nevertheless, this item is discussed qualitatively in Section 5.2 in accordance with NSW Government (2012)

In recognition of the broad range of impacts of the Refined Project, the costs and benefits shown have been separated into two categories. First, the costs and benefits that directly affect the financial outcomes of the proponent can be classified as internal effects of production. The externalities category incorporates the broader implications of the Refined Project for third party stakeholders, such as residents and external businesses from the local community, the Hunter and Central Coast regions, and beyond.

Section 5.2 describes the techniques used to value each of these items and provides the justification behind the classification of each as a cost or benefit.

As recommended in CBA guidelines such as NSW Treasury (2007), where it is difficult to place a value on a particular cost or benefit of the Refined Project, a qualitative analysis has been undertaken. The items considered qualitatively are marked in the table above and are discussed thoroughly in the sections below. In some cases these items have been considered qualitatively because there is expected to be no significant difference in outcomes under the baseline and Refined Project case (such as related public expenditure, groundwater quality and surface water quality) or because there is no reliable method available to value them in these particular circumstances (such as Aboriginal heritage).

5.2 Valuing costs and benefits

This section details the approach taken to provide a value for each of the costs and benefits identified in 5.1. For the costs and benefits that fall within the production category, a market value can usually be assigned using the financial information provided by Mount Owen. In contrast, it is generally more difficult to attach a monetary value to the non-priced externalities.

The approach to valuation taken in this analysis is described below. Further discussion on the advantages and disadvantages associated with the different valuation techniques mentioned can be found in Appendix B.

Firstly, in cases where there is a market price available, this price is used. Alternatively, if a standard industry approach is available, then this value is used. For example, transport costs are outlined in publications from Transport for NSW (2013). When neither of these options are available, there are then two alternative possible approaches. The first is to undertake a literature review and apply benefit transfer techniques to the local context if required. This can be done using databases of non-market values such as 'Envalue', which was maintained by the NSW Department of Environment and Climate Change up until 2004, or its more recently updated international equivalent, the Environmental Valuation Reference Inventory (EVRI) developed by Environment Canada. These databases can be augmented by a direct review of the relevant literature for non-market valuation. Current literature on non-market valuation involves a number of specialised methodologies (e.g. the travel cost method, contingent valuation or choice modelling), which all require extensive surveys, or alternatively empirical analysis such as hedonic pricing, which uses existing market data from an affected sector (e.g. residential property market).

In the event where there is insufficient literature available, a final alternative is to undertake original research into non-market values.

The discussion throughout this chapter draws on the findings in Appendix C, which reviews the unit value evidence for each item considered in this report.

All present values reported in this section are calculated using a 7% discount rate, are reported in 2016 price terms, and are discounted back to 2016. Undiscounted estimates of each cost and benefit are also provided for comparison purposes.

5.2.1 Gross mining revenue

Gross revenue from mining activity at Mount Owen is calculated using forecasts of annual production quantities and annual prices for each coal product.

This analysis utilises production quantity forecasts of semi-soft coking coal and thermal coal provided by Mount Owen, for each year of operation under the baseline and Refined Project case.

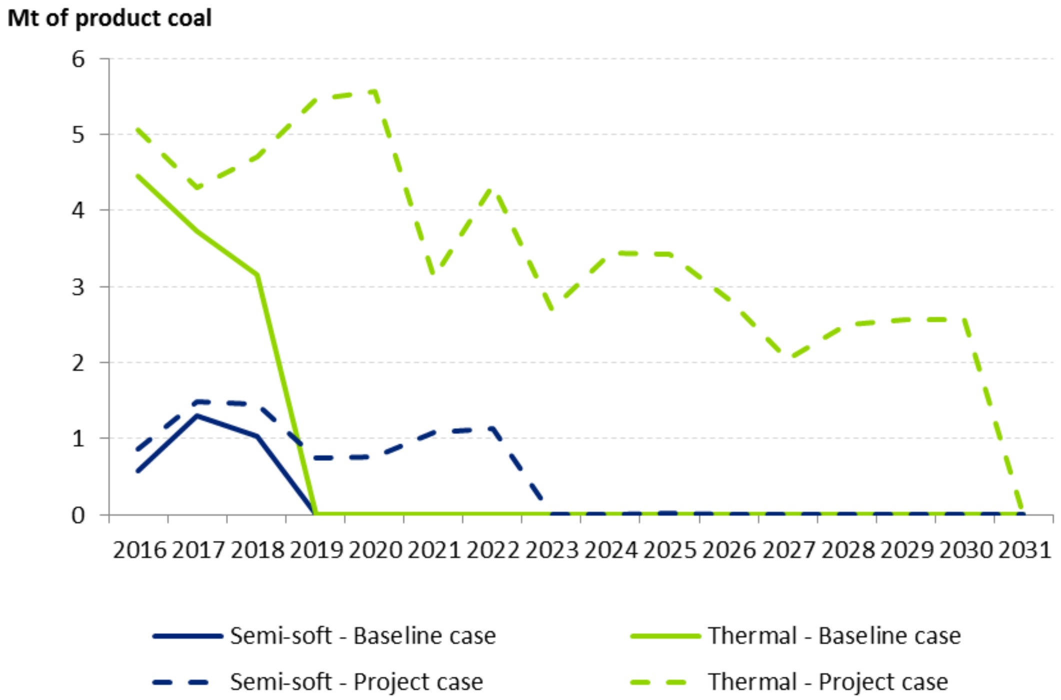
As illustrated in Chart 5.1 below, under the baseline case, a total of 14.3 Mt of saleable coal will be produced between 2016 and 2018 from mining activity at the Mount Owen North Pit.

Should the Refined Project receive approval, the annual production profile at the Mount Owen North Pit will be slightly varied between 2016 and 2018 compared to the baseline, to accommodate continued operations from 2019 out to 2030. At Ravensworth East, mining at the BNP will take place from 2016 to 2022.

Overall, a total of 62.1 Mt of saleable coal will be produced between 2016 and 2030 under the Refined Project case, an additional 47.9 Mt of product coal compared to the baseline.

As Chart 5.1 shows, the proportional split between semi-soft coking coal and thermal coal is expected to vary from year to year in both cases. Nevertheless, approximately 90% of the 47.9 Mt of additional saleable coal under the Refined Project case is expected to be thermal. Under the Refined Project case, production of semi-soft coking coal is expected to cease by 2027.

Chart 5.1: Production profile – Mount Owen Complex*, 2016 – 2031



Source: Mount Owen

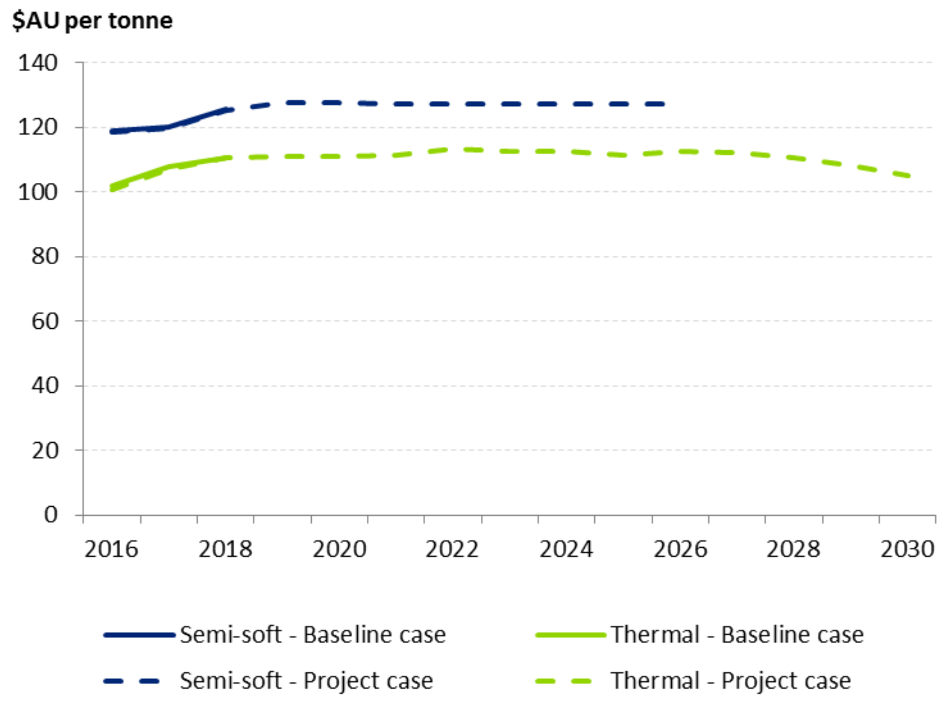
*Mining at the North Pit (Mount Owen) and Bayswater North Pit (Ravensworth East)

The prices used in this section of the report were derived from consensus forecasts for thermal and semi soft coking coal provided by Mount Owen, as at June 2014. These are the same prices that were used in the previous CBA. Maintaining the prices from the previous CBA allows for the results of this section to be compared to the results from the precious CBA. An update for current market conditions is provided in Section 7.

These benchmark prices were converted from US dollars to Australian dollars using a consensus forecast of the exchange rate, starting at 0.92 USD$/AUD$, declining gradually to around 0.83 USD$/AUD$ by 2020, and constant thereafter. The prices used in the analysis were then obtained by adjusting the benchmarks for coal quality, using time series data on the estimated calorific value of each saleable coal product for each year under the baseline and Refined Project cases, provided by Mount Owen. This is the same exchange rates and approach that was used in the previous CBA.

The resulting coal price forecasts are illustrated in Chart 5.2 below.

Chart 5.2: Coal price forecasts – Mount Owen Complex, 2014 market conditions



Source: Consensus Economics

Applying these values and assumptions gives a central present value estimate of $1,365 million for gross mining revenue in the baseline, and $4,622 million in the Refined Project case. In undiscounted terms, gross mining revenue is estimated at $1,558 million in the baseline and $6,935 million in the Refined Project case.

5.2.2 Other onsite revenue (e.g. agriculture)

It is also necessary to incorporate the impact of the continued operations under the Refined Project case on any additional revenue streams within the Project Area as part of the CBA. Given that the Refined Project will not impact mining activity at the Glendell Mine, this item focuses on the use of surrounding landholdings for agricultural activities such as grazing.

Assessments have indicated that the majority of the proposed disturbance area is 'unused grazing land' with soil suitable for low to moderate intensity grazing, either LSC Class 4 or greater. As noted in the Agricultural Impact Statement, currently, approximately 25 hectares of the proposed North Pit Continuation Area is used for this activity.

However, as the value of this land is included in the baseline estimate of the residual value of land (see Section 5.2.9), revenue foregone under the Refined Project case has not been separately quantified under this item to avoid double counting.

5.2.3 Exploration costs

Exploration expenditure consists of any costs associated with preparatory activities before extraction commences. Where these costs are yet to be incurred, it is appropriate to include them in a CBA.

For the Refined Project, Mount Owen has advised that any exploration costs associated with either the baseline or Refined Project case have been incorporated in the ongoing operating costs estimates. For instance, under the Refined Project case, an allowance of around $400,000 has been made for ongoing exploration between 2016 and 2025. Accordingly, no separate values have been assigned to this item in either case.

5.2.4 Capital investment costs

In this analysis, capital investment costs encompass all expenditures on infrastructure associated with the existing and proposed operations.

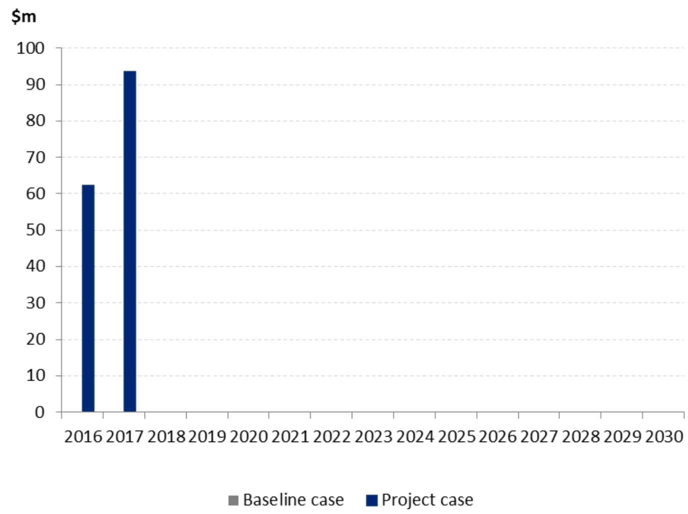
Mount Owen has advised that no further capital investment is expected under the baseline case, as defined for the purpose of this analysis.

However, should the Refined Project receive approval, this modelling assumes that capital investment of approximately $156 million is proposed to be incurred across 2016 and 2017. This includes expenditure on proposed mine industrial area works, stockpile pad extension works, the Hebden Road Rail Overpass, upgrade of the Hebden Road bridge over Bowmans Creek, rail upgrades and water management works. Given the uncertainty around approval timelines, capital expenditure is assumed to commence towards the end of 2016 for the purpose of this analysis. In practice, some of this expenditure may end up occurring in 2017. Assuming that the expenditure commences in 2016 is a conservative assumption as capital expenditure enters the CBA as a cost as so incurring costs earlier reduces the estimated net benefits.

The anticipated profile of Refined Project case capital investment is illustrated in Chart 5.3 below.

In present value terms, capital investment is therefore estimated at $140 million in the Refined Project case. This is attributed in the CBA as a cost of the Refined Project.

Chart 5.3: Capital investment, 2016 - 2030



Source: Mount Owen, updated to 2016 prices

5.2.5 Operating costs excluding taxes

Operating costs encompass the expenditure incurred as a direct result of extracting ROM coal, processing it into saleable product and delivering it to a port before loading, known as free on board (FOB) costs, as well as ongoing expenditure on the purchase and maintenance of equipment and machinery necessary for production.

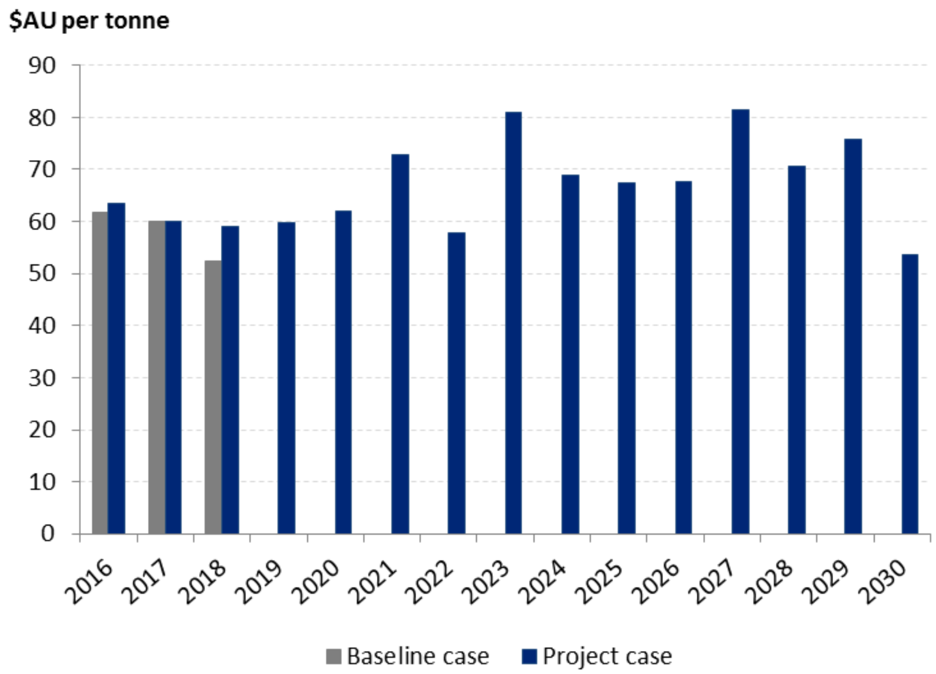
For this analysis, FOB costs have been estimated based on econometric modelling undertaken by Shafiee, Nehring and Topal, using data on open cut coal mines (2009). The authors define per tonne operating costs as a function of deposit average thickness, the stripping ratio, capital cost and the daily production rate.

Mount Owen has provided estimates for these parameters in the baseline and Refined Project cases, which are expected to vary over the course of production. The inputs provided imply that, under the baseline case, operating costs will vary between $52 and $62 per product tonne, from 2016 to 2018.

Under the Refined Project case, FOB costs operating costs are likely to range between $54 and $82 per product tonne, as illustrated in Chart 5.4 below.

The variation is due to changes in the stripping ratio and the average daily production rate from year to year. These costs also incorporate distribution and selling expenses of $9.47 per tonne of product coal from 2016 and 2023, and $8.65 per tonne of product coal from 2024 onwards, based on information provided by Mount Owen. The variation in distribution and selling expenses over time is due to anticipated changes in internal costs.

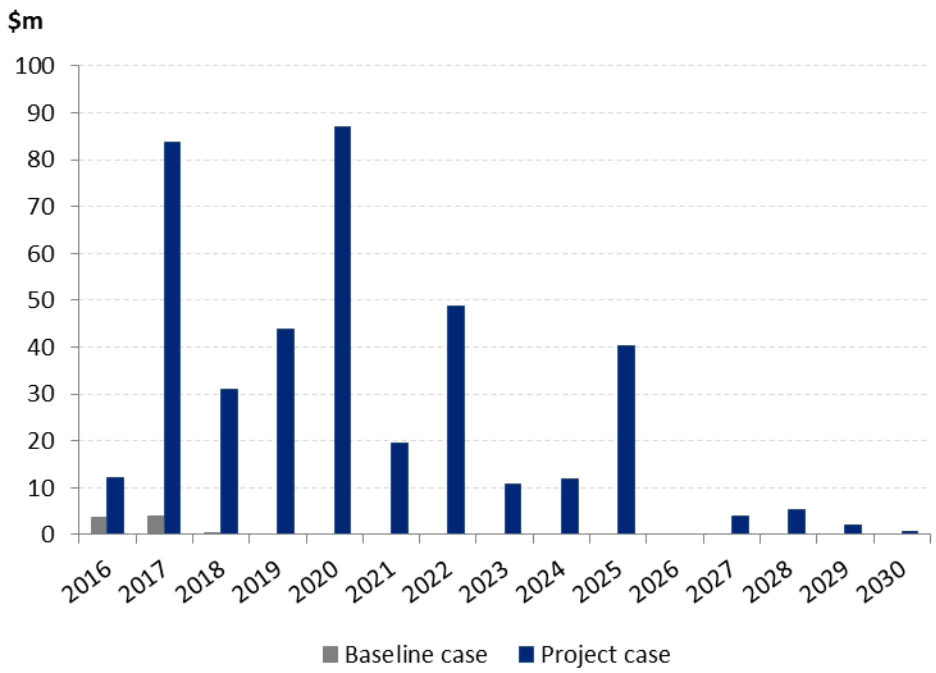
Chart 5.4: FOB costs per tonne, 2016 – 2030



Source: DAE estimates based on modelling by Shafiee, Nehring and Topal (2009), Mount Owen

Estimates of ongoing expenditure on mobile equipment including sustaining capital and exploration were provided by Mount Owen. This is treated as operational expenditure for the purpose of this analysis. The anticipated profile of this expenditure under the baseline and Refined Project case is presented in Chart 5.5 below.

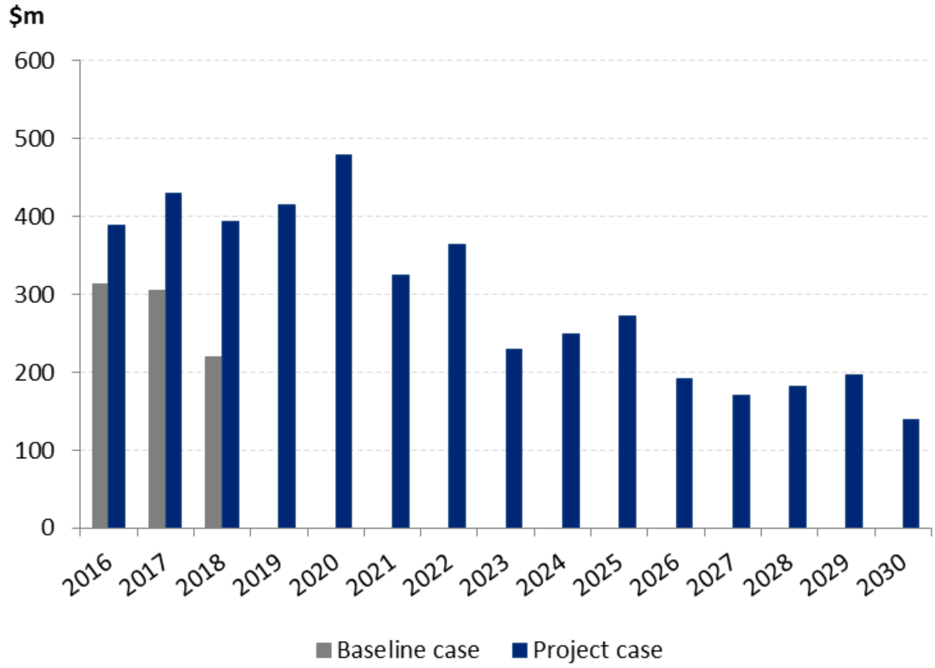
Chart 5.5: Ongoing expenditure on equipment, 2016 – 2030



Source: Mount Owen, updated to 2016 prices

Overall, total operating costs under the baseline case are estimated at $838 million ($739 million in present value terms using a 7% discount rate). Under the Refined Project case, operating costs are estimated at $4.4 billion, equivalent to $2.9 billion in present value terms. The time series of these total cost estimates are presented in Chart 5.6 below.

Chart 5.6: Total operating costs, 2016 – 2030



Source: DAE estimates; Mount Owen, updated to 2016 prices

It is noted that these aggregates do not incorporate the cost of royalties and other taxes. This is because taxes are a transfer of funds, with the expense incurred by the company offset by a gain for government. As such, it is not appropriate to include them in a cost benefit analysis. These transfer payments will, however, be considered in Section 6 which focusses on the net benefits to NSW.

5.2.6 Rehabilitation costs

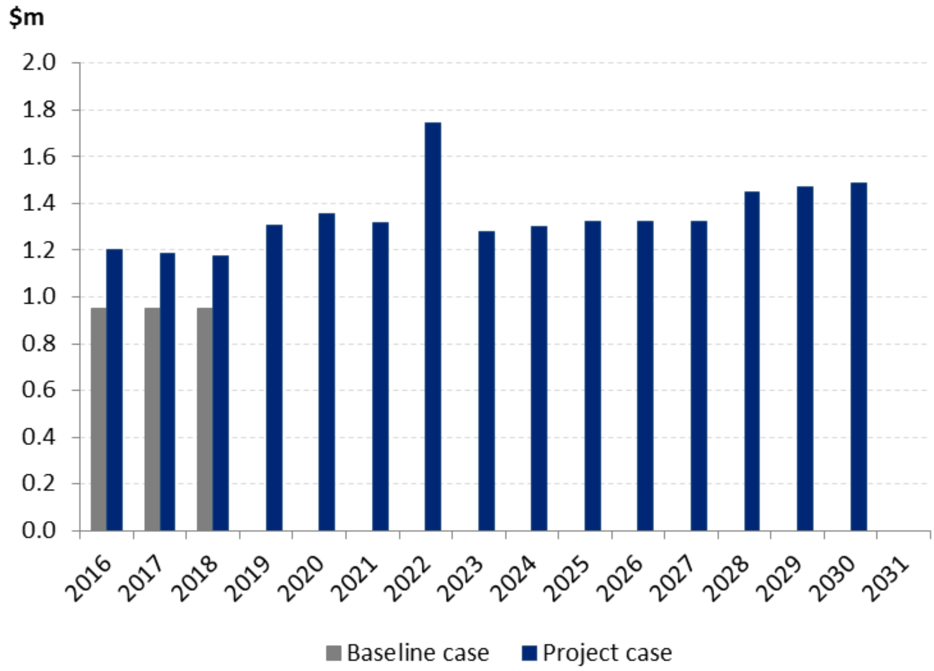
Land rehabilitation works are required in both the baseline and Refined Project case. As the timing and magnitude of this expenditure differs between the two scenarios, these costs have been included in the analysis.

Mount Owen has advised that rehabilitation costs for the baseline case will amount to $2.8 million at the North Pit, with works taking place between 2016 and 2018. This is equivalent to $2.5 million in present value terms.

Should the Refined Project receive approval, land rehabilitation will continue to be undertaken progressively between 2016 and 2030, generating a total cost of $20.2 million, encompassing both the North Pit and Bayswater North Pit mining areas. This is valued at $12.1 million present value terms using a 7% discount rate.

The timing of this expenditure, under the baseline and Refined Project case is presented in Chart 5.7 below. Overall, the additional costs of $9.6 million (in present value terms) are attributed as a cost of the Refined Project.

Chart 5.7: Rehabilitation costs, 2016 – 2031



Source: Mount Owen

5.2.7 Decommissioning costs

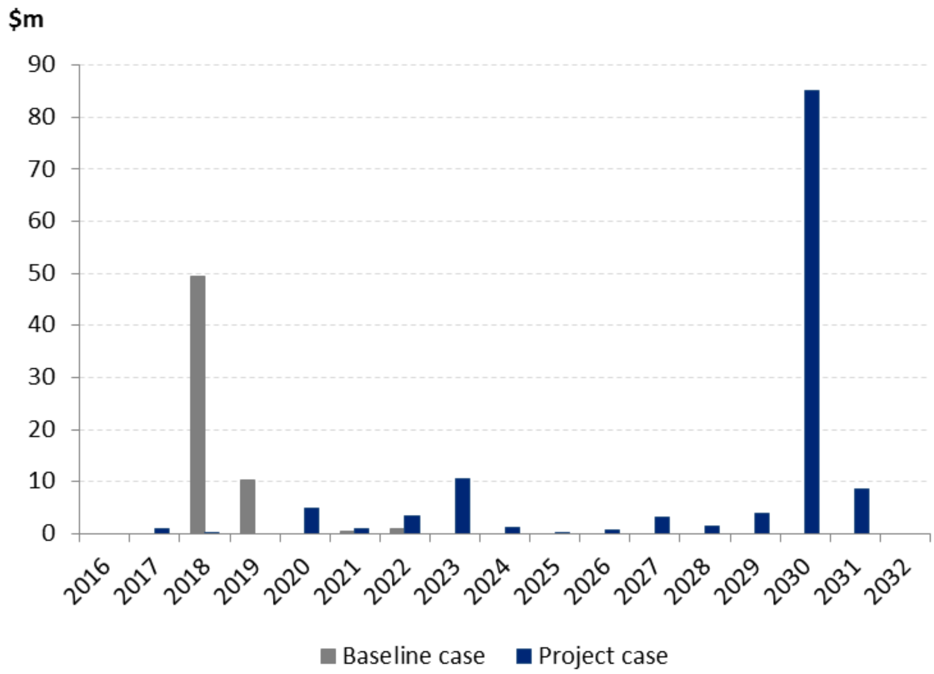
Decommissioning costs comprise costs associated with employee management at the conclusion of mining operations and the removal of old assets or infrastructure – in general, the costs involved in the closure of the mine within the Project Area.

Mount Owen has provided data on the anticipated timing and magnitude of these costs under the baseline and the Refined Project case. This is presented in Chart 5.8 on the following page.

As indicated, Mount Owen expects to incur $61 million in decommissioning costs between 2018 and 2022 under the baseline case, with the majority of expenditure taking place in 2018. These costs relate specifically to the closure of the North Pit. No decommissioning costs have been included for Ravensworth East in the baseline case to present a conservative analysis of the incremental costs of the Refined Project with a combined development consent. Therefore, baseline decommissioning costs are valued at $49 million in present value terms.

Under the Refined Project case, total closure costs are estimated at $125 million. It is expected that these costs will be incurred over the period from 2017 to 2031. This is equivalent to $52 million in present value terms, using a 7% discount rate.

Chart 5.8: Decommissioning costs, 2016 – 2032



Source: Mount Owen

5.2.8 Residual value of capital

Upon completion of mining, companies can generate additional revenue from the sale of remaining capital goods.

In the context of this Project, Mount Owen has advised that the assets will be fully depreciated over the life of the mine under both the baseline and Refined Project cases. Accordingly, no residual asset values have been incorporated in the CBA.

5.2.9 Residual value of land

Similarly, it is necessary to assign a value to the land within the proposed disturbance area, at the completion of mining activity. This value primarily depends on the ability of the land to support future activities of economic or social value. If the land is not suitable for further uses, such as agriculture or rehabilitation, then it is unlikely that there would be any substantial demand or willingness to pay for it. In this case, the value of the land will be zero.

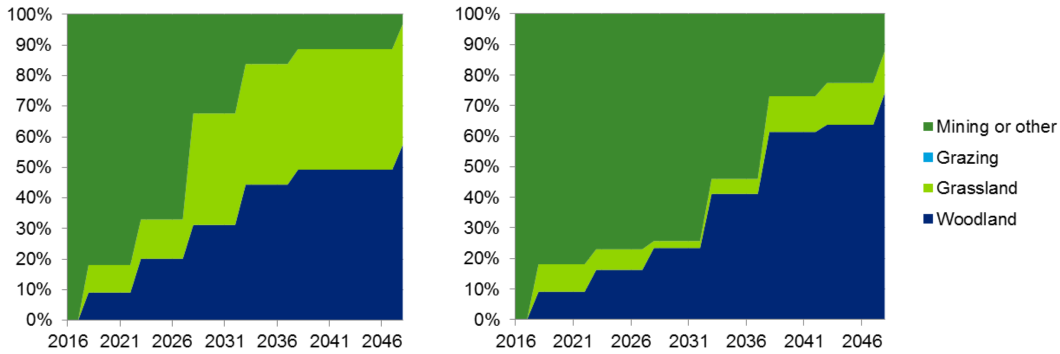
In the context of this analysis, Umwelt has advised that the proposed disturbance area currently consists of native woodland vegetation, derived native grassland and some land suitable for cattle grazing. Under the baseline, the area of land which could be potentially used for cattle grazing has been valued at the estimated social value of grassland. This is a conservative assumption as, in this case given the nature of the grazing land, our analysis indicates that valuing it at the social value of grassland produces a greater cost of loss of use.

Should the Refined Project receive approval, these land uses will be precluded as a result of the continuation of the North Pit, and the proposed infrastructure works. While some land will remain as a void, or be impacted by infrastructure such as roads, other areas will be rehabilitated over the life of the mine. It is expected that this rehabilitation work will be completed by around 2035, once the closure phase of the Refined Project is finalised. The residual land is then estimated to reach its final form in around 2048.

The charts below present details of the anticipated timing of land use in the Refined Project and in the baseline.

Chart 5.9: Comparison of land use in the baseline and Refined Project

a. baseline **b. Refined Project**



Source: Umwelt

This information can be utilised to ascertain the value of the land use under each case. As set out in Appendix B, valuations should rely on market prices where available. Accordingly, the social value of areas used for native woodland and forest vegetation, and derived native grassland, has been estimated using data from the NSW Office of Environment and Heritage's BioBanking scheme. Specifically, the BioBanking public register provides information on biodiversity credit transactions and agreements. The value of ecosystem credits is determined by a range of factors including the type of vegetation on the land. Details from the register can be used as an estimate for the social value of conservation land.

Umwelt has advised that the existing native woodland and forest vegetation consists of a number of vegetation communities, over 50% is covered by the Central Hunter Ironbark – Spotted Gum – Grey Forest Endangered Ecological Community. In addition, under the Refined Project case, this is the prominent vegetation community for rehabilitation. Table 5.2 lists BioBanking transaction records relating to the 'Grey Ironbark – Spotted Gum – Grey Box open forest on the hills of the Hunter Valley, Sydney Basin' vegetation category (type HU556).

Table 5.2: BioBanking ecosystem credit data for vegetation type HU556

Transaction date	Number of credits	Price per credit	Vegetation area (ha)	Estimated value per hectare*
30 January 2013	620	$1,260	103.41	$7,554.39
13 June 2013	606	$1,462	82.56	$10,731.25

Source: NSW Office of Environment and Heritage
* DAE calculation

The difference in the estimated value per hectare for each transaction reflects the way in which a number of factors influence BioBanking credit prices. The higher estimate was chosen as a price reference in this analysis as it is drawn from the most recent transaction. After updating to 2015 prices an estimate of $11,164 per hectare was obtained.

Next, to account for the fact that areas assigned to native woodland vegetation in each case would be of lesser quality than the site valued through the BioBanking transaction, this social value has been discounted by 50% in the baseline case, and 75% in the Refined Project case. We are not aware of any specific research that looks into how rehabilitated land should be valued relative to existing land but consider that the significant discounts used in the analysis are conservative assumptions as they work to reduce the estimated benefits of land rehabilitation that will be undertaken.

A similar research process was undertaken to ascertain an estimate of the social value of derived native grasslands within the proposed disturbance area. For the purpose of this valuation, Umwelt advised that, in general, the vegetation on the land could be described as 'Spotted Gum - Narrow-leaved Ironbark shrub - grass open forest of the central and lower Hunter. However, no BioBanking transactions have involved credits for this vegetation type. Accordingly, this analysis uses an estimate of $10,009 per hectare as a reference price, derived from a transaction on 13 June 2013 relating to the 'Spotted Gum – Broad leaved Ironbark grassy open forest of dry hills of the lower Hunter Valley, Sydney Basin' vegetation category (type HU629), updated to 2015 prices. Although this description does not exactly reflect the composition of grasslands in the disturbance area, it is likely that the value of the vegetation would be similar. To account for any reduction in quality of the vegetation due to rehabilitation, this value was also discounted by 50% in the baseline case and 75% in the Refined Project case. We are not aware of any specific research that looks into how rehabilitated land should be valued relative to existing land but consider that the significant discounts used in the analysis are conservative assumptions as they work to reduce the estimated benefits of land rehabilitation that will be undertaken.

Applying these values to the areas of land in the baseline the Refined Project case, produced an estimate of the residual value of land of $5.91 million in the base case and $6.71 million in present value terms for the Refined Project case. The increase in value in the Refined Project case reflects the increased presence of woodland which is valued more highly than grassland. This results in an overall net benefit of $0.8 million in the CBA in present value terms.

5.2.10 Related public expenditure

In some cases, a project may generate additional costs for government. Where this is the case, these external costs should be included in a CBA.

Mount Owen has advised that the baseline case is not expected to generate any additional public expenditure by any level of government. In the Refined Project case, it is assumed that public expenditure at a LGA level, potentially generated by the continued operations would be covered by Mount Owen through the Voluntary Planning Agreement (VPA) with Singleton Council.

This agreement will allocate resources for costs in relation to changes in community infrastructure in the region. As such, public expenditure under this agreement will not be additional to the budgeted costs for the council.

Thus, the refined Project will not generate additional public expenditure. As payments under the VPA are transfer payments between Singleton Council and Mount Owen, they have not been included in the CBA.

5.2.11 Offsite agricultural revenue

Mining activity can potentially affect the productivity of agriculture in surrounding areas, ultimately reducing the revenue earned by these activities. Where appropriate, it is important to account for these impacts in a CBA. The method of valuing the impacts of mining on agricultural revenue is described in Appendix C.

Currently, some of the Glencore-owned areas surrounding the Mount Owen Mine are utilised for grazing. The main agricultural uses of the adjacent land not owned by Glencore include cattle grazing and fodder crops on irrigated floodplain and terrace landforms along Glennies Creek.

Potential impacts on the productivity of surrounding agricultural areas (specifically, within 10km radius from the Project Area) have been considered in the Agricultural Impact Statement (AIS). As described in the AIS, a detailed analysis of soil capability has confirmed that there are no biophysical strategic agricultural land (BSAL) areas[2] within the proposed disturbance area.

However, the AIS has identified that there is a low to moderate risk of reduced productivity of surrounding agricultural systems and enterprises as a result of the Refined Project. These risks are to be managed through Mount Owen's water quality, air quality and land management controls.

While the potential impact on agricultural productivity is acknowledged, there is no clear empirical evidence which enables the relationship between noise or dust and agricultural productivity to be quantified. Furthermore, research by Environment Australia has found

[2] This category of land incorporates areas with "the best quality landforms, soil and water resources which are naturally capable of sustaining high levels of productivity and require minimal management practices to maintain this high quality" (NSW Department of Primary Industries, 2012).

that mine dust deposition rates and impacts “tend to decrease rapidly away from the source”, while “in the majority of situations dust produced by mining operations is chemically inert” (1998:2).

Accordingly, it is considered appropriate to treat these potential impacts qualitatively in this analysis. Umwelt has advised that should any agricultural properties be acquired, the agricultural uses of the land are likely to continue, which suggests that any decline in revenue as a direct result of the Refined Project would be minimal.

5.2.12 Groundwater quality

Mining activity can potentially impact the quality and quantity of groundwater supplies, with implications for other users that are not adequately captured in market transactions. As a result, it is necessary to assign a value to the costs borne by third parties as part of a CBA.

In the context of this Project, there are two main hydro geological features located directly within or surrounding the Project Area: the alluvial aquifers along the creek lines and the deeper hard rock aquifers containing the coal measures. The first feature is characterised by shallow and highly porous aquifers with rapid transmission of groundwater, while the second exhibit slower groundwater movement. Water yields from both alluvial and hard rock aquifers in the Project Area are not considered to be high.

An assessment study of the potential groundwater impacts of the Refined Project on these hydrogeological features (measured over a 20km distance around the Project Area) was prepared by Jacobs in accordance with the DGRs and relevant water planning policies and guidelines. The findings from the assessment are summarised in the EIS and indicate that any groundwater impacts associated with the operations of the Refined Project are negligible. This is summarised in the table below.

Table 5.3: Summary of groundwater impact predictions

Potential environmental impact	Assessment predictions
Leakage of groundwater from shallow alluvial aquifers of Bowmans and Glennies creeks and associated tributaries	Negligible Impact
Changes to baseflows in surface drainage systems	Negligible Impact
Impacts on water supply bores and wells	Negligible Impact
Change in water quality	Negligible Impact
Groundwater dependent ecosystems	Negligible Impact

Source: Umwelt/Jacobs

According to the assessment, existing coal mining operations in the area has led to the depressurisation of the hard rock aquifer affecting the local hydrogeological regime. However, the nearest privately owned bore is located over 4 kilometres from the Project Area, while all other 47 registered bores located within 4 kilometres of the Project Area are owned by Glencore operations or other mining companies. Therefore, any of the potential impacts outlined above are unlikely to affect other external users in non-mining industries or private landholders.

Based on Jacobs' hydrogeological modelling, the incremental impacts on groundwater flows and quality associated with the Refined Project are assessed to be negligible, relative to the baseline case. Any groundwater extractions will be subject to existing water licences, and it is not anticipated that any further licenses will need to be purchased by Mount Owen. Accordingly, no value has been assigned to this item in either the baseline or Refined Project case in the CBA.

5.2.13 Surface water quality

Changes in the quality of surface water should also be valued as part of a CBA where those changes are caused by a project and generate substantive impacts on third parties and the surrounding environment. The impacts of the Refined Project on surface water are assessed in the EIS.

The main water resources surrounding Mount Owen are the Bowmans Creek catchment (consisting of Stringybark Creek, Yorks Creek, Swamp Creek and Bettys Creek) and the Glennies Creek catchment (Main Creek). The Surface Water Assessment notes that historic water quality within these catchments have complied with the threshold levels set in the ANZECC Guidelines 2000. These threshold levels have been set to 'provide certainty that there will be no significant impact on water resource values if the guidelines are achieved'. As such, no costs associated with reduced surface water quality have been considered under the baseline case.

The Surface Water Assessment describes the likely impact of the Refined Project in relation to surface water volumes, quality and the cumulative impact on downstream water users. The main findings are that:

- The Refined Project will result in changes to the catchment areas for Yorks Creek, Swamp Creek, Bettys Creek and Main Creek, relative to the areas anticipated under current approvals – however the change in flows are less than the seasonal and annual variations in flow volumes observed when comparing dry and wet years. As such, it is predicted that the Refined Project will have a limited impact on waterway stability, scour potential, ecosystems and downstream users.
- The reduction in total contributions to the downstream Bowmans Creek and Glennies Creek catchments are negligible (less than 0.6%).
- Water quality impacts will be managed through the Mount Owen Water Management System over the life of the Refined Project (including erosion and sediment control measures and water quality monitoring), such that the Refined Project is considered to have negligible impacts to water quality on downstream watercourses.
- Private landowners along Main Creek will experience reduced flood peaks and flood durations as a result of the Refined Project. Overall, the Refined Project is considered to have negligible impacts on downstream water users.

These findings indicate that the impact of the Refined Project on surface water quality is anticipated to be negligible, relative to the baseline case. The implications of the Refined Project on surface water supplies are acknowledged, but not considered quantitatively in the CBA.

5.2.14 Subsidence

In instances where mining activity is likely to lead to subsidence, the implications of this effect should be included in a CBA.

In the context of this analysis, Umwelt has advised that no subsidence effects are anticipated under the baseline or Refined Project case, as a result of existing or continued open cut mining activity at Mount Owen. Accordingly, no costs have been included for this item in the CBA.

5.2.15 Carbon emissions

The continuation of mining activities will generate additional carbon emissions than in the baseline case. It is important to incorporate the costs of these additional emissions in the CBA. This requires estimates of the quantity of emissions in each scenario, along with an appropriate unit value of the social cost of an emission.

This analysis focuses on the valuation of 'Scope 1' and 'Scope 2' emissions. Scope 1 emissions incorporate all direct emissions from sources owned or controlled by Mount Owen, such as emissions from the combustion of diesel and release of fugitive emissions during the mining process. Scope 2 emissions encompass indirect emissions generated from use of electricity at the mine.

Scope 3 emissions managed by third parties were not assessed as:

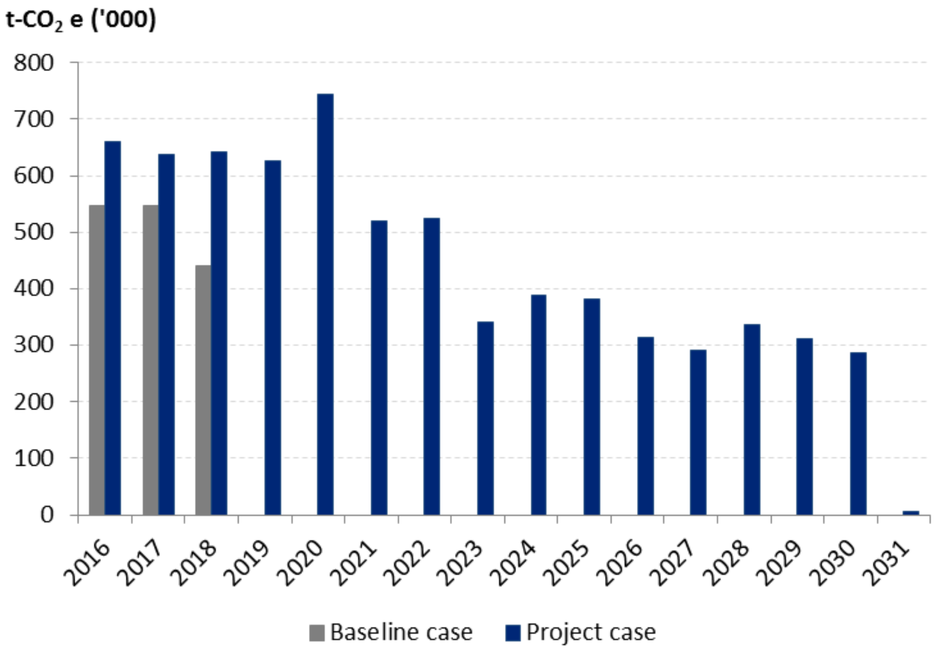
- it is methodologically unclear to what extent they should be included in a CBA;
- there is great difficulty in establishing a realistic baseline case for emissions; and
- there is a lack of data on emissions throughout the mining value chain.

An estimate of the total level of Scope 1 and Scope 2 emissions associated with the construction, operation and closure stages of the Refined Project were obtained from the updated Greenhouse Gas and Energy Assessment undertaken by Umwelt. Specifically, it is expected that the Refined Project will generate:

- approximately 4.7 million tonnes CO_2-e of additional Scope 1 emissions during the continued operations from 2016 to 2030;
- approximately 0.8 million tonnes CO_2-e of additional Scope 2 emissions during the continued operations from 2016 to 2030; and
- approximately 6,000 t CO2-e of additional Scope 1 emissions in 2031, during the closure phase of the Refined Project.

Given that the Refined Project is expected to involve extraction of an additional 86 Mt of ROM coal from 2016 to 2030, the average emissions per tonne of ROM during mining operations was estimated at 0.05 t CO_2-e for Scope 1 emissions and 0.01 t CO_2-e for Scope 2 emissions. This was then applied to the annual ROM estimates under the baseline and Refined Project case, to obtain estimates of annual emissions per year, under both cases from 2016 to 2030. These series are illustrated in Chart 5.10 below.

Chart 5.10: Predicted carbon emissions, 2016 – 2031



Source: Mount Owen; Umwelt

As described in Appendix C, it is appropriate to value carbon pollution using the observable market prices of carbon permits. Following the repeal of Australia's carbon pricing mechanism, this study utilises the forecasted European Union Emissions Allowance Units price, based on futures derivatives published by the European Energy Exchange.

This price series was used in the review of the NSW Energy Savings Scheme (NSW Government, 2015). The series assumes that the cost of carbon is included in wholesale electricity prices from 2021 onwards. When scaled up to 2015-16 price terms using the Consumer Price Index (ABS, 2016), the estimates increase gradually from \$8.65 / t CO_2-e in 2016 to \$13.60 / t CO_2-e in 2030. Recognising that this is conservative estimate of the cost of carbon, alternative price assumptions have also been considered in the sensitivity analysis presented in Chapter 7.

Overall, the social cost of carbon emissions is valued at \$12 million (\$13.7 million) under the base case, and \$47 million (\$73.5 million) in the Refined Project case, in present value (and undiscounted) terms. This implies that the additional social cost of carbon emissions under the Refined Project case is \$35 million (\$60 million).

5.2.16 Air quality impacts – particulate matter

The air pollution produced by mining activity and its impact on the built and natural environment, and the health in the surrounding area, is a key issue within the assessment of any mining project. Given that the health impacts of reduced air quality are generally considered to be most significant, the quantification of health costs is the focus of this analysis.

Particulate matter (PM) is often classified into one of the following three size ranges:

- TSP – total suspended particulate matter, which refers to all suspended air particles, with an aerodynamic diameter typically up to 30-50 micrometers;
- PM_{10} – coarse particulate matter, which includes all particles with an equivalent aerodynamic diameter of less than 10 micrometers; and
- $PM_{2.5}$ – all particles with an equivalent aerodynamic diameter of less than 2.5 micrometers, often referred to as fine particles.

As described in Appendix C, there are a number of important methodological issues to be considered when valuing the health impacts associated with these pollutants. Firstly, these pollutants are strongly correlated, making it very difficult to attribute health costs to the emissions of each individual pollutant without the risk of double-counting. The usual approach in valuation is to focus on one pollutant and indirectly capture part of the costs associated with other correlated pollutants.

The other key issue in valuation is the measure of the quantity of emissions. The literature discussed in Appendix C uses a number of measures, including the number of days pollution exceeds health guidelines, tonnes of emissions, and also annual average concentration levels.

For this revision, Pacific Environment (PEL) (2016) has produced a detailed analysis of the likely economic costs relating to particulate matter emissions from the Refined Project. This assessment is incorporated into the Response to PAC Review Report as Appendix 8. This estimate uses an approximation of the impact pathway approach to provide specific estimates for the Refined Project given its geographical location, its proximity to population centres and the potential effect of particular matter emissions.

The approach presented in the Pacific Environment report is considered to be preferable to that presented in other sources as it is specifically designed for the Refined Project and addresses some of the caveats on use that are mentioned in the PAEHolmes (2013) report.

Overall, drawing information from the Pacific Environment report indicates that the cost associated with the increases in $PM_{2.5}$ concentration under the Refined Project case is estimated at $4.6 million in present value terms ($7.8 million in undiscounted terms). It should be noted that these costs may differ from those reported in the Pacific Environment report as they are discounted to 2016 values in this report.

5.2.17 Air quality impacts – other pollutants

Mining activity is also associated with emissions of other air pollutants, such as nitrogen dioxide. Common sources of these pollutants include blasting fumes, diesel powered equipment and vehicle exhausts.

Particulate emissions from diesel combustion are captured in the assessment of particulate emissions discussed in Section 5.2.16.

The 2014 Pacific Environment Air Quality Impact Assessment (AQIA) for the 2014 Project assessed other potential air quality pollutants associated with diesel combustion on site and found that all were within accepted criteria (PEL 2014).

PEL (2014) also modelled potential NO_2 impacts associated with blasting assuming worst case fume scenarios. The purpose of this assessment was to identify whether potential exceedences were limited to specific meteorological conditions to enable the risk to be eliminated by avoiding blasts during these conditions. The AQIA found that potential exceedences were restricted to specific conditions and Mount Owen has committed to implementing specific controls for all blasts that could occur under these conditions. This is expected to eliminate the risk of NO_2 criteria being exceeded at any residences.

For these reasons, the potential costs of additional nitrogen dioxide, sulphur dioxide and carbon monoxide are acknowledged, but not considered quantitatively in this analysis.

5.2.18 Noise impacts

The community consultation undertaken as part of the 2014 Project has identified that the impact of noise pollution from continued mining operations is a key issue of concern to members of the local community. It is necessary to place a value on the noise impacts expected to be borne by local residents as part of the CBA.

The first step of the valuation process is to compare the levels of noise associated with mining activity under the Refined Project case, compared to the baseline where the Refined Project does not receive approval. This analysis utilises 10th percentile operational noise level predictions provided by Umwelt from the Noise Impact Assessment. These noise levels are measured in A-weighted decibels (dB(A)) for 112 residential properties in the vicinity of the Mount Owen Mine, for day, evening and night periods. Estimates are presented for three representative years in the Refined Project case (2016, 2020 and 2025). Additional modelling was available for community buildings and vacant land but has not been included in the valuation as the valuation is based on the effect of the noise on residents.

As expected, the data indicates that the noise levels experienced by a property are likely to vary between the day, evening and night periods. In order to assign a conservative value to the level of noise experienced as a result of mining activity, this analysis utilises the maximum predicted noise level experienced by each property, as an estimate for the general noise level experienced over the course of that year.

Next, for each property, the noise level which could be directly attributed to mining at Mount Owen was estimated by applying a 30 dB threshold, to account for the level of background noise which is likely to be experienced by residents in any case.

This background noise level is the minimum rating background noise level used in the EPA's Industrial Noise Policy, and has been confirmed by background noise monitoring to apply to the majority of the area surrounding the Refined Project.

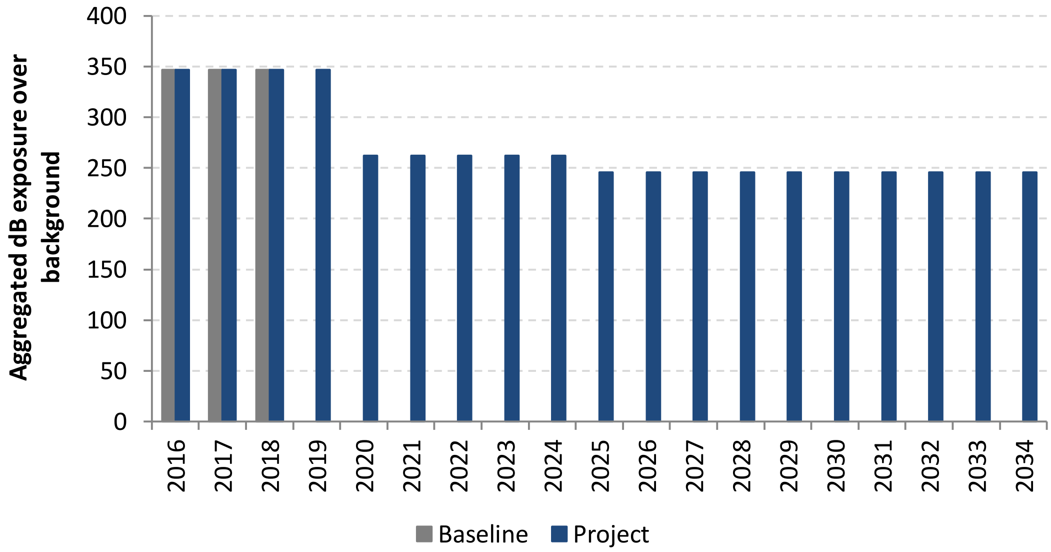
Under the Refined Project case, the total additional dB(A) exposure of the 112 residential properties for 2016, 2020 and 2025 was calculated by adding together these estimated property level noise exposures, attributable to Mount Owen mining operations for each year.

A Refined Project case time series of noise impacts was then developed by assuming no change in the level of exposure between the representative years. For example, it was assumed that the noise impacts in 2016 would remain constant out to 2019. In addition, noise impacts in the Refined Project case were extended out to 2034 to account for noise impacts during the closure phase. It is assumed that the noise exposure from baseline case production between 2016 to 2018 is consistent with predicted Refined Project case exposure in 2016.

These estimates are presented in Chart 5.11 below.

It should be noted that these aggregated values do not have a meaningful interpretation, as decibels are measured on a logarithmic, rather than a linear scale. Instead, the aggregates provide indicative estimates of the additional noise impacts that could be associated with the Refined Project, relative to the baseline.

Chart 5.11: Aggregated household dB exposure estimates (over background noise)



Source: DAE estimates, inputs from Noise Impact Assessment

Having identified the ‘quantity’ of noise pollution likely to be experienced in the baseline and Refined Project case, it is then necessary to apply a monetary value, representing the cost of an additional decibel of noise borne by a household.

This study applies a value of $63.58 per dB per household per year, based on the upper limit of the range recommended by Navrud (2002), converted to 2015 dollars. The recommendation was made to the European Commission DG Environment based on the results of a comprehensive literature review. This value was chosen due to its broad evidence base, and the inconclusive hedonic pricing findings for the Mount Owen region making it inappropriate to transfer an estimate from an out-of-context hedonic pricing study. The chosen value should be considered as indicative of the scale of noise related externality costs, not a precise valuation, particularly as it relates to traffic noise rather than the noise impacts of mining.

Applying this value to the aggregated dB exposure estimates yields a noise pollution cost of $0.05 million in present value terms in the baseline, and a cost of $0.16 million in the Refined Project case.

Noise impacts will be managed through:

- equipment location and scheduling;
- modification of operations during adverse meteorological conditions, if required;
- continuous and attended noise monitoring; and
- reviews of noise monitoring data and adaptive management.

In addition, specific mitigation measures will be implemented for properties located within the Management Zone, as determined by the Noise Impact Assessment. This includes a commitment to regular monitoring and management of noise impacts, residence specific management for some properties, and potential acquisition of three additional residential properties.

5.2.19 Visual amenity

It is recognised that mining activity has the potential to detract from the visual amenity of a community. The visual effects of converting an existing landscape to an area featuring emplacement areas, machinery, vehicles and artificial light are therefore important considerations for a CBA.

The affected area is currently surrounded by a mix of rural land and mining landscapes from Mount Owen along with other mines in the Ravensworth area (e.g. Integra and Ashton Coal Mines). Mount Owen's mining activities can currently be observed from the New England Highway, Main Northern Rail Line, and a number of surrounding properties. The visual amenity at night is currently affected by a night time glow from the mining operations in the region. To address this issue, Mount Owen has introduced directional lighting and management controls for mobile lighting.

Likely visual impacts of the refined Project have been assessed through a series of radial analyses, panoramic photographs and visual montages.

The radial analyses concluded that the Refined Project will not be visible from residences located in the Camberwell Village and north and east areas, but could affect the visual amenity of a small number of residences in the Middle Falbrook area. Specifically, three private residences and two public viewing locations were identified as having the highest potential for visual impacts.

These properties (in the Middle Falbrook area) and public roads were subject to a more detailed visual impact analysis. The impact analysis found that, out of the five locations listed above, only one private residence location and two public viewing locations (namely, the Middle Falbrook Road and Glennies Creek Road Intersection; and the Hebden Road and New England Highway Intersection) will have views affected by existing and proposed operations under the Refined Project. Therefore, the current visual impacts from Mount Owen under the baseline are expected to continue at a similar level in the Refined Project.

Umwelt expects that with ongoing rehabilitation as part of the Refined Project, the visual impacts of current mining operations will be reduced over time.

Mount Owen has incorporated measures to minimise the visual impacts of the Refined Project, including:

- progressive rehabilitation across all areas will reduce visible soil exposure;
- management of mobile lighting will reduce the impacts of lighting at night; and,
- all fixed lighting to follow *Australian Standard AS4282 (INT) 1995 – Control of Obtrusive Effects of Outdoor Lighting.*

For these reasons, no quantitative values have been assigned to this item in the analysis.

5.2.20 Traffic

The effect of the Refined Project on traffic constitutes another element for consideration in the CBA. In this analysis, there are a number of key impacts which should be accounted for. They are:

- the impact of additional vehicle journeys associated with construction and continued mining operations on the service level of local roads;
- the impact of the proposed two lane bridge on Hebden Road over Bowmans Creek on travel times and road safety; and
- the impact of the proposed Hebden Road overpass over the Main Northern Rail Line on travel times.

The Mount Owen Complex is located east of the New England Highway, between Singleton and Muswellbrook. Mount Owen Mine Access Road runs off Hebden Road, which connects with the New England Highway in two places. The first intersection is located immediately north of Lake Liddell, while the southern intersection is at Ravensworth. The majority of vehicles use this southern intersection point to access the Mount Owen Complex. Hebden Road is also used to access public properties, other industrial operations (such as quarries), and the northern side of Lake Liddell.

Operational phase impacts on service levels of local roads

According to the Traffic Impact Assessment, average daily traffic volumes on Hebden Road and Glennies Creek Road are moderate to low, (i.e. less than 1,400 vehicles per day). This is equivalent to a level of service (LoS) 'B' or better for rural roads, defined by Austroads.

Similarly, the Assessment found that the New England Highway intersections at Hebden Road and Glennies Creek Road are currently both operating with ample spare capacity, minimal delays and virtually no queues in peak times, with an 'A' LoS.

The Assessment found that as the Refined Project does not involve a change to operational staffing levels or shift times, there will be no adverse impacts on these existing acceptable traffic conditions and service levels during the continued mining operations. It is noted that while there is likely to be further improvements in traffic conditions beyond 2018 under the baseline case, any relatively longer travel times experienced under the Refined Project case are likely to be negligible.

Construction phase impacts on service levels of local roads

That said, it is also important to assess the impact of additional vehicles associated with the construction phase of the Refined Project, proposed to begin within 12 months of the commencement of mining beyond the currently approved mining. For the purpose of this analysis, it is assumed that this construction phase will begin in 2016.

The Traffic Impact Assessment reports the outcome of modelling of the impact of these vehicles on the Hebden Road and Glennies Creek Road intersections with the New England Highway. As described in the EIS, over the 18 month construction period, average delays will increase by between 0.2 and 4.1 seconds during the AM and PM peaks on weekdays. This will temporarily increase the travel times experienced by other users of the intersections during those times.

Based on estimates of the AM and PM peak two way traffic volumes at these two intersections from the Traffic Impact Assessment (presented in Table 5.4 and Table 5.5), these delays are estimated at 85 and 4 vehicle hours per year at the Hebden Road and Glennies Creek Road intersections respectively.

Table 5.4: Hebden Road – New England Highway Intersection traffic data

	Weekday AM Peak (6 - 7am)	Weekday PM Peak (6 - 7pm)
Two Way Traffic Volume	189	104
Proportion of medium / heavy vehicles	16%	22%
Average delay – baseline case	2.1 seconds	2.7 seconds
Average delay – Refined Project case construction phase	6.2 seconds	6.5 seconds
Additional delay during construction phase	4.1 seconds	3.8 seconds

Source: Traffic Impact Assessment (Appendix 16 of EIS)

Table 5.5: Glennies Creek Road – New England Highway Intersection traffic data

	Weekday AM Peak (6 - 7am)	Weekday PM Peak (6 - 7pm)
Two Way Traffic Volume	84	51
Proportion of medium / heavy vehicles	0%	2%
Average delay – baseline case	1.2 seconds	0.9 seconds
Average delay – Refined Project case construction phase	1.4 seconds	1.7 seconds
Additional delay during construction phase	0.2 seconds	0.8 seconds

Source: Traffic Impact Assessment (Appendix 16 of EIS)

As described in Appendix C, vehicle hours can be valued using a standard industry cost approach. This analysis utilises the following rural travel time values published by Transport for NSW (2013), updated to 2015 prices:

- $24.33 per vehicle hour for private cars;
- $33.72 per vehicle hour for light commercial vehicles; and

- $36.57 per vehicle hour for heavy commercial vehicles.

This analysis applies the private car value to the delay borne by light vehicles. An average travel time value of $34.45/hour for medium and heavy vehicles was derived using the average proportions of medium and heavy vehicles utilising rural roads, estimated by Transport for NSW (2013).

In addition, it is necessary to account for vehicle operating costs incurred while each vehicle is waiting for the level crossing to reopen. This analysis applies Transport for NSW's (2013) value of $9.62 per vehicle hour, (updated to 2015 prices) to all vehicle types.

The resulting estimates of additional travel time costs per year at each intersection, under the Refined Project case are presented in Table 5.6 below. Assuming that the construction phase begins in 2016, aggregating these costs for an 18 month period implies that the present value of additional travel time costs during the construction phase amount to $4,060 in present value terms, using a 7% discount rate. This has been included as a cost in the Refined Project case. It is noted that while this cost does not include any impacts outside the weekday peak hours, the magnitude of the peak hour costs suggests that this has no material impact on the conclusions of this analysis.

Table 5.6: Additional travel time costs during construction phase

Intersection	AM Peak Cost of Delay / Year	PM Peak Cost of Delay / Year
Hebden Road	$1,993	$1,033
Glennies Creek Road	$41	$101

Source: DAE estimates

Impact of proposed dual lane bridge over Bowmans Creek

The existing single lane bridge on Hebden Road over Bowmans Creek is located approximately 400m east of the existing Main Northern Rail Line level crossing. The Traffic Impact Assessment estimates that during the AM peak, southbound traffic is delayed by approximately 18.5 seconds on average, with queues reaching 28 metres 5% of the time. This is equivalent to LoS 'B'.

It is noted that the replacement of the existing bridge with a dual lane bridge will reduce travel times along Hebden Road further with preliminary estimates indicating that these are unlikely to exceed $22,000 in present value terms, using a 7% discount rate. This estimate has not been included in the analysis as it relies on the assumption that the average delay at the bridge under the baseline case is constant at the AM peak delay of 18.5 seconds, regardless of the time of day, and thus is likely to be overestimated.

It is also acknowledged that the new, wider bridge may improve road safety and reduce the incidence of vehicle accidents. To that extent, additional benefits would accrue under the Refined Project case. However, due to uncertainty regarding the likely prevalence of incidents on the bridge under the baseline and Refined Project case, this benefit is considered qualitatively.

Impact of proposed Hebden Road overpass

The most significant impact of the Refined Project on traffic and travel times is expected to be the construction of an overpass on Hebden Road over the Main Northern Rail Line. Currently, there is a rail level crossing where the line intersects Hebden Road. The Traffic Impact Assessment notes that approximately 100 trains utilise the crossing per day, with an average crossing closure time of 110 seconds per train. Based on this information, it is estimated that 12.7% of vehicles that travel across the railway line must stop while a train passes through.

Based on the average daily traffic volume of 1,318 vehicle journeys, this implies that the level crossing causes a total delay of 2,011 vehicle hours per year. It is estimated that 22.6% of this delay is borne by medium or heavy vehicles, consistent with the data available in the Traffic Impact Assessment.

Using the travel time values from Transport for NSW described above, it is estimated that the current level crossing imposes costs of $67,825 per year. This is valued in perpetuity from 2015 under the baseline case, producing a total cost of around $0.97 million in present value terms. Under the Refined Project case, the construction of the rail overpass is expected to eliminate these costs from 2018 onwards. As such, the travel time costs in the Refined Project case are lower at $0.23 million in present value terms.

Conclusion

Overall, the Refined Project is expected to reduce total traffic costs by around $0.79 million, in present value terms, taking into account the impact of construction phase traffic and the proposed Hebden Road Rail Overpass. This creates a benefit for the CBA.

5.2.21 Biodiversity (flora and fauna)

It is also necessary to compare the risks to biodiversity in both the baseline and Refined Project case as part of a CBA.

Umwelt has advised that the Refined Project will impact native woodland forest vegetation, along with native grassland. These areas include the following vegetation communities:

- Derived native grassland;
- Central Hunter Ironbark – Spotted Gum – Grey Box Forest endangered ecological community (EEC);
- Central Hunter Bulloak Forest Regeneration;
- Planted Ironbark – Spotted Gum – Grey Box Forest EEC;
- Central Hunter Swamp Oak Forest;
- Central Hunter Grey Box – Ironbark Woodland EEC;
- Kunzea Closed Shrubland; and
- Hunter Valley River Oak Forest.

The EECs noted above are state listed. There are no federally listed EECs located within the disturbance area.

A number of threatened species of flora and fauna have been identified in the disturbance area and broader Project Area. The Ecological Assessment (Appendix 11 of the EIS) found that, in particular, the vegetation community in the Central Hunter Ironbark – Spotted Gum – Grey Box Forest EEC (noted above), along with the following species have the potential to be significantly impacted by the Refined Project:

- spotted-tailed quoll (*Dasyurus maculatus*);
- squirrel glider (*Petaurus norfolcensis*);
- masked owl (*Tyto novaehollandiae*);
- brown treecreeper (*Climacteris picumnus victoriae*);
- speckled warbler (*Chthonicola saggitata*);
- grey-crowned babbler (*Pomatostomus temporalis temporalis*);
- varied sittella (*Daphoenositta chrysoptera*);
- hooded robin (*Melanodryas cucullata cucullata*);
- diamond firetail (*Stagonopleura guttata*);
- brush-tailed phascogale (*Phascogale tapoatafa tapoatafa*);
- yellow-bellied sheathtail-bat (*Saccolaimus flaviventris*);
- east coast freetail-bat (*Mormopterus norfolkensis*);
- southern myotis (*Myotis macropus*); and
- greater broad-nosed bat (*Scoteanax rueppellii*).

In order to mitigate against any potential biodiversity impacts, Umwelt has prepared a Biodiversity Offset Strategy, with the objective to "maintain or improve ecological features within the Refined Project Area and to compensate for unavoidable impacts on the ecological values of the proposed disturbance area". The strategy involves the creation of four offset areas, as listed in Table 5.7. It is anticipated that these offsets will be maintained in perpetuity from 2016 onwards.

Table 5.7: Proposed offset areas

Offset site	Area (ha)
Cross Creek Offset Site	367
Esparanga Offset Site	303
Stringybark Creek Habitat Corridor	97.5
Mitchell Hills	143.7

The offset strategy is designed to mitigate against any loss in biodiversity which may occur as a result of the Refined Project, relative to the baseline. Based on the information provided, the risks to biodiversity generated by the Refined Project are considered qualitatively in this analysis.

However, there are costs associated with the management of these offset areas. This analysis utilises a rate of $3,381 per hectare of land as an estimate of the lifetime costs of offset management, consistent with the NSW Office of Environment and Heritage Credit Calculator (2012), updated to 2015 prices.

Given that these costs are likely to be incurred from 2016, total offset management costs under the Refined Project case are estimated at $2.5 million in present value terms, using a 7% discount rate.

5.2.22 Conservation

It is also important to recognise the extent to which the Refined Project will affect conservation areas surrounding the mine.

The continuation of the North Pit, continued mining on previously disturbed land and other infrastructure works will not impact on the Mount Owen Mine Voluntary Conservation Area or any existing Biodiversity Offset Areas.

In contrast, four Biodiversity Offset Areas will be established as part of the Refined Project, in addition to those that currently exist under the baseline.

As discussed above, the costs associated with managing these areas have been included in the CBA under the biodiversity item, while the social value of these areas offsets the negative biodiversity impacts of the Refined Project. Therefore, to avoid double-counting, no quantitative values have been assigned to the conservation item in the baseline or Refined Project case.

5.2.23 Quality of open space

As described in Appendix C, valuation of impacts on the quality of open space incorporates two main elements – the visual amenity associated with the space, and the types of activities that are undertaken in the space. To avoid double-counting, this item is focused on the second component, since the visual amenity impacts of the Refined Project have been discussed in Section 5.2.19 above.

In the context of this Project, the Social Impact and Opportunities Assessment (SIOA) indicates that the Project Area is not utilised for recreational activities. Nearby sites used for recreation include the Lake Liddell Recreation Area, located to the west of the Project Area, and potentially the Ravensworth State Forest in the future, although the latter is currently part of Mount Owen's mining leases and is therefore unlikely to be used for recreation activities in the short to medium term. The Refined Project will not directly impact either site, or the level of public access to those sites, relative to the baseline case.

It is noted that access to the Lake Liddell Recreation Area from Hebden Road from the south would likely be affected during the construction period. However, any associated costs would be more than offset by the reduced travel times as a result of the Hebden Road Rail Overpass and dual lane bridge over Bowmans Creek from 2018 onwards. Furthermore, it is noted that the Lake Liddell Recreation Area is also accessible on Hebden Road from the north, providing an alternate route during the construction period.

Based on this evidence, it is considered that the Refined Project is unlikely to cause a material change in the ability of local residents or visitors to use the open spaces surrounding the Project Area for other activities. Accordingly, no quantitative values have been assigned to this item in the baseline or Refined Project case.

5.2.24 Rural amenity and culture

The impact of a proposal on rural amenity and culture should also be considered where a project is likely to affect the composition of the community.

The SIOA includes an assessment of the social risks of the Refined Project, within the Upper Hunter region. The aspects considered relevant to rural amenity and culture include:

- impacts of population change;
- impacts on community and infrastructure services;
- sense of community and cohesion; and
- community sustainability and intergenerational equity.

As described in the SIOA, the mitigated technical risk for each of these areas was rated as low, in cumulative terms, taking into account the existing mining activities within the region.

Given the prominence of the mining industry in the Hunter Valley it is difficult to attribute a cost of this impact to the Refined Project specifically. However, one potential approach is to quantify the costs associated with an additional family relocating out of the local area. While it is difficult to determine the number of people who would choose to relocate as a direct result of the Refined Project, the number of additional residential properties which meet acquisition criteria due to Project impacts can be used as a proxy measure.

This is a proxy measure only, as, in the first instance, it is uncertain whether property owners would choose to trigger those rights and relocate. Secondly, Mount Owen has indicated that should it acquire the property, it would attempt to lease it out for residential purposes, as it has done with a number of other residences.

Those points noted, in the context of this study, Umwelt has indicated that a total of three additional, privately owned residential properties are predicted to meet acquisition criteria in relation to air quality and/or noise impacts of the Refined Project.

The next step is to apply a monetary value. Appendix C describes some studies which have attempted to estimate the value of maintaining rural communities. This analysis utilises the results of a choice modelling study undertaken by Bennett, van Bueren and Whitten (2004). As this study was undertaken for a different policy context than that considered in this analysis (the effects of increased environmental protection on rural populations, rather than continued mining activity), it provides an indicative value of the impact of the Refined Project on rural amenity and culture.

As described in Appendix C, the study undertook a number of surveys to illustrate the variation in willingness to pay estimates for different policy contexts. Using a general survey at the national level, it was found that Australian households were willing to pay an average of $0.09 per year, over a twenty year period, to prevent 10 people leaving rural communities across the country. A separate, region-specific survey of households in Rockhampton found that they were willing to pay $2.24 per year over twenty years, for every ten people leaving the Fitzroy Basin region.

The difference in these estimates is likely to reflect a combination of both higher costs borne by the Rockhampton community, compared to the national average; and the impact of more specific questions used in the regional survey, compared to the general questions used in the national survey. As such, it is inappropriate to aggregate the values from the regional survey beyond a regional population.

In the context of this analysis, the results of the study present two options for valuation of the impact of the Refined Project on rural amenity and culture. In the first instance, it is plausible to aggregate the national estimate for all households in Australia. Alternatively, the regional value can be aggregated for all households in the Hunter Valley / Newcastle area. This analysis uses the results of the former approach, as it generates a more conservative estimate of costs.

The first step in this valuation process is to convert the value of $0.09 per year over twenty years, into a one-off payment. Using a perpetuity formula and a discount rate of 7%, this was converted into a cost of $0.95 per household, measured in 2004 prices. Inflating this value to 2015 prices produced a value of $1.27 per household, for every ten people leaving a rural community. This was then converted into a cost per person leaving the community of $0.13 per household.

Based on the number of residences likely to meet acquisition criteria (three) and the average household size in the Singleton LGA, based on 2011 Census data (2.7), it was estimated that, on average, 8.1 people might relocate from the immediate surrounding area as a result of the Refined Project. Using the household cost of $0.13 per person relocating, this implies a total cost of $1.03 per household in Australia. Applying this value to the number of households in Australia as at the 2011 Census (9.1 million) produces a national cost estimate of $9.3 million. It is assumed that the acquisition rights for each property would be granted from Project approval. Given the uncertainty around approval timelines, acquisition is assumed to take place towards the end of 2016 for the purpose of this analysis. Accordingly, this cost was then discounted back to $8.6 million in present value terms, using a 7% discount rate.

It is evident that this valuation involves a number of assumptions. Accordingly, this final estimate should be interpreted as an indicative value of the rural amenity and culture impacts of the Refined Project, particularly for the following reasons:

- The context of the survey undertaken by Bennett, van Bueren and Whitten is quite different from the context of this study – trade off for a reduction in rural populations was the implementation of environmental protection strategies. In the context of mining activity, it is likely that the costs associated with a decline in rural communities would be higher.
- This analysis assumes that the number of households in Australia in 2016 is the same as the number of households reported in the 2011 Census. This also has the effect of underestimating the social costs.
- It is also uncertain whether it is appropriate to apply the values obtained from the survey so far into the future. Assuming that the survey was undertaken in 2004, the twenty year time period for which the reported values apply to ends in 2024. Future generations might experience costs that are smaller or larger than those reported in this analysis.

- As noted above, it is possible that the Refined Project would not directly cause any families in the local community to relocate, which would not otherwise do so under the baseline case.
- Also, these costs may be offset to some extent by community investments made by Mount Owen over the course of the Refined Project, such as support for Mount Pleasant School.

5.2.25 Aboriginal heritage

Aboriginal heritage sites are associated with substantial historical, cultural and scientific value. Where a proposal is anticipated to damage these sites, it is critical that these impacts be considered in a CBA to adequately account for the costs of the Refined Project.

The Mount Owen Mine, along with the proposed North Pit Continuation Area are located in the centre of the traditional country of the Wonnarua people, which is also part of the Wanaruah Local Aboriginal Land Council.

To assess any potential effects of the Refined Project on these areas, Mount Owen undertook an Aboriginal Cultural Heritage Assessment (ACHA) in consultation with relevant Registered Aboriginal Parties (RAPs).

The cultural heritage assessment has shown that the wider regional cultural landscape surrounding the Project Area does hold high cultural and historical significance to Wonnarua people. The landscape within the Project Area however is highly disturbed and fragmented, resulting in much of the past archaeological record already having been lost by agriculture and coal mining. The cultural heritage assessment found that the archaeological sites and the remnant cultural landscape within the Project Area have undergone considerable modification since European settlement and are therefore of lower cultural significance than the surrounding region. Thus, there are no adverse impacts affecting the areas of higher regional significance sites under the baseline or the Refined Project case. The basis for the assessment and its findings are described in more detail below.

The significance of cultural heritage values was assessed through the meaning of all aesthetic, historical, scientific, social and spiritual values that a place or object embeds. In addition, outstanding features, such as rarity, representativeness and conditions, integrity and authenticity, are used to indicate the place or object's degree of cultural significance. Based on this analysis, the following cultural heritage values of medium or high significance have been found in the region:

- **Prominent visual landmark (aesthetic value)**: two prominent landmarks, Bowmans Creek and the remnants of Bettys Creek, have been identified in the region – *high* regional significance, *low* Project Area significance.
- **Relationship with key events or themes in history (historic value):** The wider region is significant for the very early documented interactions between white settlers and Aboriginal peoples, and is the canvas for stories of contact, conflict, death, and dispossession. It is also the backdrop for a narrative of survival, cultural adaption and the on-going interaction of Wonnarua people with the non-Aboriginal community – *high* regional significance, *medium* Project Area significance.
- **Area showing creative or technical achievement (historic value):** within the Project Area, the archaeological sites are typical of assemblages and artefact types in this

region, and there is no other physical evidence of creative or technical achievement within the Project Area– *high* regional significance, *low* Project Area significance.

- **Patterns in the development of history (historic value):** the Project Area once formed part of the Ravensworth Estate, which has long and deep historical associations with many Wonnarua people. The association with early settlers features in recounted stories of frontier conflict, dispossession, but also of survival, adaption and the persistence of Wonnarua people – *high* regional significance, *medium* Project Area significance.
- **Project area important as a local marker or symbol (social value**): there does not appear to be any unique cultural markers or symbols within the Project Area, however, the landscape in its entirety was part of a totemic and culturally rich landscape to Wonnarua people. There are places within the wider region that are generally of greater significance – *high* regional significance, *low* Project Area significance.
- **Contribution to the spiritual identity or belief system of a cultural group (spiritual value)**: the Project Area is a component of the identity and belief systems of many of the Wonnarua people – medium regional significance, medium Project Area significance.
- **Contribution to investigation, to provide more understanding about people or places, which is not currently available (scientific value):** there is limited research potential for the archaeological sites identified within the Project Area. There is some potential for research into Traditional Ecological Knowledge in the Project Area and surrounds – *medium* regional significance, *low* Project Area significance.

In terms of the scientific value from archaeological sites, the disturbance area contains 34 Aboriginal archaeological sites. However, the scientific significance of these sites is low due to clearance of trees and major soil loss, as well as existing mine infrastructure, revegetation and previous archaeological salvage. The concentration of mining has initiated many archaeological salvage programs that have effectively removed well over half of these archaeological site types from the surrounding region. Another eight sites that were identified outside of the disturbance area will not be affected by the Refined Project.

Having established the presence of items of heritage value, the next issue is whether a monetary value can be reasonably placed on those items. To quantify the values people place on heritage sites, stated preference techniques are the predominant method used to eliciting willingness-to-pay estimates through surveys. However, as described in Appendix C, very little research has been undertaken in the Australian context.

A review of available studies in EVRI identified two sources, both of which relied on choice modelling. The first, Rolfe and Windle (2003), assessed the value of protecting an additional 1% of Aboriginal Heritage sites in Central Queensland and found that local Aboriginal communities placed a positive value on protecting Aboriginal heritage but that the general population did not. The other study is based on a choice modelling survey of NSW households undertaken by Gillespie (2009). This study found a value of $29.71 per household per significant Aboriginal site removed.

As described in Appendix B, there are a number of issues which should be noted in using and interpreting the results of contingent valuation or choice modelling surveys:

- By measuring willingness to pay for the conservation of Aboriginal sites, the survey identifies non-use benefits that may not be revealed through actual choices to visit heritage sites. This figure indicates the total value to people in the state of knowing that a site hasn't been destroyed and isn't dependent on the use or access to that site.

- The extent to which it is appropriate to apply the values derived from a small survey to the broader population is uncertain.
- The nature of the questions asked will determine the relevance of the site being valued across respondents, e.g. a Sydney resident may place a different value on the removal of an Aboriginal heritage site than a Singleton resident. The valuation on the importance of heritage may also vary between sites.

As such, it is difficult to obtain an accurate valuation for Aboriginal heritage sites relevant to this Project. Therefore, the impact of the Refined Project on Aboriginal heritage is acknowledged qualitatively only in this analysis. There are a number of management measures that will be undertaken to preserve heritage values in the Project Area as outlined in the ACHA (refer to the EIS).

5.2.26 Historic heritage

Similarly, it is also important to consider the impacts of a proposal on European heritage sites, relative to the baseline. To do so, this analysis relies on the findings of the Historic Heritage Assessment (refer to the EIS). The Assessment identifies the likely impact on nine listed heritage items and eleven unlisted areas with potential heritage value.

It was found that the Refined Project would have no direct or indirect impact on any of the listed heritage items, as they are all located outside the Project Area, and are not expected to experience significant ground vibration levels. That said, given the proximity of one listed item, the former Ravensworth Public School, to the proposed Hebden Road Rail Overpass, Mount Owen has proposed to survey the surface of the land on the north side of Hebden Road (within the proposed disturbance area) for items that might be associated with the site, and to develop protection or mitigation plans in consultation with the Heritage Division of the Office of Environment and Heritage if potential items are found. For these reasons, no costs to listed heritage sites have been included in the CBA.

With respect to the identified potential heritage items, nine of the eleven items have been identified within the Project Area, with three of those within the proposed disturbance area. Each item has been assessed as having no significance with no research potential, apart from the Ravensworth Village, which is located within the disturbance area. However, it is acknowledged that the former Hebden Public School site and John Winter Memorial site are considered to be of local significance, primarily in terms of their potential associative and social significance.

Specific proposed management measures with respect to these sites of potential significance are described below.

Ravensworth Village: an area approximately 180 x 100 metres located to the south of Hebden Road will be disturbed as a result of the proposed Hebden Road Rail Overpass. Although part of this area has been previously disturbed, it has the potential for a locally significant archaeological resource. Management measures include:

- documentation of an archaeological work method statement, to be endorsed by the Heritage Branch of the Office of Environment and Heritage;

- an on-site archaeological investigation of the proposed disturbance area, prior to the construction of the overpass, including a machine stripping of the grass cover and recording and hand excavation of any identified archaeological remains; and
- machine excavation of a series of test trenches to identify the potential for surviving archaeological remains surviving.

Former Hebden Public School site: this is located within the north-west corner of the Project Area, approximately 880 metres north-west of the proposed Bayswater North Pit. A structural analysis of the site identified that the predicted maximum ground vibration at the site as a result of blasting at the proposed BNP is 6.3 mm/s well below the limit of 16-19 mm/s. As such, there are not expected to be any impacts (either direct or indirect as a result of vibration from blasting).

John Winter memorial site: the memorial and potential grave site are within the north-west corner of the Project Area, approximately 880 metres north-west of the proposed Bayswater North Pit. Vibration limits at the site have been identified as 250 mm/s. The predicted maximum ground vibration at the site as a result of blasting at the proposed BNP is 6.4 mm/s. As such, there are not expected to be any impacts (either direct or indirect as a result of vibration from blasting).

Overall, it is considered appropriate not to place any quantitative value on the impact of the Refined Project on historic heritage, given that there are no known heritage sites which will be affected. That said, the potential for heritage items to be located at the former Ravensworth Village site is acknowledged. As the extent to which heritage items are located at in this area remains uncertain, and that management measures will be put in place to mitigate these risks, it is not considered necessary to quantify these potential losses.

That said, based on the value of heritage sites estimated by the Allen Consulting Group (2005), as described in Appendix C, the costs to NSW as a result of the impact on the area of land within the former Ravensworth Village are likely to be less than $0.69 million in present value terms, using a 7% discount rate. However, this valuation implicitly assumes that the area to be disturbed is a known heritage site, and ignores the interpretation issues identified by the Productivity Commission in its Inquiry into Conservation of Australia's Historic Heritage Places (2006). As such, the impact of the Refined Project on areas of potential local heritage significance is considered qualitatively in this analysis.

5.2.27 Health

The final element which should be considered in a CBA is the impact of mining activity on the health of local residents and employees of the mine.

However, it is not appropriate to consider this item separately in this analysis, given that health impacts are explicitly captured in the valuation of air pollution, and to some extent, implicitly captured in the costs of noise pollution. In particular, the Pacific Environment (2016) report used in Section 5.2.16 specifically estimates particulate matter costs based on the potential health impacts of particulate matter emissions.

5.3 Overall CBA results

Given the values assigned to each cost and benefit in Section 5.2, the next stage of the CBA is to compare the baseline and Refined Project cases and obtain a consolidated estimate of the net economic benefit of the Refined Project. This assessment is directly related to the DGRs which include a detailed assessment of the costs and benefits of the development as a whole.

Table 5.9 on the following page presents the incremental benefits and costs associated with each item considered in the previous section, measured in NPV terms using a 7% discount rate. A 7% discount rate is the standard discount rate recommended by the NSW Government (2007).

The additional gross mining revenue expected as a result of the open cut mining continuation is the main incremental benefit of the Refined Project in relation to the baseline case.

On the other hand, some of the key incremental costs of the Refined Project are the additional operating costs and capital investment borne by Mount Owen, along with the negative externalities associated with carbon emissions and particulate matter.

These outcomes lead to a total net benefit of the Refined Project of approximately $857 million.

The approach to this analysis allows this figure to be compared to the results in the previous CBA. To make this comparison, the difference in timing between the two assessments must be accounted for (this assessment calculates the NPV in 2016 while the previous report calculated the NPV in 2014). The net present value in the previous CBA was estimated at $758 million, this increases to $769 million in 2015 dollars and then to $880 million after accounting for the difference in NPV dates. This shows that the net benefits estimated in this report are somewhat lower than those provided in the previous economic assessment which reflects the reduction in value due to the changes between the 2014 Project and the Refined Project.

Table 5.8 illustrates the variation in these results using alternative discount rates of 4% and 10%. It is noted that this lower bound rate of 4% is recognised in the literature as a reasonable discount rate to use when there is an interest in incorporating intergenerational concerns (Arrow et al, 2012).

Table 5.8: CBA results

Discount rate	Total net benefits ($m)
4%	1,077.3
7%	857.2
10%	689.4

Source: DAE calculations, discounting back to start of 2016

The DGRs seek "a detailed assessment of the costs and benefits of the development as a whole", the total net benefit figures presented in this section are considered to be the most appropriate measure for assessing the costs and benefits of the development as a whole.

Table 5.9: Incremental benefits and costs

No.	Item	Baseline NPV ($m)	Proposal NPV ($m)	Incremental benefit ($m)	Incremental cost ($m)
1	Gross mining revenue	1,365.12	4,622.4	3,257.2	-
2	Other onsite revenue	-	-	-	-
3	Exploration costs	-	-	-	-
4	Capital investment costs	0.00	140.0	-	140.0
5	Operating costs excluding taxes	738.9	2,937.8	-	2,198.9
6	Rehabilitation costs	2.5	12.1	-	9.6
7	Decommissioning costs	49.1	51.6	-	2.4
8	Residual value of capital	0.0	0.0	0.0	-
9	Residual value of land	5.9	6.7	0.8	-
10	Offsite agricultural revenue*	-	-	-	-
11	Related public expenditure*	-	-	-	-
12	Groundwater quality*	-	-	-	-
13	Surface water quality*	-	-	-	-
14	Carbon emissions	12.0	46.8	-	34.8
15	Air quality impacts – particulate matter	-	4.6	-	4.6
16	Air quality impacts – other pollutants*	-	-	-	-
17	Noise impacts	0.1	0.2	-	0.1
18	Visual amenity*	-	-	-	-
19	Traffic costs	1.0	0.2	0.8	-
20	Biodiversity	0.0	2.5	-	2.5
21	Conservation*	-	-	-	-
22	Quality of open space*	-	-	-	-
23	Rural amenity and culture	0.0	8.6	-	8.6
24	Aboriginal heritage*	-	-	-	-
25	European heritage*	-	-	-	-
26	Health*	-	-	-	-
				3,258.8	2,401.6

Source: DAE calculations – note numbers may not add due to rounding

NPV measured in real 2015 dollar terms, as at the end of 2016, using a 7% discount rate

* Considered qualitatively

6 Benefits to NSW

6.1 Introduction

While a CBA provides a clear picture of the overall benefits and costs of the Refined Project, it is not well suited to show that costs and benefits are distributed between the different stakeholders. For example, some of the costs of the negative externalities are borne by the local community, while the benefits of increased taxation accrue to the NSW and Australian Governments. These regional benefits are considered in the following sections.

This section presents the results of the cost benefit analysis at the project level but focussing on the share of each item that is attributable to NSW. The benefits to NSW have been identified as:

- Net producer surplus
- Royalties
- Company income tax
- Economic benefit to existing landholders
- Economic benefit to workers
- Economic benefit to suppliers
- Net environmental, social and transport-related costs
- Net public infrastructure costs

Each of these categories is composed of items from the project level CBA. This relationship is summarised in the following table:

Table 6.1: Benefit and cost items considered in the CBA

Item	Benefit components	Cost components
Net producer surplus	Gross mining and other revenue	Operating costs
	Residual value of land	Capital costs
	Residual value of capital	Exploration costs
		Decommissioning costs
		Environmental mitigation costs
		Transport management costs
		Rehabilitation costs
		Purchase costs for land
		Related public expenditure
		Taxes (Australian, state and local)
		Royalties
Royalties	Royalties payable to NSW Government	
Company income tax	NSW's share of company income tax payable to the Australian Government	
Economic benefit to existing landholders	Payments to existing landholders	Opportunity cost of land
Economic benefit to workers	Wages paid to workers	Foregone wage
Economic benefit to suppliers	Revenue paid to suppliers	Opportunity cost of supplier goods and services
Net environmental, social and transport-related costs		Carbon emissions
		Air quality
		Traffic
		Noise
		Biodiversity, Conservation and Open Space*
		Ground and surface water*
		Subsidence*
		Aboriginal heritage*
		Non-Aboriginal heritage*
		Visual amenity*
		Health*
		Rural amenity and Culture

* Item has been considered qualitatively

6.2 Costs and benefits to NSW

6.2.1 Net producer surplus attributable to NSW

As Mount Owen Pty Limited is ultimately owned by Glencore plc, a listed company, we have assumed that 0% of the net producer surplus will remain in NSW. This is a conservative assumption as it is possible that some of the firm's ultimate shareholders are located within NSW. As a result, there is no net producer surplus of the Refined Project attributable to NSW.

6.2.2 Royalties

The Refined Project is estimated to generate around $259 million (in present value terms) in additional royalties for the NSW Government, relative to the base case

This estimate incorporates allowable deductions of $3.50 per tonne of product coal that is subjected to a full cycle of washing. However, the estimate excludes potential for further deductions related to payment of levies, insurance and other items such as bad debts and bank commissions, due to the variability in such payments and the difficulty to forecast them accurately over time. These deductions are unlikely to have a large effect on the estimated royalties as they are removed from gross revenue before calculating royalties payable, not removed from royalties payable.

The components used to estimate royalties are presented in Table 6.2. These include:

- Revenue from the sale of coal product over the life of mining operations in the base case and Refined Project case (from 2016) using the price and quantity assumptions detailed previously.
- Allowable deductions for beneficiation in each case, on the basis that all product coal will be subject to a full cycle of washing. These deductions were calculated at the rate of $3.50 per tonne of product coal, as prescribed in Schedule B of the Determination under Section 283(5) of the Mining Act 1992 (Minister for Mineral Resources, 2008).
- Net disposal value, calculated as the difference between annual gross mining revenue and the total value of allowable deductions.
- Annual royalty payments, calculated using the ad valorem 'Open Cut Royalty rate' of 8.2% of the net disposal value for each year, as specified in the Mining Regulation.
- The undiscounted value of royalty payments was obtained by taking the total sum of annual royalty payments. The NPV estimate was produced by taking the present value of the annual royalty payments using a 7% discount rate.

Comparing estimates for the base case and Refined Project case indicates the net increase in royalties payable to the NSW Government.

Table 6.2: Estimation of additional royalties ($m, 2015 prices)

Estimate	Base case ($m, NPV)	Refined Project case ($m, NPV)	Incremental benefits ($m, NPV)
Coal Production (Mt)	14.2	62.13	47.88
Gross mining revenue ($m) (R)	$1,365	$4,622	$3,257
Total allowable deductions for beneficiation ($m) (D) (@ $3.50 per tonne)	$44	$145	$101
Net disposal value ($m) (R – D)	$1,321	$4,477	$3,156
Total royalties ($m) (R – D) * 8.2%	$108	$367	$259

Note: NPVs have been calculated using a 7% discount rate

6.2.3 Company income tax payable

The net increase in company income tax payable to NSW is estimated at $71 million in present value terms.

This estimate was produced by applying the 30% corporate tax rate to an estimate of taxable income in each year. For the purpose of this analysis, taxable income was estimated as gross mining revenue, less total costs (inclusive of FOB costs, rehabilitation and decommissioning costs, environmental mitigation costs and property acquisition costs), royalties and depreciation. Calculations of annual income tax payable also took into account accrued tax losses. The exclusion of interest deductions indicates that these estimates are likely to be somewhat overestimated.

Income tax payable to NSW was then estimated on the basis that NSW accounts for 32% of the Australian population and so receives around 32% of all income tax payments generated within the state.

6.2.4 Benefits to existing landholders

Net benefits of the Refined Project to existing landholders in the surrounding area depend on any changes to the productivity of land or purchases of landholdings. Based on the results presented in the project CBA, there is not expected to be any benefits or costs to existing landholders in terms of productivity.

In terms of landholding, any payments made to landowners, are assumed to be made at market value, such that there is no additional surplus for those landholders.

6.2.5 Benefits to workers

Net benefits to workers include any wage premiums paid to workers in the Refined Project above the minimum (reservation) wage that workers would accept elsewhere in the mining sector.

It is conservatively assumed that workers employed by the Refined Project are not expected to receive a wage premium. This assumes that workers will receive a wage consistent with market rates. To provide an illustration, an average net market wage for the industry is estimated to be $74,493. This represents the average annual income in the mining industry within the Lower Hunter region as at the 2011 Census (ABS) adjusted to 2015 prices using the Private Sector Mining Wage Price Index (ABS, 2016), and discounted for predicted income tax payable using ATO (2016).

This approach assumes that there is no wage increase for workers already working in the mining sector and any wage increase accrued from gaining employment in the Refined Project from outside the mining sector or from other areas of NSW is compensation for changes in working conditions, rather than a wage premium.

6.2.6 Benefits to suppliers

To estimate the net benefits to suppliers it is necessary to examine the extent to which the Refined Project will deliver additional producer surplus relative to what they would otherwise receive in the base case.

Due to weakening global coal prices, a number of mines in NSW are currently operating at sub-economic levels, despite productivity and efficiency gains across the sector. To the extent that those mines cease operations, there is likely to be some flow on impacts for suppliers. Accordingly, it is conceivable that the Refined Project could deliver an additional benefit to suppliers relative to the base case.

However, as the outcomes for suppliers under the base case are not readily observable, this benefit is difficult to measure. Accordingly, it is conservatively assumed that suppliers to the Refined Project will earn similar margins relative to what they could have received from other sources under the base case.

6.2.7 Net environmental, social and transport costs

It is estimated that the Refined Project will generate net environmental, social and transport costs of $47 million, in present value terms. Around $18 million of these costs are attributable to the NSW community (see Table 6.3). This overall result is summarised in the table below.

Table 6.3: Attribution of environmental, social and transport costs to NSW

Item	Total incremental cost ($m, NPV)	NSW community share (%)	Incremental cost to NSW ($m, NPV)
Aboriginal heritage*	-	-	-
Air quality	4.59	100%	4.59
Biodiversity, conservation and open space*	-	-	-
Carbon emissions	34.82	32%	11.14
Ground and surface water*	-	-	-
Health*	-	-	-
Historic heritage*	-	-	-
Noise	0.10	100%	0.10
Rural amenity and culture	8.60	32%	2.75
Subsidence*	-	-	-
Traffic	-0.79	100%	-0.79
Visual amenity*	-	-	-
Net environmental, social and transport costs	**47.34**	**-**	**17.81**

Source: Deloitte Access Economics calculations

* Considered qualitatively

6.3 Overall results

It is estimated that the Refined Project will deliver a net economic benefit to the NSW community of approximately $312 million (in present value terms).

Table 6.4 presents the overall results of the CBA for the NSW community, while Table 6.5 provides a detailed summary of the results by item. Each estimate is measured in NPV terms, calculated using a 7% discount rate.

The additional royalties to the NSW Government is the main incremental benefit to NSW of the Refined Project in relation to the base case. The key incremental costs of the Refined Project (within the NSW community) are the additional external costs, such as the cost of greenhouse gas emissions.

Table 6.4: Overall CBA results for NSW community

Discount rate	Overall net benefit of Project for NSW community ($m, NPV)
4%	383.2
7%	311.7
10%	257.4

Source: Deloitte Access Economics calculations

Table 6.5: Breakdown of CBA results by item

Item	Incremental effect ($m, NPV)	NSW community share (%)	Net benefit to NSW ($m, NPV)	Net cost to NSW ($m, NPV)
Royalties	259	100%	259	
Company income tax	221	32%	71	
Net environmental, social and transport costs	47	See Table 6.3	-	18
Total			**330**	**18**

The DGRs seek "a detailed assessment of the costs and benefits of the development as a whole, and whether it would result in a net benefit for the NSW community", the total net benefit figures presented in this section are considered to be the most appropriate measure of the net benefits for NSW.

7 Sensitivity analysis

The CBA results presented above are subject to the assumptions and valuations applied to each cost and benefit, as outlined in Section 5.2. Accordingly, it is necessary to test the sensitivity of the estimate of net economic benefit by varying the size of a number of parameters of interest. This provides an insight into the range of possible outcomes that could be expected from the Refined Project, given a number of different scenarios. The importance of testing scenarios is also recognised in the NSW Government Guidelines for Economic Appraisal (NSW Treasury, 2007).

7.1 Project level

The approach to sensitivity analysis in this section is in line with the approach set out in the NSW Department of Urban Affairs and Planning (2002) Guidelines. That is, they focus on the sensitivity of the overall project level results. The sensitivity analysis in this section takes the results from Section 5 as its starting point.

The variations undertaken as part of this analysis include:

- increasing coal price forecasts by 10% from their 2014 level;
- decreasing coal price forecasts by 35% from their 2014 level;
- increasing Project capital investment by 25%;
- decreasing Project capital investment by 25%;
- increasing the estimate of operating costs per tonne by 10%;
- decreasing the estimate of operating costs per tonne by 10%;
- pricing the cost of carbon according to alternative prices used in the Australian Treasury Clean Energy Future Policy Scenario (around 300% higher than the prices used in the central case scenario, on average); and
- pricing the cost of carbon according to alternative US EPA Social Cost of Carbon estimates (5% discount rate scenario) (around 80% higher than the prices used in the central case scenario, on average).

The sensitivity ranges for the export coal prices were arrived at through an analysis of data over the period from January 1995 to April 2016. Specifically, the range used covers approximately 67% of the range of historical monthly coal prices over this period. The minimum price in the lower sensitivity scenario, forecast for 2016, is placed at around the 16th percentile of historical coal prices. Meanwhile, the maximum price in the upper sensitivity scenario is placed around the 83rd percentile.

The alternative prices for the cost of carbon have been identified in the Review of the NSW Energy Savings Scheme (NSW Government, 2015). As the cost of carbon series used in both the central case of the CBA and this sensitivity analysis rely on assumptions that are not completely transferable to the Australian context, the sensitivity analysis series have been used to provide a range of the potential costs associated with greenhouse gas emissions.

A comparison of the total net benefits of the Refined Project obtained in each of these scenarios, using a 4%, 7% and 10% discount rate is presented in Table 7.1 below.

Table 7.1: Sensitivity Analysis – comparison of Total Benefits

Parameter	Variation in Parameter	Total Net Benefits ($m)		
		4%	7%	10%
Central CBA	N/A	1,078	857	689
Coal price forecasts	+ 10%	1,477	1,183	959
	- 35%	-320	-283	-254
Project capital investment	+ 25%	1,041	822	656
	- 25%	1,114	892	723
Operating costs per tonne	+ 10%	842	665	531
	- 10%	1,314	1,049	848
Cost per tonne of carbon emissions	Australian Treasury Clean Energy Future Policy Scenario prices (approx. + 300%)	962	766	616
	US EPA Social Cost of Carbon prices 5% discount rate scenario (approx. + 80%)	1,040	827	665

Source: DAE calculations, discounting back to start of 2016

While the above sensitivity scenarios have not been developed with a view to considering situations where, for example, coal prices are lower and operating costs are higher at the same time, the possibility of these circumstances does bear some discussion:

- High coal prices are most likely to be associated with higher operating costs and capital costs. High coal prices will tend to bring online existing coal producers and will also tend to drive up the price of inputs to coal production. This was the case in 2008-2010 when an increase in costs and prices were seen at the same time.
- The social cost of carbon should be relatively independent from short run fluctuations in price. Modelling of the social cost of carbon should take into account the long run costs of carbon emissions on the economy rather than short term fluctuations. However, experience in carbon markets following the Global Financial Crises indicates that short term reductions in output can be correlated with large reductions in market prices of carbon emissions.

7.2 Benefits to NSW

The approach to sensitivity analysis in this section is in line with the approach set out in the 2015 Guidelines (NSW Government 2015) and focusses on the sensitivity of benefits to NSW.

The variations undertaken as part of this analysis are:

- increasing coal price forecasts by 10% from their 2014 level;
- decreasing coal price forecasts by 35% from their 2014 level;
- increasing incremental royalties by 25%;
- decreasing incremental royalties by 25%;
- increasing Refined Project case company tax by 50%;
- decreasing Refined Project case company tax by 50%;
- pricing the cost of carbon according to alternative prices used in the Australian Treasury Clean Energy Future Policy Scenario (around 300% higher than the prices used in the central case scenario, on average); and
- pricing the cost of carbon according to alternative US EPA Social Cost of Carbon estimates (5% discount rate scenario) (around 80% higher than the prices used in the central case scenario, on average).

The sensitivity ranges for the export coal prices were arrived at through an analysis of data over the period from January 1995 to April 2016. Specifically, the range used covers approximately 67% of the range of historical monthly coal prices over this period. The minimum price in the lower sensitivity scenario, forecast for 2016, is placed at around the 16th percentile of historical coal prices. Meanwhile, the maximum price in the upper sensitivity scenario is placed around the 83rd percentile.

The alternative prices for the cost of carbon have been identified in the Review of the NSW Energy Savings Scheme (NSW Government, 2015). As the cost of carbon series used in both the central case of the CBA and this sensitivity analysis rely on assumptions that are not completely transferable to the Australian context, the sensitivity analysis series have been used to provide a range of the potential costs associated with greenhouse gas emissions.

A comparison of the total net benefits obtained in each of these scenarios, using a 4%, 7% and 10% discount rate is presented in Table 7.2.

Table 7.2: Sensitivity analysis – comparison of net benefits for NSW

Parameter	Variation in Parameter	Net Benefits for NSW ($m)		
		4%	7%	10%
Central CBA	N/A	383	312	257
Export coal price forecasts	+ 10%	451	367	303
	- 35%	177	142	116
Incremental royalties	+ 25%	463	376	311
	- 25%	304	247	204
Refined Project case company income tax	+ 50%	426	347	287
	- 50%	340	276	228
Social cost per tonne of carbon emissions	Australian Treasury Clean Energy Future Policy Scenario prices (approx. + 300%)	346	282	234
	US EPA Social Cost of Carbon prices 5% discount rate scenario (approx. + 80%)	371	302	250

Source: Deloitte Access Economics calculations

While the above sensitivity scenarios have not been developed with a view to considering situations where, for example, coal prices are lower and operating costs are higher at the same time, the possibility of these circumstances does bear some discussion:

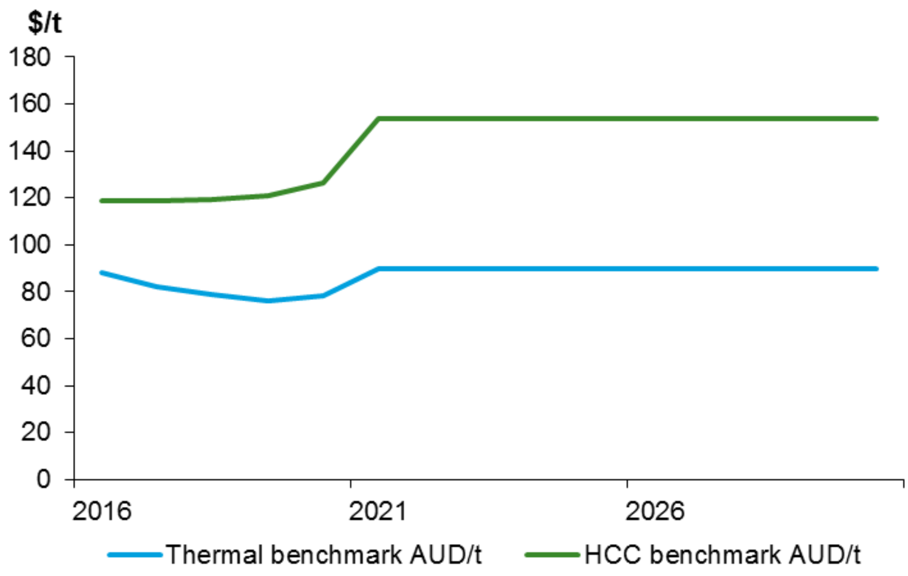
- High coal prices are most likely to be associated with higher operating costs and royalties. High coal prices will tend to bring online existing coal producers and will also tend to drive up the price of inputs to coal production. This was the case in around 2008-2010 when an increase in costs and prices were seen at the same time. Higher prices will also naturally lead to higher royalties as royalties are calculated directly from prices.
- Company income tax is likely to have a complex relationship with other variables. Periods of high price will be associated with increased revenue and so will tend to be associated with higher level of income tax. However, the precise relationship will depend on changes in costs (both operating and capital costs).
- The social cost of carbon should be relatively independent from short run fluctuations in price. Modelling of the social cost of carbon should take into account the long run costs of carbon emissions on the economy rather than short term fluctuations. However, experience in carbon markets following the Global Financial Crises indicates that short term reductions in output can be correlated with large reductions in market prices of carbon emissions.

7.3 Current market prices

The analysis in Sections 5 and 6 are based on prices derived from Consensus forecasts for thermal and semi soft coking coal provided by Mount Owen, as at June 2014. Maintaining the prices from the previous report allows for the results to be directly compared to the results from the previous CBA.

However it is also appropriate to update the analysis to take into account more recent price forecasts. An update is important as current coal prices are at around the 18th percentile of all observed coal prices since 1995 (after accounting for inflation). These updated prices were developed from contract price consensus forecasts published by Consensus Economics in March 2016. These benchmark price forecasts are shown in the chart below.

Chart 7.1: Coal price forecasts – Benchmarks, 2016 market conditions



These benchmark prices were converted to Australian dollars using the annual average foreign exchange consensus forecasts published by Consensus Economics in January 2016. Nominal consensus price forecasts from 2017 to 2021 were also converted to real 2016 price terms using inflation rate assumptions published by the Department of Industry, Innovation and Science (2016).

The benchmark prices were then adjusted based on coal quality information provided by Mount Owen to account for variations in product types (based on their predicted energy content) under each year of production. In addition, the price for semi-soft coking coal was calculated at 67% of the reported price forecast for coking coal, based on a high-level comparison of historical prices presented in the Department's Resource and Energy Quarterly (2015). Over time, as the Refined Project will access new areas, providing coal of different quality and market value, coal prices are expected to vary from year to year.

Adjusting these prices and leaving all other variables unchanged provides the following estimated net benefits of the Refined Project.

Table 7.3: CBA results

Discount rate	Total Net Benefits ($m)	Net Benefits to NSW ($m)
4%	174.03	231.5
7%	108.10	185.7
10%	59.90	151.4

This analysis indicates that the level of benefits generated by the Refined Project are highly sensitive to current market conditions and forecasts of the price of coal but that the benefits to NSW are less sensitive to these assumptions.

Overall, with these lower forecast prices, the Refined Project is still estimated to provide significant benefits to the State.

7.4 Alteration of the base case

The peer review and PAC report identified that it would be valuable for results to be provided in the case where operational activity at Ravensworth East is incorporated into the baseline case as well as the Refined Project case. Adjusting production quantities and operating costs but leaving all other parts of the CBA unchanged results in the following estimated net benefits.

Table 7.4: CBA results – Ravensworth East in baseline case

Discount rate	Total Net Benefits ($m)	Benefits to NSW ($m)
4%	938.35	349.3
7%	725.74	279.6
10%	565.06	226.9

It should be noted that these estimates are conservative as including Ravensworth production volumes in the base case would also result in the transfer of some externality costs to the base case.

8 Flow on economic impacts

This chapter has not been updated as part of this report. The results have not been updated as current Guidelines (NSW Government 2015) do not require the use of CGE analysis. Accordingly, updated CGE analysis has not been undertaken.

References

The Allen Consulting Group (2005) *Valuing the priceless: the value of historic heritage in Australia*, Research Report 2, http://www.dpcd.vic.gov.au/__data/assets/pdf_file/0003/36885/allens_rpt2_pt1.pdf

Australian Bureau of Statistics (ABS) (2008) *Agricultural Commodities: Small Area Data, Australia, 2006-07*, Catalogue No. 7125.0, http://www.abs.gov.au/ausstats/abs@.nsf/Products/7125.0~2006-07~Main+Features~New+South+Wales?OpenDocument, viewed 08 August 2013.

ABS (2012a) Census 2011, accessed 7 August 2013, http://www.abs.gov.au/websitedbs/censushome.nsf/home/Census

ABS (2012b) Value of Agricultural Commodities Produced, Australia 2010-11, accessed 7 August 2013, http://www.abs.gov.au/AUSSTATS/abs@.nsf/allprimarymainfeatures/9901FE06C26DFDEECA257B7B00125B8F?opendocument

ABS (2013) Building Approvals, Australia, June 2013. Cat. 87310, accessed 7 August 2013, http://www.abs.gov.au/ausstats/abs@.nsf/mf/8731.0

Arrow, K. J., Cropper, M. L., Gollier, C., Groom, B., Heal, G, M., Newell, R. G., Nordhaus, W. D., Pindyck, R. S., Pizer, W. A., Portney, P. R., Sterner, T., Tol, R.S.J., and Weitzman, M. L. (2012) "How Should Benefits and Costs Be Discounted in an Intergenerational Context?", http://www.rff.org/RFF/Documents/RFF-DP-12-53.pdf

Bennett J, van Bueren M & Whitten S (2004) “Estimating society’s willingness to pay to maintain viable rural communities”, *The Australian Journal of Agricultural and Resource Economics*, 48:3, pp. 487-512.

Bureau of Resources and Energy Economics (BREE) (2013) “Resources and Energy Quarterly September Quarter 2013”, http://www.bree.gov.au/documents/publications/req/REQ-2013-09.pdf

Consensus Economics (2016), “Energy and Metals Consensus Forecasts”.

Department of Employment (2014) “Small Area Labour Markets publication”, https://employment.gov.au/small-area-labour-markets-publication

Department of Environment and Conservation NSW (2005) “Air Pollution Economics: Health Costs of Air Pollution in the Greater Sydney Metropolitan Region”, http://www.environment.nsw.gov.au/resources/aqms/airpollution05623.pdf

Environment Australia, Department of the Environment (1998) “Dust Control: Best Practice Environmental Management in Mining”, http://www.ret.gov.au/resources/Documents/LPSDP/BPEMDustControl.pdf

Frontier Economics (2009) "Review of Weighted Average Cost of Capital estimate proposed by Goldfields Gas Transmission", http://www.erawa.com.au/cproot/8024/2/20091009%20Frontier%20Economics%20-%20Review%20of%20WACC%20estimate%20proposed%20by%20GGT%20-%20Final%20Draft%20Report%20Prepared%20for%20the%20ERA.PDF

Gillespie Economics (2009) "Proposed Warkworth Extension Benefit Cost Analysis"

MarketWatch (2014), *ICE ECX EUA Futures (ICE EU) Dec 2014*, http://www.marketwatch.com/investing/future/ecx%20emissions?CountryCode=uk, viewed 23 July 2014.

Navrud S (2002) 'The state of the art on economic valuation of noise', *Final Report to the European Commission DG Environment*, http://cevreselgurultu.cevreorman.gov.tr/dosya/background_information/noise_monetisation_EU_WG_HSAE.pdf

NSW Department of Primary Industries (2012) "Summary of gross margins for NSW beef enterprises, December 2012", http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0006/175533/Summary.pdf

NSW Department of Primary Industries (2012) "Strategic regional land use policy: Development of protocol for site verification and mapping of Biophysical Strategic Agricultural Land (BSAL)", http://www.planning.nsw.gov.au/Portals/0/DevelopmentAssessments/OnExhibition/miningsepps/protocol_for_site_verification_and_mapping_of_Biophysical_Strategic_Agricultural_Land_Fact_Sheet.pdf

NSW Department of Urban Affairs and Planning (2002) "Guideline for economic effects and evaluation in EIA", http://cmsdata.iucn.org/downloads/11_guideline_for_economic_effects.pdf

NSW Government (2000) 'Coal mines and associated infrastructure – EIS guideline', accessed 13 August 2012, http://www.planning.nsw.gov.au/assessingdev/pdf/gu_prepcoalst.pdf

NSW Government (2011) "State Significant Development - Director General's Requirements Mount Owen Open Cut Optimisation Project (SSD-4960)", https://majorprojects.affinitylive.com/public/247d8432abbd56c044d609817f86f2bb/10.%20Mount Owen%20Coal%20Extension%20Project%20-%20Director%20General's%20Requirements.pdf

NSW Government (2012) "Guideline for the use of Cost Benefit Analysis in mining and coal seam gas proposals", http://www.planning.nsw.gov.au/LinkClick.aspx?fileticket=1IW95ZTjemY%3D&tabid=205&mid=1081&language=en-AU

NSW Government (2015) "Guidelines for the economic assessment of mining and coal seam gas proposals", http://www.planning.nsw.gov.au/en/Policy-and-Legislation/Mining-and-Resources/~/media/C34250AF72674275836541CD48CBEC49.ashx

NSW Office of Environment and Heritage (2012) *BioBanking Credit Calculator version 2*, http://www.environment.nsw.gov.au/biobanking/calculator.htm

NSW Office of Environment and Heritage (2013) *BioBanking public register*, http://www.environment.nsw.gov.au/bimsprapp/BiobankingPR.aspx.

NSW Treasury (2007) "NSW Government Guidelines for Economic Appraisal", http://www.treasury.nsw.gov.au/__data/assets/pdf_file/0016/7414/tpp07-5.pdf

Pacific Environment Limited (2016) "Economic Costs of Air Quality Impacts – Mount Owen Continued Operations."

PAEHolmes (2013) "Methodology for valuing the health impacts of changes in particle emissions – final report", http://www.epa.nsw.gov.au/resources/air/HealthPartEmiss.pdf

Productivity Commission (PC) (2006) "Conservation of Australia's Historic Heritage Places", http://www.pc.gov.au/__data/assets/pdf_file/0011/92369/heritage.pdf

Reserve Bank of Australia (2014), *Exchange Rates*, http://www.rba.gov.au/statistics/frequency/exchange-rates.html, viewed 23 July 2014

Shafiee S, Nehring M & Topal E (2009) 'Estimating average total cost of open pit coal mines in Australia', *Australian Mining Technology Conference 27-28 October 2009*, pp. 134-145.

Transport for NSW (2013) *Principles and guidelines for economic appraisal of transport investment and initiatives*, version 1.5, released March 2015, http://www.transport.nsw.gov.au/sites/default/files/b2b/publications/tfnsw-principles-and-guidelines-for-economic-appraisal-of-transport-initiatives.pdf

Appendix A: Checklist against guidelines

NSW Treasury (2007) NSW Government Guidelines for Economic Appraisal

Table A.1: Key issues mentioned in NSW Treasury (2007)

Draft Guidelines	Addressed	Reference
Identify Options		
"Do nothing" option	Yes	4.1
Option development	Yes	4.2
Identify Benefits		
Avoided Costs	Yes	5.1
Savings	Yes	5.1
Revenues	Yes	5.1
Benefits to consumers not reflected in revenue flows	Yes	5.1
Benefits to the broader community	Yes	5.1
Identify Costs		
Identify all relevant cost items	Yes	5.1
Stream of costs should cover full project period	Yes	5.1
Identify Qualitative Factors		
Identify costs and benefits that cannot be quantified	Yes	5.1
Other impacts include environmental considerations, industrial relations, social or regional impact, safety, public relations, resource availability	Yes	5.1
Assess Net Benefits		
Assessment of benefits in real terms	Yes	5
Discount at 7% rate, with 4% and 10% for sensitivity testing	Yes	5.3
Net Present Value	Yes	5.3
Net Present Value per $ of capital outlay	NA	
Benefit-Cost Ratio (BCR)	NA	
Internal Rate of Return (IRR)	NA	
Sensitivity Testing		
Projected outcomes under alternative scenarios	Yes	7
Emphasis given on pessimistic alternatives	Yes	7
Ecologically Sustainable Development		
Inter-generational equity principle	Yes	5.3
Identification of Environmental Impacts	Yes	5.1
Valuation of Environmental impacts	Yes	5.2
Sensitivity and Threshold Analyses	Yes	7
Use of ENVALUE	Yes	Appendix C

Note: NAs in this table reflect summary measures that were not assessed as being necessary to reach conclusions.

NSW Department of Urban Affairs and Planning (2002) Guideline for economic effects and evaluation in EIA

Table A.2: Key issues mentioned in NSW Department of Urban Affairs and Planning (2002)

Draft Guidelines	Addressed	Reference
Conduct Preliminary Assessment		
Review main elements of proposed projects, alternatives and surrounding environment	Yes	4
Review information on environmental impacts of proposal	Yes	5.2
Determine spatial and temporal boundaries for analysis	Yes	4.4
Specify relevant community and major groups affected	Yes	6
Specify the kinds of economic values affected	Yes	5.1
Obtain preliminary estimates of likely magnitude of benefits and costs	NA	
Assessment of scale of economic effects relative to regional or local economy	Yes	8
Determine whether an economic impact assessment is required	Yes	8
Scoping the economic study		
Consider environmental impacts and economic values predicted in preliminary analysis	Yes	5.2
Consider time, skills and budget for analysis	NA	
Determine values to be quantified in benefit-cost analysis, sources of information and methodology	Yes	5.1
Determine extent and approach to community consultation	NA	
Identify level and extent of other economic assessments	NA	
Derive economic values and conduct efficiency analysis		
Specification of baseline scenario	Yes	4.1
Valuation of direct benefits and costs of proposal and alternatives	Yes	5.2
Valuation of environmental effects	Yes	5.2
Set up benefit-cost assessment framework	Yes	5.1
Summarise all economic values	Yes	5.3
Calculate NPV and other criteria specified by State Treasury	Yes	5.3
Conduct incidence analysis identifying distribution of costs and benefits	Yes	6
If required, conduct economic impact analysis to assess economy wide-effect		
Specify economic boundaries for assessment	Yes	8
Specify linkages between project and economy	Yes	8
Apply relevant economic impact assessment model	Yes	8
Estimate results, including changes in output, employment and income for sectors of the economy	Yes	8
Incorporate any results into BCA	NA	
Apply ESD principles		
Ensure predicted changes in natural resources and environment have been comprehensively valued	Yes	5.2
Assess risk, uncertainty and irreversible environmental impacts	Yes	5.2, 7
Address intra- and inter- generational equity issues	Yes	5.3
Conduct integrated assessment of options		
Summarise results on economic efficiency	Yes	5.2, 5.3, 7
Summarise results on intra- and inter-generational equity	Yes	5.2, 5.3, 7
Document and report main findings	Yes	Report as a whole

Note: NAs in this table reflect tasks completed elsewhere in the EIS

NSW Government (2012), "Guideline for the use of Cost Benefit Analysis in mining and coal seam gas proposals"

Table A.3: Key issues mentioned in the Guideline

Draft Guidelines	Addressed	Reference
Key features		
Scope: all first round impacts	Yes	5
Net public benefit or cost	Yes	5, 6
Discount rate of 7% with sensitivity analysis	Yes	5.3, 6.3, 7
Appropriate timeframe	Yes	4
Risk Neutral approach	Yes	5
Discussion of unquantified factors	Yes	5
Stages of analysis		
Identify the Base Case	Yes	4.1
Define Project and Develop Options	Yes	4.2
Estimate the Impacts of the Project	Yes	5
Estimate the monetary value of these impacts	Yes	5
Estimate the Overall Net Value of the project	Yes	5.3
Test for Uncertainty and Risk	Yes	7
Prepare Report Including CBA Results and Qualitative Impacts	Yes	All
Distribution effects	Yes	6
CBA at the regional or catchment level	Yes	6
Costs and benefits		
Revenues from mining or CSG per annum	Yes	5.2.1
Any other revenues from the land use during or after mining	Yes	5.2.2
Capital expenses	Yes	5.2.4
Exploration expenses	Yes	5.2.3
Infrastructure contributions	Yes	5.2.10
Operating expenses per annum	Yes	5.2.5
Remedial costs post mining	Yes	5.2.6
Value of rural output forgone	Yes	5.2.2, 5.2.11
Value of residential amenity forgone	Yes	5.2.12-5.2.27
Cost of changes in infrastructure	Yes	5.2.10
Air quality	Yes	5.2.16, 5.2.17
Health	Yes	5.2.16, 5.2.27
Groundwater	Yes	5.2.12
Noise	Yes	5.2.18
Biodiversity	Yes	5.2.21
Heritage	Yes	5.2.25, 5.2.26
Other economic impacts		
Increased wages for workers	Yes	6.2.5
Increased profits for suppliers to the mining sector	Yes	6.2.6
Changes in incomes in tourism or other local businesses	Yes	6.2.6

NSW Government (2015), "Guidelines for the economic assessment of mining and coal seam gas proposals"

Table A.1: Key issues mentioned in the Guideline

Draft Guidelines	Addressed	Reference
Establish the base case	Yes	
Existing land use on the project area	Yes	4.1
Assess interactions with projects in the surrounding area	Yes	4.1
Define project	Yes	4.2
Cost benefit analysis	Yes	
Estimate royalties payable	Yes	6.2.2
Estimate company income tax	Yes	6.2.3
Net producer surplus (and attribution to NSW)	Yes	6.2.1
Indirect benefits (and attribution to NSW)	Yes	6.2.7
Indirect costs to NSW	Yes	
Aboriginal cultural heritage	Yes	5.2.25
Air quality	Yes	5.2.16, 5.2.17
Ambient noise	Yes	5.2.18
Biodiversity	Yes	5.2.21
Greenhouse gas	Yes	5.2.15
Groundwater	Yes	5.2.12
Non-Aboriginal heritage	Yes	5.2.26
Surface water	Yes	5.2.13
Traffic	Yes	5.2.20
Visual amenity	Yes	5.2.19
Net present value	Yes	6.3
Sensitivity analysis	Yes	7
Local Effects analysis	NA	
Effects on local employment	NA	
Effects on non-labour project expenditure	NA	
Effects on other local industries	NA	
Environmental and social impacts on the local community	NA	
Flow-on effects	NA	

Director General's requirements

Table A.2: Key issues mentioned in the DGRs

DGR Key Issues	Addressed	Reference
potential direct and indirect economic benefits of the development for local and regional communities and the State	Yes	Whole of report
a detailed assessment of the costs and benefits of the development as a whole, and whether it would result in a net benefit for the NSW community;	Yes	Whole of report

Source: NSW Government (2013), *State Significant Development – Director General's Requirements Mount Owen Continued Operations Project (SSD – 5850)*

Appendix B: Valuation techniques

This appendix provides a general overview of the range of possible approaches to valuing items in a cost benefit analysis. This appendix is intended to provide background on approaches and techniques that could be used in the CBA itself. The approaches outlined below encompass a range of techniques including the use of:

- project financials;
- market prices;
- foregone revenue;
- hedonic pricing;
- stated preference;
- travel time costs;
- defensive expenditure; and
- value of statistical life.

These techniques cover direct approaches where either financial or market information is available as well as indirect approaches where values have to be discerned from behaviour. The application of these techniques to particular costs and benefits is discussed in Appendix C.

Project financials

Project financials or other information provided by the project proponent can be used to value many of the expected inputs and outputs associated with the proposal. Minimal analysis is required to derive this data, as the values are usually stated explicitly and provided by the project proponent. This approach is particularly useful when attempting to estimate values like the expected size of the work force, scale of operations or output produced.

However it is important to note and critique the validity of assumptions used to generate the projected values provided as the proponent has an interest in the implications of the data.

It should be noted that project financial data is sometimes chosen to serve as a "best estimate", and is therefore prospective in nature. Thus, in undertaking any critique of the information, it may be more valid to compare projected financials to other prospective data sources such as futures prices, rather than historical data.

Observable market prices

Market prices – the price of goods actually traded on the market – represent the revealed value of an object as determined by those who buy and sell it. For commoditised items (e.g. a tonne of coal), this price can be readily observed in the spot market. An idea of future price movements can also be gained through futures markets. For goods that are less commoditised (e.g. housing or land), market prices are derived by looking for comparable goods traded on the market and estimating a market price for a good.

Market prices are thus best used for commodities that are regularly traded, or have comparable goods that are regularly traded.

Market prices are seen as the most reliable way to estimate the value of an item as, in the presence of a relatively efficient market, prices are empirically based, do not require the use of any theoretical assumptions, are normally free from extreme influence by any one individual or organisation and involve actual cash transactions rather than statements of preference or policy.

An important property of market prices is that they are affected by future expectations. This means that prices can be affected by announcements or the perceived likelihood of future events happening. When calculating the impact of a project on market prices, it may be important to correct for the fact that prices may have already reacted to announcements regarding the project, and thus partially account for the expected future impact. A further implication of the forward looking nature of prices is that, if a project is likely to dramatically affect the cost of a good (e.g. wages in a local economy), it may not be appropriate to use pre-project prices to estimate the cost of such a good.

A constraint of market prices is that they necessarily reflect *effective* demand, that is to say, a person must be both willing and *able* to purchase a product for the market to reflect their valuation. Thus, if people's purchasing decisions are constrained then their valuation may not be reflected in market prices. For example, if people in an area experiencing pollution are unable to access credit to move away, the cost of pollution to such people may not be reflected in the market price of housing.

Having noted these considerations and limitations, it is still the case that a valuation on market prices is the most preferable way to value items within a CBA.

Forgone revenue or increased costs

Foregone revenue or increased cost are attempts to make a comparison between a proposal and a counterfactual, by observing the revenue that would have been earned by a particular entity (or entities) as a result of the proposal, or the increased costs faced as a result of the proposal. Both techniques require modelling scenarios with and without the proposal. Furthermore, they require explicit mention of the means by which the proposal could affect the party involved. As examples, a project could distort prices of inputs (price effects), create secondary consequences (externalities) or even compete directly with local entities (direct competition).

It should be noted that measures such as foregone revenue and increased costs are not, necessarily, themselves measures of overall costs. Foregone revenue and increased costs can sometimes represent transfers of wealth between different segments in a community (such as a transfer from employees to employees) and may thus overstate the impact of a project on the overall community. In this case, an advantage consideration of foregone revenue or increased costs allows for an assessment of the distributional impact of a project.

Hedonic pricing

Hedonic pricing is a method of using observable market prices to value intangible goods or particular properties of goods. To do this, hedonic pricing tries to compare the price of goods that are similar in every respect except for the property being compared. An example would be an attempt to value the cost of discomfort from noise pollution, by comparing the market price of houses which are substantially similar except for the presence of noise pollution.

Hedonic pricing relies on observable market prices, and is thus considered revealed preference data (as opposed to stated preference data). It is therefore a more empirical approach as it relies on data from market transactions rather than just statements about preferences.

A critical drawback of hedonic pricing is that any attempt to value properties or goods in this way is dependent on the theoretical model used to determine the value of an object. As it is often difficult to find two items that are identical in all respects except for a given property, comparisons are made using a theoretical model that attempts to describe the way in which different properties are combined to produce a particular value. The most common method of doing so would involve assuming that the costs of different properties are independent and additive. For example, when valuing a house, one might assume that the decline in value from noise pollution and the decline in value from air pollution are independent of the other properties of the house and that the decline in value from having both noise pollution and air pollution together is the sum of the decline in value of noise pollution and air pollution.

Stated preference, willingness to pay, choice modelling and similar

As opposed to revealed preference approaches which are based on prices, such as hedonic pricing, this methodology determines the maximum value assigned by an individual, that is, their willingness to pay, using a structured survey. Stated preference approaches are particularly useful for the valuation of externalities – costs or benefits which are not incorporated in market transactions, such as the environmental, cultural and social impacts of economic activity.

Stated preference valuations are undertaken using one of two techniques – contingent valuation, or choice modelling (Fujiwara & Campbell, 2011). The main difference between the two is that contingent valuation surveys generally relate to the overall valuation of a non-market good, while choice modelling surveys aim to ascertain valuations of certain characteristics of that good. When multiple attributes are considered in choice modelling, an overall valuation can also be obtained (Fujiwara & Campbell, 2011). Both contingent valuation and choice modelling surveys can take a number of different forms. These vary according to the manner in which respondents are asked to indicate their preferences.

In the case of choice modelling, each survey question asks respondents to rank, rate or choose between multiple hypothetical scenarios, including a status-quo option. These scenarios vary according to the state of different attributes, generally including non-market impacts, such as the extent of the effect on flora, fauna or water quality, and an associated level of cost to be borne by the individual which limit the effects to this level. Depending on the complexity of the scenario, a large number of questions may be required.

Statistical methods are then applied to quantify the trade-offs between each characteristic, establishing estimates of willingness to pay and implicit prices for marginal changes in each attribute. Specifically, discrete choice models such as multinomial, nested or mother logit models are utilised in this analysis process.

While stated preference methods can provide useful insights on the valuations of non-market impacts, they are associated with a number of important practical considerations. In particular:

- the process of developing an appropriate questionnaire involves substantial costs;
- the scenarios posed in question sets should be realistic and reflect local circumstances; and
- an adequate sample size of data must be collected to provide statistically significant results.

Even if these methodological challenges are overcome, the computation of model parameters and the resulting willingness to pay estimates is another complex process, which requires an understanding of underlying assumptions and the issues relating to aggregation of results for the entire population.

Further details regarding these matters are outlined in the summary guide prepared by the UK Department for Transport, Local Government and the Regions (DTLR) (2002) and the accompanying manual (Bateman et al, 2002).

Travel time costs

The travel time cost method is a surrogate market technique useful for valuing physical sites which are not subject to price mechanisms, such as recreational facilities (Parsons, 2003). The methodology is based on the assumption that the costs an individual incurs in travelling to a site provide an insight into the value they assign to that facility and the activities which they participate in at the location (Planning NSW, 2002). The aim is to use this information to derive a demand curve for the recreational benefits of a site.

Travel time cost valuation methods usually take the form of a single site or multiple site model (Parsons, 2003). Where there are minimal substitutes for a facility and the focus of valuation is to determine society's willingness to pay to access the site, a single site model will usually suffice. Multiple site models are particularly useful for capturing the effects of variation in site attributes on valuations, such as the effect of changes in environmental quality on willingness to pay. In this regard, multiple site models may be appropriate for valuing the environmental impact of mining activity. As the name suggests, multiple site models can also take substitution effects into account, providing simultaneous estimates of access values at a number of locations.

According to Parsons (2003), the process of estimating one of the most common multiple site models, the random utility maximisation (RUM) model, can be broken down into 11 steps. These are listed and briefly described in the table below.

Table B.1: Brief outline of modelling travel time costs with a random utility maximisation model

Step	Action	Brief description
1	Identify the impacts to be valued	• Identify the site characteristics of interest • Consider whether these can be measured objectively
2	Define the population of users to be analysed	• Identification of all current users and potential users of sites, with and without characteristic changes
3	Define the choice set	• Determining which sites an individual will be assumed to consider when making a visitation choice
4	Develop a sampling strategy	• Identifying the method for sampling and data collection
5	Specify the model	• Identifying variables for site characteristics and individual characteristics which influence their likelihood to make a trip
6	Gather site characteristic data	• Using data from primary/secondary sources • May involve results of an auxiliary regression, using observable features as inputs
7	Decide on the treatment of multiple purpose trips	• Choose to either identify and drop multiple purpose trips, or include dummy variables in site characteristics which account for other opportunities nearby
8	Design and implement the survey	• Obtain information from respondents on their frequency of trips over a defined time period, details of their last trip, and demographics
9	Measure trip cost	• Involves computation of distances travelled and travel time for every site in each individual's choice set
10	Estimate model	• Undertake a regression to estimate the parameters of the theoretical model
11	Calculate access and/or quality change values	• Ascertain access valuations, or valuations of changes in the attributes of site/s

Source: Parsons (2003)

It is evident that, like the stated preference approach, development of a travel time cost model involves many practical considerations and substantial costs. In particular, it can be difficult to obtain precise estimates of the value of travel time (Planning NSW, 2012) although estimates of travel time costs can be obtained from Austroads (2010).

Defensive expenditure

Another methodology useful for the valuation of externalities, such as environmental impacts, is the defensive expenditure approach (Planning NSW, 2012). This revealed preference technique utilises data on the expenditures that people make in order to protect themselves from some risk or impact (Whitehead et al, 2007). The extent of these defensive expenditures on market goods can be used as proxy values of associated non-market, environmental goods. For example, investments in double glazed windows can be used as an estimate of the value of reduced exposure to road traffic noise (Fujiwara & Campbell, 2011).

The defensive expenditure method provides a partial, or lower bound estimate of the valuation of environmental impacts (OECD, 2006). This is due to the fact that the expenditures may not be directly related to the impacts (Planning NSW, 2002).

Rather, the accurateness of the valuation produced by this method is dependent on an interaction between environmental quality and the effectiveness of the defensive expenditure (Sotelsek, 1998). It is therefore generally assumed that that the costs incurred in protection reflect a minimum valuation of the environmental benefits (Planning NSW, 2002). Meanwhile, recognition of broader benefits associated with defensive expenditure is critical to the accuracy of this methodology. Under these circumstances, it can be difficult to isolate a valuation that is specific to the environmental benefit of interest (Planning NSW, 2012).

Value of statistical life, DALY, wage differential and similar

The health impacts of economic activity can be valued according to human capital or willingness to pay approaches, although the latter is most common and is considered most appropriate (Jalaludin et al, 2009 & OBPR, 2008). There are also a number of health-specific valuation concepts useful for placing values on the cost of mortality and morbidity. These include the value of statistical life, and the disability-adjusted life year.

The value of statistical life (VSL) represents an "estimate of the financial value society places on reducing the average number of deaths by one" (OBPR, 2008). As noted by the World Bank (2003), the measure is not intended to reflect the fundamental value of human life. Although the VSL is a well-established economic concept, there is a great deal of variability in estimates. According to the OBPR (2008), the most appropriate measurement technique for VSL is willingness to pay – that is "estimating how much society is willing to pay to reduce the risk of death". Using this framework, it was estimated that the VSL in an Australian context is approximately $3.5 million (OBPR, 2008).

An alternative health metric is the disability-adjusted life year (DALY). This is a measure of the burden of disease, incorporating the effects of mortality and morbidity, with a single DALY representing "one lost year of healthy life" (WHO, 2013). The inclusion of the mortality component in the DALY calculation implies that if used in a CBA, it should substitute, rather than complement VSL measures to avoid double-counting (BTRE, 2005). However, it appears that a number of practical issues constrain this transition, including a lack of data on DALY monetary valuations (Jalaludin et al, 2009).

Hedonic pricing analysis of wage differentials is another technique which has been applied to obtain valuations of health impacts. These models analyse wage differentials with the aim of ascertaining a value for risk exposure. Specifically, wages are modelled as a function of individual characteristics and job characteristics, to derive an estimate of the compensation paid for risk of fatal and nonfatal injury (World Bank, 2003). However, the accuracy of this technique relies on a number of theoretical assumptions relating to employee mobility and access to information which may not hold in practice (Jalaludin et al, 2009).

The final method used for valuing health impacts is the human capital approach (Planning NSW, 2002). This technique estimates the economic output foregone as a result of reduced productivity caused by "absenteeism, temporary or permanent disability and premature mortality" (Jalaludin et al, 2009). While this methodology is often used to value the health impacts of environmental degradation, such as pollution, the estimates are not alternative measures of the VSL (Planning NSW, 2002). However, lost earnings due to premature mortality could be considered as a minimum estimate of VSL (World Bank, 2003).

Appendix C: Approaches to valuing specific costs and benefits

This appendix provides a general outline of the available approaches to valuing the various costs and benefits identified in the guidelines for CBA published by the NSW Government, and summarises the evidence produced by quantitative valuations. It is intended as a guide to the approach taken in the CBA and to provide views on alternative data sources.

Gross mining revenue

Gross mining revenue would be provided by the project proponent or evident in the project financials. This mining revenue would be based on the value of output, a factor of both the volume of output and the relevant coal price. Relevant coal prices can be estimated using the spot price of coal or through the price of coal futures. The volume of output is usually estimated by the project proponent themselves. It is important to note that the volume of output is selected to match the marginal cost of production with the current market price of coal.

Coal prices

Coal prices are observable market prices – Australian thermal coal was valued at around $72 per metric ton in April 2015, measured in Australian dollars (Index Mundi, 2016). The current price of coal is observable on the spot market. The future price of coal is observable in the futures market, although that may not be necessary as efficient commodities markets should result in current prices of coal taking into account future expectations.

Mine related costs

Mining exploration costs are also data which the project proponent would have on hand. Expenditure on mining capital investment and operating costs would be detailed on project financials. Rehabilitation expenses, such as landform reconstruction and revegetation, would also be accounted for as project costs on financial statements.

Forgone agricultural revenue

Forgone agricultural revenue can be estimated based on financial information on agricultural land use prior to mine development. Open cut coal mining competes directly with agricultural land use as it removes land with agricultural potential to reach coal underneath. Furthermore, both open cut coal mining and underground coal mining can impact on the local water system and thus affect agriculture across a given water system.

The effect of a mining activity on agriculture can be assessed by first considering the productivity of the agricultural land in regions of interest. This land productivity data can then be combined with information on the area of land that is likely to be affected by mining activity to provide a decrease in agricultural activity that can be attributed to increased mining activity.

We believe that this process of estimating the effect on agricultural production from coal mining is likely to be generous. Previous analysis undertaken by Deloitte Access Economics suggests that mining operations often take place in areas of grazing, cropping and forestry which will have significantly lower productivity than average.

As there is no empirical evidence on the relationship between agricultural productivity and the noise or dust impacts of mining activity, it is difficult to quantify the extent of these externalities in monetary terms. In addition, impacts are generally:

- highly dependent on the local geology;
- often manifests as a risk, rather than an event; and
- not clearly established in scientific literature.

Therefore, any estimates of declines in agricultural productivity should be seen as indicative, included to ensure that the issue is taken into account, without being interpreted as a precise quantification of the effects of mining on agriculture.

Changes in related public expenditure

Changes in related public expenditure would be information specific to each project and would be provided by the project proponent. For example, public expenditure on water or sewerage may change, where a region is transformed from residential to mining. Further, public investment in transport or road infrastructure may change, with the possibility of increased spending on roads to facilitate movement of coal to ports in key mining areas.

This may also manifest as a potential benefit, as some mining projects may include upgrades or construction of new infrastructure. This infrastructure may be usable by the general public either during or after the operation of the mine.

Water quality

The impact of mining on water quality varies according to the form of mining activity (open cut or underground), the proximity of the mine to water sources and the properties of aquifer systems. These factors influence the way in which fracturing of hard rock, mine runoff and dust pollution can lead to a reduction in the overall quality of ground and surface water.

This section reviews the literature on the use values of water quality, given its importance for households and industry. The valuation of groundwater and surface water are considered separately.

Quality of groundwater

Groundwater refers to water that has accumulated within soil or cracks or pores in rocks, known as aquifers (Geoscience Australia, 2013a). Some mining activity has been associated with the in-flow of saline groundwater, degradation of alluvial aquifers and an overall reduction in the quantity of groundwater supplies (Department of Planning, 2005; R.W. Corkery & Co, 2009; Smith, 2009). It is important to assess the implications of these effects for other groundwater users.

Groundwater is a critical source of drinking water in various locations across Australia, particularly in Western Australia (Geoscience Australia, 2013a). The primary methods utilised to assess the value of drinking water quality are the contingent valuation and defensive expenditure approaches. As described by Koteen, Alexander and Loomis (2002:9), it is difficult to estimate household demand for water quality, 'as households cannot directly purchase water of varying quality'. Nevertheless, it is important to consider the benefits that individuals gain from the awareness that the water they receive is of high quality.

Very little research has been undertaken in Australia on the values that households assign to the quality of drinking water, with the available evidence fairly dated. The appropriateness of these findings is contingent on the relevance of the measures listed, which in turn depends on the nature of any anticipated change in water quality caused by mining activity.

There is also little evidence in an Australian context of the value of groundwater for agriculture, irrigation and other industrial uses, at different quality levels. Instead, the literature has focused on valuation of the costs that would be incurred by these commercial users of groundwater, in the instance that the groundwater supply was completely depleted (Marsden Jacob Associates, 2012). This is known as the deprival value approach, with values representing the cost of a worst case scenario where total degradation of water quality takes place.

Nevertheless, it may be possible to estimate the value of water in its existing state by observing prices in the water markets. In addition, it is important to note that the impact of a reduction in water quality on the agricultural industry is likely to be captured by estimates of forgone agricultural revenue.

In some parts of Australia, groundwater is also used for other residential purposes, such as watering gardens, as well as other public purposes such as the maintenance of parks. Given that these purposes might also be captured in the value of open space or visual amenity, they are not considered in this section.

Quality of surface water

Rivers, lakes, wetlands and other forms of surface water can also be affected by mining activity. The quality of water can be reduced as a result of runoff or dust pollution. It may also be affected as an indirect result of mining impacts on groundwater, although the interaction between groundwater and surface water varies according to topography, geology and climate (Geoscience Australia, 2013b).

The majority of Australia's water supply is derived from surface water. Therefore, changes to the quality of surface water will impact households and industry. Valuation of the impact of changes to surface water quality is subject to the same issues discussed above. However, there is substantially more evidence on the value of water quality specific to recreation at surface water sites.

Within Australian literature, stated preference approaches such as contingent valuation and choice modelling are the predominant methodologies employed. When transferring these values to a new context, it is important to consider the similarity of waterway characteristics, population characteristics, the scale of the change in quality and whether the focus is on quality improvements or maintenance of existing standards (van Bueren & Bennett, 2004).

It is likely that, in most instances, these factors will not align exactly. In those cases, the use of benefit transfer values should be seen as indicative, included to ensure that the impact of changes in water quality is taken into account, rather than as a precise estimate.

Particulate matter

The main methods of valuing the costs of air pollution are hedonic pricing, stated preference techniques or through use of a direct costing approach.

Hedonic pricing is usually measured by examining the price differential associated with distance to a project, in order to determine the cost associated with the externalities generated. It is particularly useful as it is a form of revealed preference and is very difficult to manipulate. However, hedonic pricing, if undertaken without a direct measure of air pollution (e.g. measures of particulate matter in the air), cannot disaggregate the price difference caused by a project into its components such as air pollution, noise pollution, loss of visual amenity and convenience. Furthermore, hedonic pricing relies on the fact that individuals are aware of and can appropriately value the cost of air pollution to their utility (Abelson, 2007). Therefore, hedonic pricing serves as a way to measure the aggregate impact of a variety of measures, a point that should be noted to avoid double counting costs or benefits.

Contingent valuation studies involve asking individuals regarding their willingness to pay to reduce the impact of air pollution. Similarly to hedonic pricing, this valuation methodology assumes that individuals are sufficiently aware of and can appropriately value the impact of air pollution to their utility. The life-satisfaction approach was used by Ambrey et al. (2012) to estimate the cost of air pollution from particulate matter in South East Queensland. This study yields an implicit willingness to pay of $6,000 per household for a one day decrease in the number of days pollution exceeds health guidelines in their local area.

An alternative method of measuring the impact of air pollution is to measure its medical impact on health and life expectancy of the population exposed to it. One method of valuing health and life is use of Quality Adjusted Life Years (QALY). The effects of air pollution can thus be measured in the number of QALYs lost as a result of the pollution (Coyle et al., 2003). This value can then be combined with an appropriate monetary value placed on life as determined elsewhere.

Recently, PAEHolmes published unit damage cost estimates per tonne of $PM_{2.5}$ emissions in a report for the NSW Environment Protection Authority (PAEHolmes, 2013). These estimates were developed for specific locations using the ABS Significant Urban Area structure for urban centres with more than 10,000 people. This analysis was undertaken to provide health cost estimates that take into account population-weighted exposure, for use in economic appraisals.

Cost estimates produced by the PAEHolmes study are reported for Significant Urban Areas in Australia. In some circumstances, where more specific information is not available and where SUAs are a reasonable approximation for the area that will be affected by particulate matter, these are likely to be the best available estimates of the cost of particulate matter for cost-benefit analysis in NSW.

However, in some cases, where emission sources are located on the boundary of a Significant Urban Area, the approach used by PAEHolmes may provide significant over or underestimates of the likely costs associated with emissions, this issue can be addressed by commissioning specific research for each individual project.

For this revision, Pacific Environment (2016) has produced a detailed analysis of the likely economic costs relating to particulate matter emissions from the Refined Project. This assessment is incorporated into the Response to PAC Review Report as Appendix 8. This estimate uses an approximation of the impact pathway approach to provide specific estimates for the Refined Project given its geographical location, its proximity to population centres and the potential effect of particular matter emissions.

Beyond TSP, PM_{10} and $PM_{2.5}$, a core component of the particulate emission of any coal mining project is dust. It is created by the disturbance of particles which occurs throughout the mining process by activities such as blasting, handling and transporting. However, mine dust rarely presents a serious threat to the wider environment. In the majority of situations the dust produced is chemically inert and deposition rates tend to decrease rapidly away from the source (Environment Australia, 1998). Buffer zones have evolved to become common practice in an effort to mitigate the effect of dust, noise and vibration on surrounding agricultural lands.

Carbon pollution

The cost of carbon emissions can be estimated in a variety of ways. It is important to note that the cost of carbon is usually measured as the marginal social cost of emitting one metric ton of carbon (or one metric ton of carbon dioxide). The main methods of pricing carbon emissions are based on modelling, observed market prices and defensive expenditure.

Considering market prices, while Australia no longer enforces a carbon pricing mechanism, there are market systems in place overseas. The recent Review of the NSW Energy Savings Scheme determined the appropriate carbon price is the forecast European Union Emission Allowance Units price based on futures derivatives published by the European Energy Exchange.

Noise

Noise pollution can be measured in a variety of ways. It is important to note however, that most studies of noise pollution have looked at noise from a particular source (e.g. road traffic, rail). As annoyance varies depending on the type of noise produced and individual sensitivities, noise valuation studies usually vary by source. This difficulty is noted in the recent NSW Government draft *Guidelines for the economic assessment of mining and coal seam gas proposals* – particularly for noise levels less than 45 dB(A).

A primary means of valuing noise pollution is to use hedonic pricing methods to compare house prices based on proximity to a source of noise (e.g. highway, airport). While this methodology is useful for assessing the marginal willingness-to-pay (WTP) associated with noise costs, there is no expectation that the marginal WTP will be stable across contexts. Thus, while hedonic pricing is very useful where applicable, it may not be appropriate to generalise the cost derived from hedonic pricing studies to a broader context.

As an alternative, contingent valuation methods can be used to assess the cost of noise pollution. The values derived for contingent valuation studies however, vary quite greatly with estimates for road traffic noise varying between $3.82 and $189.05 per decibel per household per year. The Final Report to the European Commission DG Environment recommended valuing road traffic noise at $3.82 to $61.11 per dB per household per year (Navrud, 2002).

Traffic

The costs and benefits associated with nearby traffic can be broken down into several categories. Traffic can produce several externalities, including noise pollution, air pollution and traffic congestion. Proximity to traffic however can also generate benefits due to the time and travel benefits associated with proximity to a mode of transport.

Valuations of the costs and benefits associated with traffic should also note that the costs and benefits do vary depending on mode of transport (Navrud, 2002) and time of day (Carlsson et al., 2004). Traffic can also be measured in intensity, either by frequency of occurrence or through a measure of the traffic density on a route (Ossokina and Verweij, 2011).

Valuing the net cost (or benefit) of traffic can thus be done using hedonic pricing by measuring property prices and proximity to particular modes of traffic, for example, railway lines, highways or airports (Ossokina and Verweij, 2011). However, hedonic pricing based on proximity to a transport line is problematic as it does not necessarily disaggregate the costs and benefits into noise pollution, air pollution, congestion and convenience. Without actual measurement of noise or air pollution levels, hedonic pricing studies tend to measure the net cost or benefit associated with living close to a mode of transport. This is something to be noted, to avoid double counting costs and benefits, and may not be a problem if a study is only interested in the net effect of traffic.

Transport for NSW (2013) provides a thorough guideline for values to use when assessing economic costs associated with traffic. These guidelines draw on a range of approaches such as willingness to pay, market prices and hedonic pricing.

Health

A consideration in the impact of a development, such as a coal mine, on an area is the impact of the development on the health of those that live near it. This cost is primarily borne by the residents that live near the mine. Most of this externality is likely to be picked up by measurements of other externalities, such as air pollution or through methods of valuation that aggregate across externalities such as hedonic pricing.

A study by Hendryx and Ahern (2008) identifies significant increases in a range of diseases due to coal production. According to Hendryx and Ahern (2008), living near a coal mine raises the incidence of Cardio-Pulmonary disease, diabetes, kidney disease, cancer and arthritis/osteoporosis.

However, this valuation is based on data from West Virginia and does not appear to be easily translatable into the NSW context, particularly due to potential differences in the regulatory regimes between the two locations.

Visual amenity

The term ‘visual amenity’ is not clearly defined in the literature. This review applies Brodbeck’s definition of scenic quality, being ‘the degree to which the visual aesthetics of a landscape are valued from a human point of view’ (2005). It is acknowledged that exposed spoil heaps and light emitted by mines can detract from the visual amenity of an area. In order to avoid overlap with the benefits of open space, discussed below, the valuation of visual amenity impacts could be restricted to those of properties that will have a direct view of the mining area.

The process of valuing visual amenity requires consideration of a number of factors including the visual characteristics of the site, the surrounding environment, the scale of the project and the current beneficiaries of the visual amenity aspects of the site. Hedonic pricing and stated preference techniques are the most common methods of quantifying visual amenity (Ambrey & Fleming, 2011).

In instances where local residents are the primary beneficiaries of visual amenity, hedonic pricing is the preferred method of valuing visual amenity (University of Hawaii Economic Research Organisation [UHERO], 2013). Controlling for other factors that influence property prices, such as number of bedrooms, backyard size and proximity to schools and parks, this methodology can infer a value for the price impact of the presence or quality of a view.

Hedonic pricing techniques are commonly used to estimate the value of amenity. Within Australia, this method has been used to value the amenity of river views, ocean views, national parks and urban wetlands (Ambrey & Fleming, 2011). Since the values obtained directly reflect the visual characteristics of specific sites, they cannot be applied to the CBA of mining projects. Instead, the process of analysis would have to be replicated in the mining context.

Hedonic pricing studies that have considered the impact of mining activity on property prices in Australia have tended to place a focus on valuing the impact of pollution. For example, Neelawala, Wilson & Athukorala (2012) assessed the impact of mining- and smelting-related lead pollution on residential house prices. This highlights the difficulties associated with isolating the visual element of amenity from other aspects such as the level of noise or dust pollution.

Alternatively, stated preference surveys can be used to obtain estimates of the value of visual amenity. This methodology is most relevant when the view of the site is primarily enjoyed by visitors to an area (UHERO, 2013). While it might be possible to pose questions in a manner which will help provide a direct estimate of the value of the visual aspect of amenity, it should be noted that there may remain a difficulty in distinguishing the value of visual amenity from the value of biodiversity or conservation, in the case of natural environments. In addition, care should be taken to ensure against double-counting, given the visual amenity benefits of open space, discussed below.

Overall, the difficulties associated with obtaining quantitative estimates of the value of amenity are acknowledged by the NSW Government. It is noted in the 2012 Guidelines that these impacts may have to be considered qualitatively in a CBA. In that case, the likely size of impacts on visual amenity should be discussed relative to the overall net public benefit of the project.

Quality of open space

Where a proposed mining development or expansion is intended to impede on open space, it is necessary to account for the loss of benefits derived by individuals who use that space. The two main ways in which individuals benefit from open space are through the visual amenity of the space and the activities that take place in the area (McConnell & Walls, 2005).

The main methods used to value the quality of open space are hedonic pricing and stated preference techniques. After reviewing the literature on the topic, McConnell and Walls note that there is substantial variation in the estimated value of open space as a result of differences in location, the type of space, the services provided by the space and the methodology utilised by the study (2005).

It is recommended that values for the quality of open space be ascertained by considering the value of the activities that take place in potential areas of impact. In some cases, this value will be captured in measurements of forgone agricultural revenue, or the value of recreational activities that take place at water sites.

Rural amenity and culture

The development or expansion of a mine may also have negative social impacts through the reduction of rural amenity and culture. The noise, light and dust pollution generated by mining activity can alter the overall rural amenity of the surrounding area by establishing an industrial ambience. Where this change causes people to leave the area, the remaining residents may experience a loss of their sense of community.

Stated preference techniques are the main method used to value rural amenity and culture.

Bennett, van Bueren and Whitten (2004) present the results of two choice modelling studies investigating household willingness to pay to maintain rural communities, within the context of environmental protection strategies.

The first study considered the value of retaining farm populations in the Murrumbidgee River Floodplain, given different wetland protection strategies. Survey respondents from Wagga Wagga, Griffith, Canberra and Adelaide were told that implementation of these strategies might cause farmers to leave the floodplain region. The responses indicated that, on average, households were willing to pay a one-off sum of $5.73 to prevent a farmer from leaving. The 95% confidence interval for this estimate was $4.21-$7.35. It was found that this valuation did not vary significantly according to the different locations.

The second study undertook three different surveys. The first was framed to ascertain values at a national level, while the two others referred to case studies of the Great Southern region in Western Australia and the Fitzroy Basin region in Queensland. The national survey was distributed to samples of households from Albany, Rockhampton and the general population. The Great Southern survey was distributed to another sample of households in Albany, while the Fitzroy Basin survey was issued to a sample of households in Rockhampton.

Estimates of household willingness to pay to prevent rural populations from declining were ascertained from the responses in each survey-sample combination. These values were measured in terms of an annual payment to be made over a 20 year period, in order to prevent 10 people from leaving a rural community. The results are summarised in Table C.1 below.

Table C.1: Willingness to pay to maintain rural communities

Survey	Sample	Annual household cost of 10 people leaving rural communities
National	National	$0.09
	Albany	$0.11
	Rockhampton	$0.06
Great Southern	Albany	$0.56
Fitzroy Basin	Rockhampton	$2.24

Source: Bennett, van Bueren & Whitten (2004)

It is evident that the benefit of maintaining rural communities varies according to the context of the analysis, with regional-based surveys generating higher willingness to pay values. This is likely to be reflective of framing or scoping effects (Bennett, van Bueren & Whitten, 2004). In addition, it is plausible that these values underestimate the value of rural culture in the context of mining, given that individuals might be more accepting of costs to the community as a result of environmental protection requirements than they are for mining developments or expansions.

A choice modelling survey was also undertaken by Ivanova et al. (2007) to assess the social effects of coal mining in the Bowen Basin in Queensland. The authors found that while residents of Blackwater were not largely concerned by changes in the size of the population, a 1% increase in the 'proportion of jobs held by people who don't live in the town' was equivalent to a reduction in welfare of $41.88 per household.

The importance of rural amenity and culture in the Hunter region was identified in a choice modelling survey undertaken by Gillespie and Bennett (2012). A sample of households in NSW were distributed an online questionnaire about how they valued different impacts of the Warkworth Mine. From the 2,354 responses, the authors identified that, on average, a household was willing to pay $33.32 to prevent one rural family from being displaced from the community. The 95% confidence estimate for this estimate was $29.31-$37.72. Although of relevance for the coal mining industry, criticisms have been made of the methodology employed in this study in decisions by the Land and Environment Court. This means that Bennett, van Bueren and Whitten (2004) is likely the most relevant study in this area.

Heritage – Aboriginal

The use values of heritage sites are derived primarily from the value associated with visiting such sites. However, the value associated with such visitation often cannot be measured through a market price and thus relies on stated preference data. As a consequence, it is difficult in practice to separate the use and non-use values associated with a heritage site. Furthermore, the value of a particular heritage site will vary depending on the demographics of the community surveyed.

For example, in a study measuring the value of protecting an additional 1% of Aboriginal heritage sites in Central Queensland, the willingness to pay of various communities was determined as per Table C.2.

Table C.2: Willingness to pay for protection of Aboriginal heritage sites

Community	Rockhampton Indigenous Community	Rockhampton General Community	Brisbane General Community
Willingness to pay for protection of further 1% of Aboriginal heritage sites (2003 Dollars)	3.22	-2.08	-1.78

Source: Rolfe and Windle (2003)

It is important to note that the Indigenous community and the general population appear to value Aboriginal heritage sites very differently. Thus the assessment of the value of Aboriginal heritage sites necessarily presents issues of equity that involve balancing the interests of different groups in the community. These results are also quite different from those in a study by Gillespie Economics (2009). As a result, it is likely that the most appropriate treatment of Aboriginal heritage in a CBA is through qualitative analysis.

Heritage – Historical

There is also an extensive literature valuing heritage sites that are residential buildings, commercial buildings and tourist places (Allens Consulting Group [Allens], 2005). Results from choice modelling studies indicate that the average willingness to pay for the protection of additional places from loss is estimated to be $5.53 per person each year for every 1000 places protected (Allens, 2005). This is equivalent to an annual willingness to pay of $0.007 per person per site protected, in 2013 dollars.

As mentioned in Appendix B, there are uncertainties involved with aggregating these individual valuations beyond the choice modelling survey sample. Table C.3 illustrates the variation in valuations according to three different levels of aggregation.

Table C.3: Variations in the value of protecting one local heritage site ($2014)

Aggregation level	Annual value of protecting one site ($m)	NPV of protecting one site in perpetuity ($m)
All residents in the Hunter and Central Coast region	0.01	0.09
All residents in NSW	0.05	0.67
All residents in Australia	0.15	2.14

It should be noted that the Productivity Commission's Inquiry into the Conservation of Australia's Historic Heritage Places (2006:145) found that these values are of little relevance for individual sites, due to the difficulty in interpreting these values and applying them in different contexts. As a result, it is likely that it is most appropriate treatment of historical heritage in a CBA is through qualitative analysis.

Biodiversity and conservation

The non-use valuation of ecological systems requires the use of stated-preference valuations, the most common of which would be contingent valuation studies. It should be noted that while such studies may not produce consistent measures of values (Dutton et al., 2010), they are a useful way to measure non-use values of an ecological site. It should be noted that non-use valuations of ecological systems often do not disaggregate value into the components of an ecosystem. Thus the valuation of a water system, ecological habitat and the biodiversity supported by it will usually be lumped together in such a valuation.

Furthermore, to ensure that the items being valued can be understood by the general population, abstract properties of ecosystems such as clean water or an absence of pollutants are usually translated into more meaningful indicators such as the number of individuals of species saved (MacDonald et al., 2011).

By virtue of the contingent valuation methodology, it may not always be possible to separate non-use values from the declared valuations in a survey. People may implicitly value an ecological site due to a future use (e.g. visiting it in the future). Although surveys may attempt to disaggregate a declared value based on motivation (Subade, 2005), not all of them do so. This is important to note to avoid double counting when summing values.

It is also important to note that the per person valuation of an ecological system is heavily dependent on the community being surveyed. Communities geographically closer to an ecosystem tend to value that ecosystem more highly (Kumar, 2010). It is therefore important to discount per person values from surveys taken of communities close to a particular ecosystem when attempting to generalise the value of an ecosystem (Bennett et al., 2007).

Lastly, an alternative means of valuing biodiversity is through the NSW Office of Environment and Heritage's BioBanking scheme. The valuations within that scheme rely on a fixed formula, as detailed in the Biobanking Assessment Methodology (NSW Department of Environment and Climate Change, 2008). A review of the BioBanking scheme found that credits were sold at a value between $2,500 and $9,500 per credit (NSW Office of Environment and Heritage, 2012). Assuming that the Office of Environment and Heritage has represented the preferences of the community in the Assessment Methodology, any damage to species or ecosystems can be offset through the program.

References for Appendix C

Abelson P (2007) *Establishing a Monetary Value for Lives Saved: Issues and Controversies*, Available at: https://www.dpmc.gov.au/sites/default/files/publications/Working_paper_2_Peter_Abelson.pdf

Allens Consulting Group (2005) *Valuing The Priceless: The Value of Historic Heritage in Australia*, Prepared for the Heritage Chairs and Officials of Australia and New Zealand, Available at: https://www.environment.gov.au/heritage/info/pubs/valuing-priceless.pdf

Ambrey CL and Fleming CM (2011) 'Valuing scenic amenity using life satisfaction data', *Griffith Business School Discussion Paper No. 2011-03*, Available at: https://www120.secure.griffith.edu.au/research/file/2cc52e2f-525f-4eb6-93b7-0ee0ed11129d/1/2011-03-valuing-scenic-amenity-using-life-satisfaction-data.pdf

Ambrey C, Fleming C and Chan A (2012) *Estimating the cost of air pollution in South East Queensland: An application of the life satisfaction nonmarket valuation approach*, Available at: http://equella.rcs.griffith.edu.au/research/file/6cce9401-4c6e-4180-b98a-303066d3e47c/1/2013-02-estimating-the-cost-of-air-pollution-in-south-east-queensland.pdf

Bennett J, van Bueren M and Whitten S (2004) 'Estimating society's willingness to pay to maintain viable rural communities', *The Australian Journal of Agricultural and Resource Economics*, vol. 48, no. 3, pp. 487-512.

Bennett J, Dumsday R, Lloyd C and Kragt, M (2007) *Non-Use Values of Victorian Public Land: Case Studies of River Red Gum and East Gippsland Forests*, Prepared for the Victorian Environmental Assessment Council, Available at: http://www.veac.vic.gov.au/documents/VEAC_Final_CM_report_1_June_07.pdf

Brodbeck S (2005) 'A view for the public', *Australian Planner*, vol. 42, no. 1, pp. 47-51.

Carlsson F, Lampi E and Martinsson P (2004) *Measuring marginal values of noise disturbance from air traffic: Does the time of the day matter?*, Available at: https://gupea.ub.gu.se/bitstream/2077/2817/1/gunwpe0125.pdf

Coyle D, Stieb D, Burnett R, DeCivita P, Krewski D, Chen Y and Thun M (2003) 'Impact of Particulate Air Pollution on Quality-Adjusted Life Expectancy in Canada, *Journal of Toxicology and Environmental Health*, *Part A: Current Issues*, vol. 66, no. 16-19, pp. 1847-1864.

Department of Environment and Climate Change NSW (2008) *BioBanking Assessment Methodology*, Available at: http://www.environment.nsw.gov.au/resources/biobanking/08385bbassessmethod.pdf

Department of Planning (2005) *Coal Mining Potential in the Upper Hunter Valley Strategic Assessment*, Available at: http://www.planning.nsw.gov.au/regional/pdf/final-draft1_5.pdf

Dutton A, Edwards-Jones G and Macdonald D (2010) 'Estimating the Value of Non-Use Benefits from Small Changes in the Provision of Ecosystem Services', *Conservation biology: the journal of the Society for Conservation Biology*, vol. 24, no. 6, pp. 1479-1487.

Environment Australia, Department of the Environment (1998), *Dust Control: Best Practice Environmental Management in Mining*, Available at: http://www.ret.gov.au/resources/Documents/LPSDP/BPEMDustControl.pdf

Geoscience Australia (2013a), *Groundwater basics*, Available at: http://www.ga.gov.au/groundwater/basics.html

Geoscience Australia (2013b), *Groundwater-surface water connectivity*, Available at: http://www.ga.gov.au/groundwater/understanding-groundwater-resources/groundwater-surface-water-connectivity.html

Gillespie Economics (2009) *Proposed Warkworth Extension: Choice Modelling Study of Environmental, Cultural and Social Impacts*.

Gillespie R and Bennett J (2012) 'Valuing the environmental, cultural and social impacts of open-cut coal mining in the Hunter Valley of New South Wales, Australia', *Journal of Environmental Economics and Policy*, vol. 1, no. 3, pp. 276-288.

Hendryx, M and Ahern MM (2008) 'Relations between health indicators and residential proximity to coal mining in West Virginia', *American Journal of Public Health*, vol. 98, no. 4, pp. 669-671.

Index Mundi (2015) *Coal, Australian thermal coal Monthly Price - Australian Dollar per Metric Ton*, Available at: http://www.indexmundi.com/commodities/?commodity=coal-australian&months=60&currency=aud

Ivanova G, Rolfe J, Lockie S and Timmer V (2007) 'Assessing social and economic impacts associated with changes in the coal mining industry in the Bowen Basin, Queensland, Australia', *Management of Environmental Quality: An International Journal*, vol. 18, no. 2, pp. 211-228.

Koteen J, Alexander SJ and Loomis JB (2002) *Evaluating Benefits and Costs of Changes in Water Quality*, United States Department of Agriculture, Forest Services, Available at: http://www.fs.fed.us/pnw/pubs/gtr548.pdf

Kumar, P (2010) *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*, UNEP/Earthprint.

MacDonald D, Morrison M, Rose J and Boyle K (2011) 'Valuing a multistate river: the case of the River Murray', *Australian Journal of Agricultural and Resource Economics*, vol. 55, no. 3, pp. 374-392.

Marsden Jacob Associates (2012) 'Assessing the value of groundwater', *Waterlines report*, National Water Commission, Canberra.

McConnell V and Walls M (2005) 'The value of open space: evidence from studies of non-market benefits', *Resources for the Future*, Washington., Available at: http://www.rff.org/rff/Documents/RFF-REPORT-Open%20Spaces.pdf

Navrud S (2002) 'The State-Of-The-Art on Economic Valuation of Noise', *Final Report to the European Commission DG Environment*, Available at: http://cevreselgurultu.cevreorman.gov.tr/dosya/background_information/noise_monetisation_EU_WG_HSAE.pdf

Neelawala P, Wilson C and Athukorala W (2012) 'The impact of mining and smelting activities on property values: a study of Mount Isa city, Queensland, Australia', *The Australian Journal of Agricultural and Resource Economics*, vol. 57, no. 1, pp. 60-78.

Office of Environment and Heritage (2012) *BioBanking review: Discussion paper*, Available at: http://www.environment.nsw.gov.au/resources/biobanking/20120062bbrevdp.pdf

Ossokina I and Verweij G (2011) 'Urban traffic externalities: quasi-experimental evidence on the effect of traffic externalities on housing prices', *CPB Discussion Paper 267*, Available at: http://www.cpb.nl/en/publication/urban-traffic-externalities-quasi-experimental-evidence-from-housing-prices

Pacific Environment Limited (2016) "Economic Costs of Air Quality Impacts – Mount Owen Continued Operations."

PAEHolmes (2013) *Methodology for valuing the health impacts of changes in particle emissions – final report*, Available at: http://www.epa.nsw.gov.au/resources/air/HealthPartEmiss.pdf

Productivity Commission (2006) *Conservation of Australia's Historic Heritage Places*, Available at: http://www.pc.gov.au/__data/assets/pdf_file/0011/92369/heritage.pdf

Rolfe J and Windle J (2003) 'Valuing the Protection of Aboriginal Cultural Heritage Sites', *Australian Archaeology*, no. 56, pp. 35-41, Available at: https://www.library.uq.edu.au/ojs/index.php/aa/article/viewFile/637/638

R.W. Corkery & Co. Pty Limited for Whitehaven Coal (2009) *Environmental Assessment for the Narrabri Coal Mine Stage 2 Longwall Project. Project Application no: MP080144*, Available at: http://www.whitehaven.net.au/operations/documents/67416ContentsandSummary.pdf

Smith S (2009) *Mining and the Environment: Briefing Paper No 6/09*, Available at: http://www.parliament.nsw.gov.au/prod/parlment/publications.nsf/0/6C4E3081F6C87AAFCA2575E700010209/$File/Mining%20and%20the%20environment%20BP%206%2009.pdf

Subade RB (2005) 'Valuing Biodiversity Conservation in a World Heritage Site: Citizens' Non-use Values for Tubbataha Reefs National Marine Park, Philippines', *EEPSEA Research Report No. 2005-RR4*, Available at: http://web.idrc.ca/uploads/user-S/11201034921RodelRR4.pdf

Transport for NSW (2013) *Principles and Guidelines for Economic Appraisal of Transport Investment and Initiatives*, Available at: http://www.transport.nsw.gov.au/sites/default/files/b2b/publications/tfnsw-principles-and-guidelines-for-economic-appraisal-of-transport-initiatives.pdf

University of Hawaii Economic Research Organisation (2013) *Methodologies to Assess the Value of the Coastal Zone Management (CZM) Special Management Area (SMA) Permit Program*, Available at: http://files.hawaii.gov/dbedt/op/czm/resource/final_methodologies_to_assess_value.pdf

Van Bueren M and Bennett J (2000) *Estimating community values for land and water degradation impacts*, Prepared for the National Land and Water Resources Audit, Project 6.1.4.

Van Bueren M and Bennett J (2004) 'Towards the development of a transferable set of value estimates for environmental attributes', *The Australian Journal of Agricultural and Resource Economics*, vol. 48, no. 1, pp. 1-32.

Wahba M and Hope C (2006) 'The marginal impact of carbon dioxide under two scenarios of future emissions', *Energy Policy*, vol. 34, no. 17, pp. 3305-3316.

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APPENDIX 8

Economic Cost of Air Quality Impacts

Pacific Environment Limited

Consulting • Technologies • Monitoring • Toxicology

Report

Economic Cost of Air Quality Impacts – Mount Owen Continued Operations – Refined Project

Umwelt (Australia) on behalf of Mount Owen Pty Ltd

Job ID. 20159F

25 May 2016

PROJECT NAME:	Economic Cost of Air Quality Impacts – Mount Owen Continued Operations – Refined Project
JOB ID:	20159F
DOCUMENT CONTROL NUMBER	AQU-NW-001-20159F
PREPARED FOR:	Umwelt (Australia) on behalf of Mount Owen Pty Ltd
APPROVED FOR RELEASE BY:	Jane Barnett
DISCLAIMER & COPYRIGHT:	

DOCUMENT CONTROL

VERSION	DATE	COMMENT	PREPARED BY	REVIEWED BY
Final	25/05/2016	Final report	Kapil Kulkarni	Jane Barnett

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EXECUTIVE SUMMARY

Pacific Environment has been engaged by Umwelt (Australia) Pty Ltd on behalf of Mount Owen Pty Limited to estimate the economic costs of air quality impacts from the Mount Owen Continued Operations Project (the Project). The Project involves the continuation of the existing mining operations at the Mount Owen Complex which consists of extended mining operations at the North Pit and continuation of approved mining operations within the Ravensworth East Mine.

The analysis of economic costs of air quality impacts (economic analysis) will be an input into the cost benefit analysis (CBA) being undertaken for the Project. The CBA will compare all quantifiable benefits and costs, including air quality impacts, attributable to the Project.

Methodology to assess the economic costs of air quality impacts

The economic analysis estimates the economic costs of air quality impacts associated with the Project (i.e. the costs associated with changes to air quality impacts associated with the Project) using two methods. The costs are first estimated using the unit damage costs approach outlined in economic assessment guidelines released by the NSW Department of Planning and Environment. A second method, which approximates an impact pathway approach (by considering the pathway from emissions to economic costs), is also adopted. The approach is considered more robust, adopts conservative assumptions (leading to a high estimate of economic costs) and has been undertaken because the damage cost approach is likely to lead to an inaccurate estimate of the economic costs of air quality impacts.

Air Quality Impact Assessment

This economic analysis utilises and builds on an Air Quality Impact Assessment (AQIA) analysis undertaken by Pacific Environment for the Project. The purpose of the AQIA was to predict emissions of selected air pollutants from the Project, and predict concentrations of those air pollutants at residences proximate to the mine.

The economic analysis used AQIA model results for both the Bayswater North Pit (BNP) and the North Pit Continuation consistent with the approach taken in the economic assessment of the Original Project. This approach will overestimate the cost of air quality impacts associated with the Project as BNP is approved under the existing Ravensworth East Mine consents.

Overview of Results

Using the approximated impact pathway approach, the economic costs of air quality impacts are estimated to be **$4.9 million** in Present Value (PV) terms (2015 dollars using a 7 per cent real discount rate), or **$5.9 million** or **$4.1 million** (using a 4 per cent or 10 per cent discount rate respectively). These estimates are based on broadly conservative assumptions (leading to an upwards bias).

The estimated costs using a damage cost approach vary according to which unit damage costs are used. Using a strict application of the economic assessment guidelines (and associated Excel workbooks), emissions from the Project would be assigned a unit damage cost corresponding to 'Not in any Significant Urban Area (NSW)'. This results in no estimated economic impacts (the workbook assigns a nil economic cost to emissions assigned to 'Not in any significant urban area (NSW)').

While not considered appropriate, if the unit damage costs for Singleton (the nearest significant urban area to the Project) are used, the economic costs of air quality impacts are estimated to be **$39.9 million**, **$48.1 million** or **$33.6 million** (using a 7 per cent, 4 per cent or 10 per cent discount rate respectively). Given the Project's location and likely surrounding population's exposure to incremental pollutant concentrations, the approximated impact pathway approach, which adopts broadly conservative assumptions, provides a much more accurate estimate of the economic costs than the damage cost approach.

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1 INTRODUCTION

This report has been prepared by Pacific Environment for Umwelt (Australia) Pty Ltd (Umwelt) on behalf of Mount Owen Pty Limited (Mount Owen), a subsidiary of Glencore Coal Pty Limited. The report includes an assessment of the economic costs of the likely air quality impacts of the proposed Mount Owen Continued Operations Project (the Project), located in the Upper Hunter Valley, New South Wales (NSW).

Pacific Environment was engaged by Umwelt to:

- estimate the economic costs of Particulate Matter (PM) emissions using the draft and final[a] Guidelines for the Economic Assessment of Mining and Coal Seam Gas Projects released by the NSW Department of Planning and Environment (the Guidelines) (**NSW Department of Planning and Environment, 2015a**; **NSW Department of Planning and Environment, 2015b**);
- provide advice on the appropriateness of, and limitations associated with, using the approach outlined in the Guidelines and the associated Air Quality Valuation Workbook (AQVW);
- estimate the economic costs of PM emissions using an alternative approach that provides a more appropriate assessment of the economic costs; and
- provide a comparison and discussion of estimates using the Guidelines and the alternative method.

The Project relates to a continuation of mining activity at the Mount Owen North Pit to 2030 however the assessment of the Project included in the Environmental Impact Statement (EIS) considers the overall impact of operations at the Mount Owen and Ravensworth East operations which are operated as an integrated operation. The Bayswater North Pit (BNP) is located in the Ravensworth East area and, while already approved, is considered as part of the incremental economic costs of air quality impacts associated with the Project to maintain consistency with the approach taken in the Cost Benefit Analysis and Economic Impact Analysis of the Project prepared by Deloitte Access Economics (DAE) for the original Project **(DAE, 2014)** which formed Appendix 17 of the EIS for the Project.

The economic analysis utilises and builds on Air Quality Impact Assessment (AQIA) analysis undertaken by Pacific Environment for the Project (**Pacific Environment, 2014**). The purpose of the AQIA was to estimate emissions of selected air pollutants from the Project, and predict concentrations of those air pollutants at residences proximate to the mine. This report refers to, and should be read in conjunction with, the AQIA.

The remainder of the report includes:

- an outline of the methodologies used to estimate the economic costs of air quality impacts (Chapter 2 – Methodology);
- a comparison of results from using the different methodologies (Chapter 3 – Results);
- concluding remarks (Chapter 4 – Conclusion); and
- references (Chapter 5 – References).

[a] Although the final guidelines take precedence over the draft, the draft guidelines are still likely to be relevant for project proponents as they provided much more detail on economic assessment approaches than the final guidelines.

2 METHODOLOGY

2.1 Overview

Pacific Environment has assessed the economic costs of air quality to provide inputs into the cost-benefit analysis (CBA). The assessment was conducted using the following two approaches:

- **Method 1:** Using the 'unit damage cost approach' and associated AQVW, as outlined in the Draft Guidelines (**NSW Department of Planning and Environment, 2015a**)
- **Method 2:** An alternative method that approximates an 'impact pathway' approach.

Both methods estimate the health impact from fine particulate matter of less than 2.5 micrometres in diameter ($PM_{2.5}$), as the economic costs of health impacts from air pollution are dominated by mortality and morbidity impacts resulting from $PM_{2.5}$ (**NSW Department of Planning and Environment, 2015a**). The economic costs estimated in this analysis are the full economic costs of health impacts and should be interpreted as the full cost to society (inclusive of lost income, value of lost community involvement, health system costs and other values captured in the estimate of a VSL).

This chapter outlines:

- assumptions relating to the Project's incremental emissions (used in both methods);
- an outline of Method 1 including a discussion on the appropriateness and applicability of Method 1 for estimating the economic costs of air quality impacts of the Project; and
- the assumptions and approach for Method 2, and an explanation for why the assumptions lead to a conservative estimate.

2.2 Incremental emissions attributable to the Project

A CBA compares the incremental costs and benefits of a project relative to an assumed baseline scenario (i.e. relative to what would occur if the Project did not proceed). The Project relates to a continuation of mining activity at the Mount Owen North Pit to 2030 and mining in BNP to 2022. Under current approvals, mining activity at the North Pit would not extend beyond 2018, due to the geographical boundaries of the current approval conditions.

The continuation of mining in the North Pit will overlap with mining in the Bayswater North Pit (BNP) which is already approved. The mining of both the BNP and North Pit Continuation concurrently will have operational benefits which flow through to the broader economic analysis of the Project Accordingly, to maintain consistency with the approach taken in the DAE economic assessment, the BNP is considered as part of the Project case and not the baseline. The mining in the North Pit in the period of 2016 to 2018 under the Project scenario will have similar production rates and will handle similar quantities of waste material to the existing approved mining in the North Pit. From an air quality perspective, the impacts from the existing approved development (the base case) and the Project in these overlapping periods are considered to be sufficiently similar to be taken as being identical for economic assessment purposes.

While mining in the RERR Pit was originally proposed, this aspect of the development no longer forms part of the Project being assessed. This analysis therefore only considers the economic costs of incremental air quality impacts from the emissions associated with the Project which, for the purposes of this assessment, are taken to be the impacts associated with mining in the North Pit Continuation area over the period 2019 to 2030 and BNP from 2016 to 2022.

The assessment undertaken as part of the AQIA separately quantifies the emissions associated with mining in the North Pit and the BNP and RERR mining area. The incremental $PM_{2.5}$ emissions (attributable to continuation of mining at the North Pit and ongoing mining of BNP), are based on results from the modelling of the Project undertaken by Pacific Environment (2014), and are shown in **Table 2.1** below.

Table 2.1: Modelled Incremental $PM_{2.5}$ Emissions from Activities Associated with Project

	Year 1-3	Years 4-7	Years 8-15
Estimated incremental $PM_{2.5}$ emissions (kg/y)	39,878	167,515	104,313

Source: Tables 8.6, 8.7 and 8.8, pp. 65-67, Pacific Environment (2014).

The estimate for Years 1-3 (corresponding to years 2016-2018) includes emissions from the BNP but does not include North Pit emissions, which would occur under the baseline scenario and therefore cannot be considered incremental. The estimates for Years 4-7 (corresponding to years 2019-2022)-include emissions from both North Pit and BNP and the emissions from Year 8 to end of life (corresponding to years 2023-2030) are the projected emissions from the North Pit only. It is noted that the North Pit emissions in Years 4 to 7 also include emissions associated with the approved haulage and handling of coal from Glendell at the Mount Owen CHPP and therefore overestimate emissions from the Project case. Given that both BNP and Glendell are already approved, the inclusion of these emissions in the analysis will overestimate the incremental costs associated with $PM_{2.5}$ emissions from the Project.

The resulting projections are shown in **Figure 2.1**.

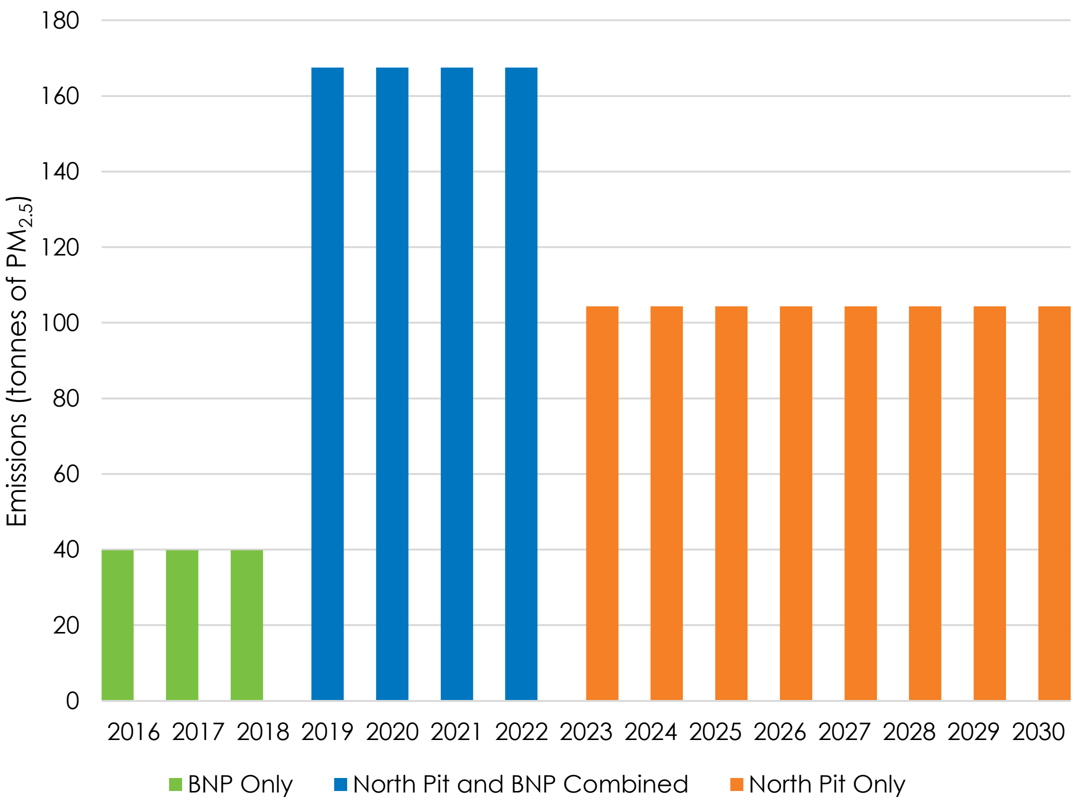

Figure 2.1: Emissions projections used in economic analysis

2.3 Damage cost approach (Method 1)

2.3.1 Overview of approach

The unit damage cost approach (Method 1) adopts the approach for the appraisal of air quality impacts as outlined in the Draft Guidelines for the economic assessment of mining and coal seam gas proposals (**NSW Department of Planning and Environment, 2015a**, pp. 43-48). This approach involves assigning a project's emissions sources to a Significant Urban Area (SUA) in NSW, and applying the unit damage costs (i.e. $ of economic impact per unit of emissions) for that SUA to estimate economic costs. NSW contains 35 SUAs, which represent regions with clusters of related urban centres with a core population of over 10,000 (**PAEHolmes, 2013**). A unit damage cost is also available for emissions not located within any of the 35 SUAs.

The Project's emissions sources are located outside of the 35 SUAs in NSW (see Figure 2.2), therefore, the unit damage cost representing 'Not in any Significant Urban (NSW)' in the AQVW has been applied. The economic costs have then been estimated following Tasks 1 – 5 for using the AQVW as outlined in the Draft Guidelines (**NSW Department of Planning and Environment, 2015,** pp.47-48). Note that Task 6 (sensitivity analysis of the quantity of $PM_{2.5}$ emissions) was not undertaken given that a range of emissions quantities have not been estimated for the AQIA.

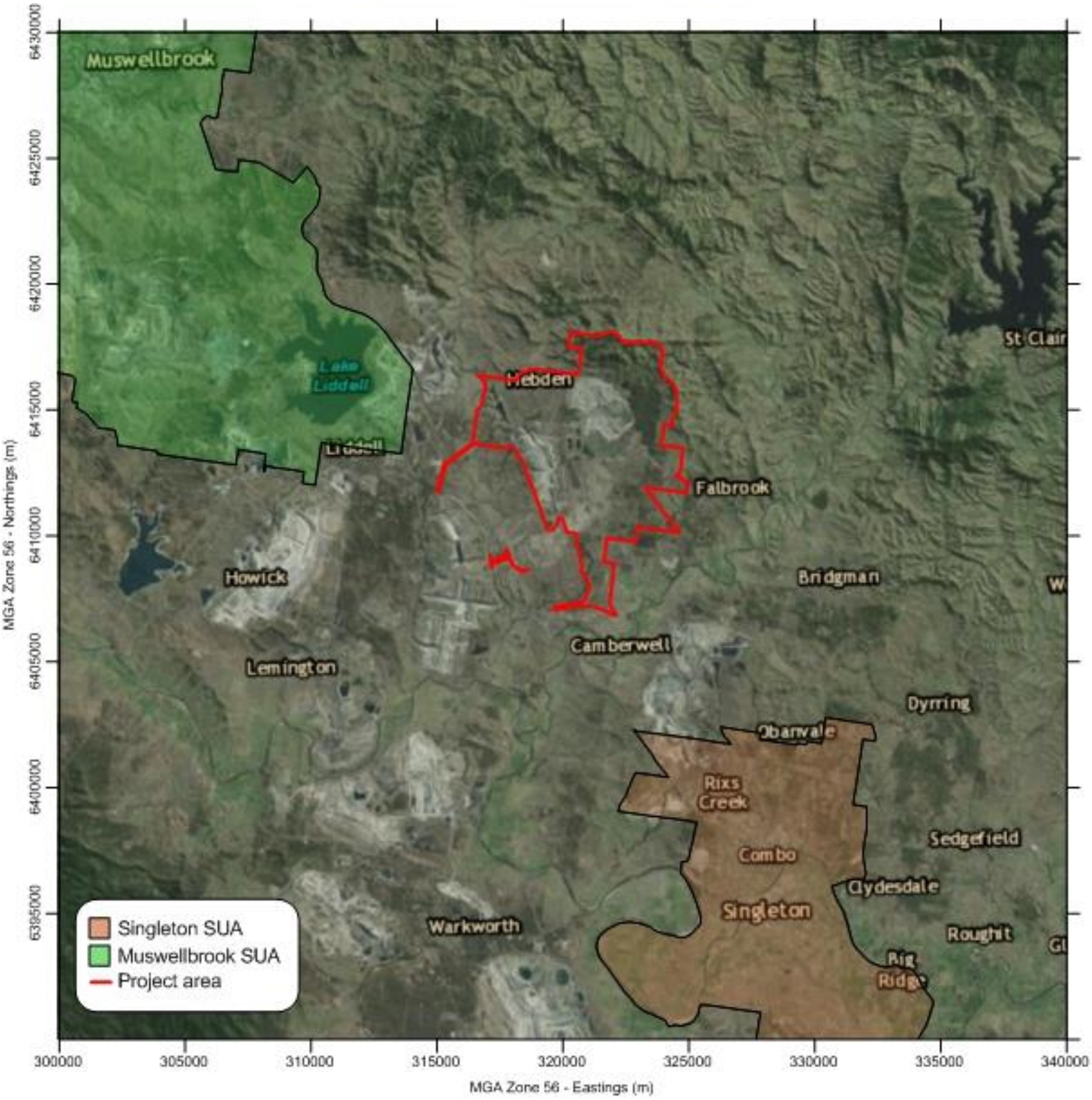

Figure 2.2: Nearby significant urban area boundaries

The nearest major town (Singleton) is in the Singleton SUA. The northern boundary of this SUA is approximately 10 km from the emitting activities from the Project[b]. To provide a point of comparison, the estimated economic costs based on application of the unit damage costs for Singleton have also been applied. However, these are not considered an accurate estimate of economic costs of the Project's air quality impacts for the reasons set out below.

2.3.2 Limitations of the damage cost approach

The unit damage cost values have been derived from work undertaken by PAEHolmes (**PAEHolmes, 2013**). The PAEHolmes report presents unit damage cost values (A$ per tonne of $PM_{2.5}$ emitted, at 2011 prices) for 'significant urban areas' (SUAs) in Australia. The method is fundamentally based upon damage cost values from the UK (Defra), with a conversion to reflect differences in the valuation of health outcomes and currency between the UK and Australia.

The differentiation between the unit damage costs for SUAs in Australia is a function of population density alone. In other words, one tonne of $PM_{2.5}$ emissions occurring in a more densely populated area is associated with higher economic costs compared with one tonne of $PM_{2.5}$ emissions occurring in a less densely populated area. This allows the location of emissions to be linked to an approximate population-weighted exposure to $PM_{2.5}$ (see Table 1 below for example damage costs).

Table 1: Selected $PM_{2.5}$ unit damage costs from PAEHolmes (2013) (2011 A$ per tonne)

SUA name	Area (km^2)	Population [a]	Population density (people/km^2)	Damage cost (A$ per tonne of $PM_{2.5}$)
Sydney	4,064	4,028,525	991	$280,000
Newcastle – Maitland	1,019	398,770	391	$110,000
Singleton	127	16,133	127	$36,000
Muswellbrook	262	11,791	45	$13,000
Not in any Significant Urban Area (NSW)	788,116	999,873	1.3	$360

[a] Based on ABS 2011 datasets

Source: p. vi, PAEHolmes (2013).

The intent of the PAEHolmes 2013 study was to provide unit damage costs that may be used for economic appraisals in NSW and Australia where a full 'impact pathway' approach is not possible or practical. Nevertheless, the report noted the limitations of the damage cost method under certain conditions, as it is based on the assumption that emissions are spatially proximate to the exposed population within the SUA (as discussed in the next subsections).

Use of Not in any Significant Urban Area (NSW) unit damage cost

The use of the Not in any Significant Urban Area (NSW) unit damage cost is likely to significantly understate the economic cost of the Project's air quality impacts. The value is derived from the population density for the large area of NSW that is not within SUA boundaries (788,166 km^2). An application of the Not in any Significant Urban Area (NSW) would only be appropriate if the Project was located in a remote area far from any significant population centres. Whereas, the Project is in fact located within less than 20 – 25 km of towns and villages.

[b] However, it should be noted that the suburb of the town of Singleton that is closest to the mine (Singleton Heights), is approximately 15 km from the nearest emitting activities. This distance (proximity of exposed population) is much more relevant to estimating economic costs than the distance from the SUA boundary, as the SUA boundaries -are somewhat arbitrarily defined.

Use of Singleton Significant Urban Area unit damage cost

Conversely, the use of the Singleton SUA unit damage cost is likely to significantly overstate the economic cost of the Project's air quality impacts and would also be inappropriate. Firstly, Project's emissions are located outside of the SUA boundaries. Secondly, even if the Project's emissions sources were located within SUA boundaries PAEHolmes note that the damage cost method is likely to over-estimate population weighted exposure for localised sources (such as coal mines), given that the damage cost values were derived from analysis of road transport emissions in the United Kingdom (UK) (**PAEHolmes, 2013**, pp. 41-42):

> *'Emissions from non-transport sources will lead to a different population-weighted exposure compared with road transport. This is reflected in the Defra*[c] *damage costs, which assign much lower levels to industry and electricity generation (as these are mostly emitted from tall stacks in rural areas). Population-weighted exposure from industrial stack emissions is not analysed separately in the UK for different areas. Further modelling work would be needed to address this issue accurately (both in the UK and Australia). It is therefore highlighted that the application of the new damage costs to industrial stack emissions will over-estimate population-weighted exposure, and it is recommended that industrial emissions are considered separately where industry dominates an area'*.

These limitations would apply when applying the damage cost method to other large but localised industrial emission sources in areas with small pockets of population. This is particularly the case for most open cut coal mining developments in NSW where the residences are located some distance from the source of emissions, and the underlying assumption that emissions are spatially proximate to the population is not accurate as most of the particulate material has settled out before it reaches the nearest residences.

While the unit damage costs account for population density differences across SUAs (by assigning lower values to emissions occurring in less densely populated SUAs), they do not account for differences in the proximity of emissions sources to those population centres within the SUA. Therefore, in the case of an emitter such as a coal mine that is located away from population centres, it is reasonable to argue that the approach will significantly over-estimate impacts and costs.

2.4 Approximated impact pathway approach (Method 2)

2.4.1 Overview of approach

Method 2 approximates an impact pathway approach. An impact pathway approach *'is the most robust valuation approach following the pathway from emissions to cost via ambient air quality concentrations, population exposure, and morbidity and mortality health impacts'* (**NSW Department of Planning and Environment, 2015a, p.46**). Whilst this method does not adopt a full impact pathway, it approximates the costs of the Project's $PM_{2.5}$ emissions by:

- making use of predicted $PM_{2.5}$ concentrations at points near the main population centres within proximity of the Project (based on modelling from the AQIA);
- projecting the incremental premature mortalities associated with the incremental increase in annual average $PM_{2.5}$ concentrations;
- monetising the incremental projected premature mortalities; and

[c] The Department for Environment, Food and Rural Affairs (DEFRA) in the UK is the government Department responsible for policies related to safeguarding the natural environment, supporting the food and farming industry, and sustaining the rural economy. DEFRA provides guidance on the economic impacts of air quality in the UK.

- applying an uplift to account for morbidity impacts.

The predicted $PM_{2.5}$ concentrations at population locations was based on AQIA modelling. Year 1 of the modelling was used for estimating economic costs in years 2016 to 2018 inclusive (using incremental predicted concentrations associated with BNP only). Year 5 of the modelling was used for estimating economic costs from years 2019 to 2022 inclusive (using incremental predicted concentrations associated with the North Pit Continuation and BNP combined). Year 10 of the modelling was used for estimating economic costs from years 2023 to 2030 inclusive (using incremental predicted concentrations associated with the North Pit Continuation only).

Note that the analysis does not include a detailed Health Risk Assessment (HRA) but rather, provides a more accurate and appropriate estimate of the economic cost of $PM_{2.5}$ emissions from the Project, relative to Method 1. While morbidity impacts are included in the estimate (through the application of an uplift), Method 2 does not include an analysis of current hospital rates and projected incremental cases of health outcomes related to morbidity (which would normally be the subject of a full HRA). This simplification is not expected to have a material impact on the estimate given that overall economic impacts are dominated by mortality (**PAEHolmes, 2013**).

2.4.2 Predicted $PM_{2.5}$ concentrations near main population centres

The economic analysis makes use of predicted incremental annual average $PM_{2.5}$ concentrations from modelling undertaken for the AQIA. The modelled area was approximately 30 km x 30 km in size, and included predictions for locations within approximately 15 – 20 km from the mine.

The modelled area fully encompassed three discrete population centres likely to experience material changes in air quality concentrations. This includes Camberwell village, a cluster of properties southeast of the Project (around Middle Falbrook and Glennies Creek) and a cluster of properties to the northwest. These are shown in **Figure 2.3**.

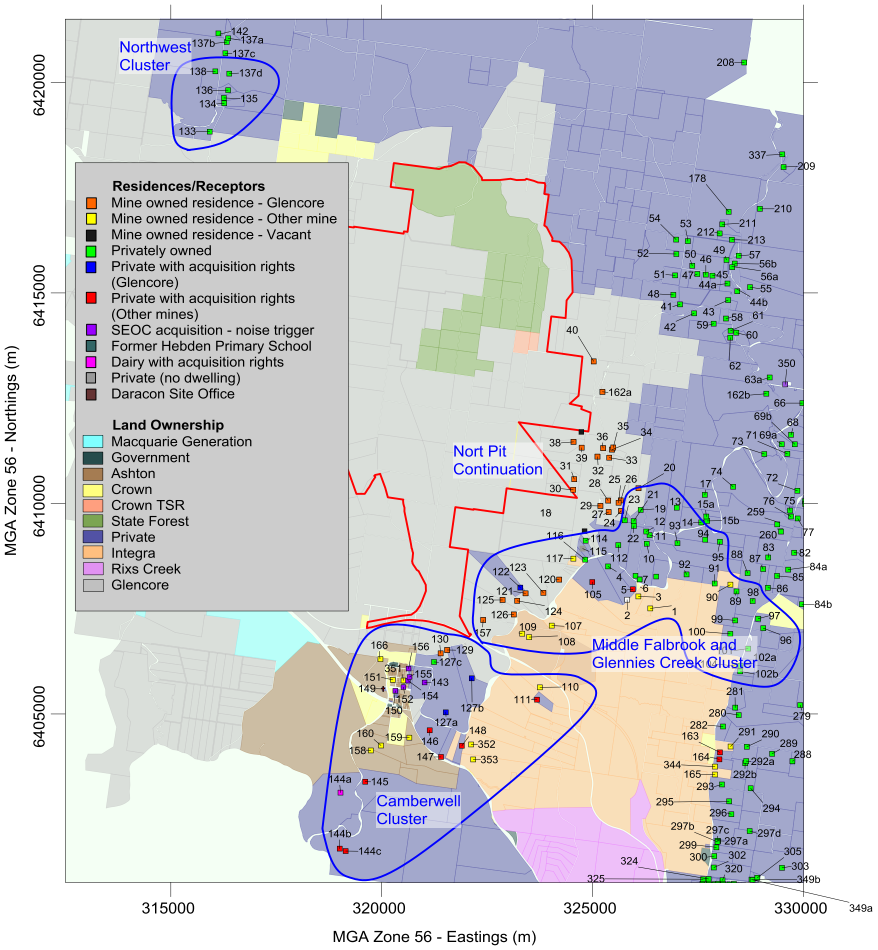

Figure 2.3: Clusters of population likely to experience exposure

However, the greatest cost of health impacts from the Project's emissions are expected at the towns of Singleton and Muswellbrook, due to a much greater population exposure at these towns. The populations of these two towns reside almost entirely outside of the modelled area (Muswellbrook is approximately 25km to the northwest of the mine and Singleton is approximately 20km to the southeast of the mine).

Therefore, a combination of approaches was used to estimate population exposure at the main population centres:

- Predicted incremental concentrations at properties in Camberwell Village[d], the cluster to the southeast[e] and the cluster to the northwest[f], were used to estimate incremental exposure for those residents.

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[d] Almost all of the properties in Camberwell Village are owned by Glencore or other mining companies. However, these have been included in the analysis to capture exposure likely to be experienced by village residents.

[e] This includes non-mine owned properties in and around the Middle Fallbrook and Glennies Creek areas, within approximately 4km distance southeast of the Project along the general axis of prevailing winds. Properties further than this distance are likely to be included in the population estimates for Singleton (which is analysed separately), and therefore excluded. Properties to the east and northeast of the Project have also been excluded as they are predicted to experience very low incremental $PM_{2.5}$ exposures (less than 0.06 µg/m³) due to be outside the axis of prevailing wind conditions.

- Average predicted incremental concentrations at locations greater than 15 km from the centre of, and in the northwest quadrant of, the modelled area were used to estimate exposure for residents of Muswellbrook.
- Average predicted incremental concentrations at locations greater than or equal to 15km from the centre of, in the southeast quadrant of, the modelled area were used to estimate exposure for residents of Singleton (including the suburbs of Singleton Heights, McDougall's Hills, Hunterview and Darlington).

The areas used to calculate average predicted incremental concentrations for Muswellbrook and Singleton are illustrated in **Figure 2.4** on the next page.

Given that the majority of population for the Singleton and Muswellbrook population centres resides outside of the modelled area, and much further than the 15 km threshold used in this analysis, the averages from the outer edges of the modelled area (as described above) results in a conservatively high estimate of the population exposure. It therefore provides an upper bound (the economic costs would be very unlikely to exceed the estimates produced by this approach).

[f] This includes private properties located approximately 8 – 10km northwest of the Project. Properties further than this distance are likely to be included in the population estimates for Muswellbrook (which are analysed separately), and therefore excluded.

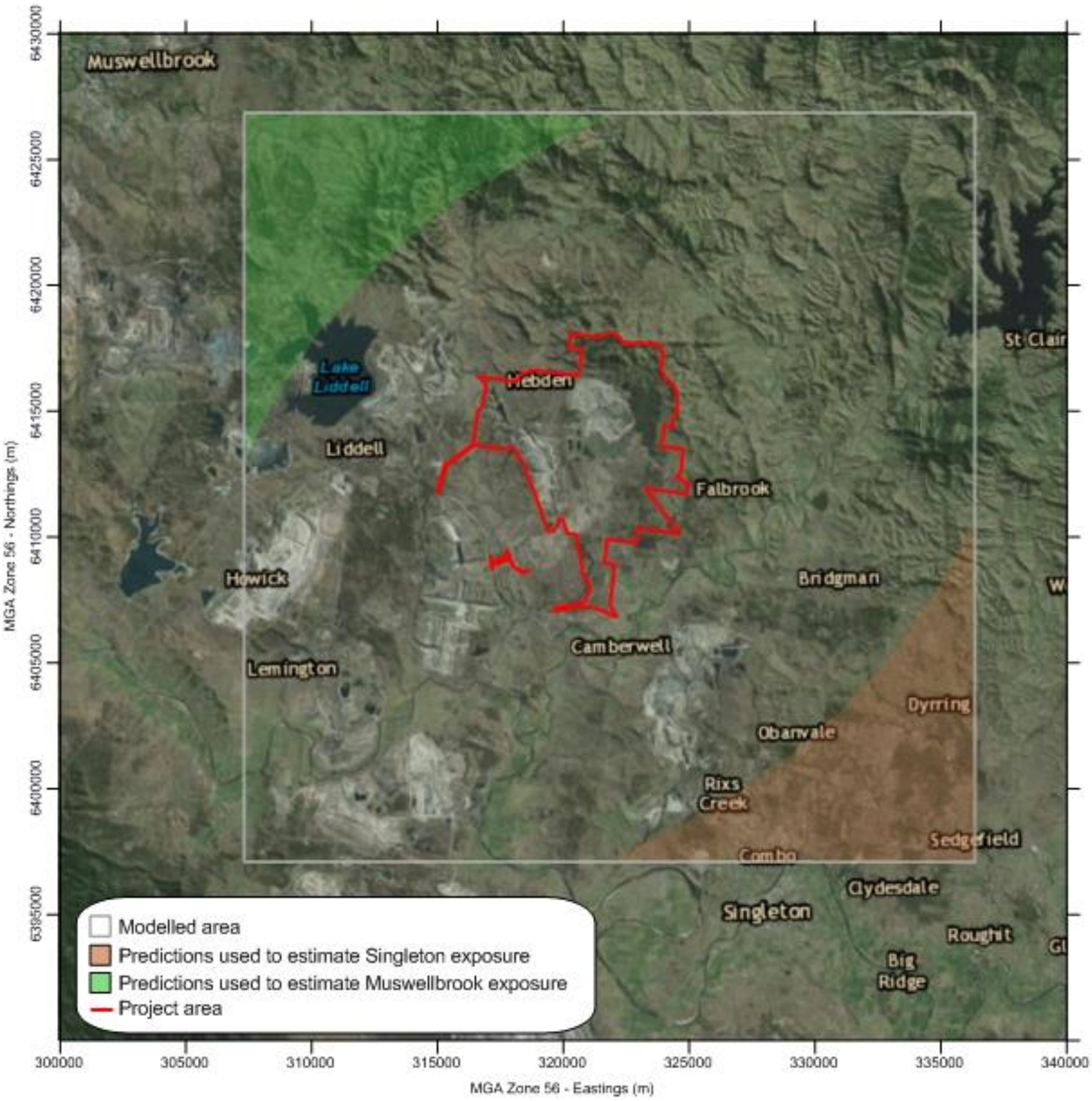

Figure 2.4: Predictions used to estimate exposure

The resulting assumed predicted incremental concentrations at the population centres, used for corresponding years in the economic analysis are shown in **Table 2.2** below.

Table 2.2: Incremental concentrations of $PM_{2.5}$ (annual average) used to estimate exposure

Population centre	Year 1 (µg/m³)	Year 5 (µg/m³)	Year 10 (µg/m³)
Camberwell Village cluster	0.09	0.31	0.16
Middle Falbrook and Glennies Creek cluster	0.07	0.56	0.39
Northwest cluster	0.07	0.43	0.27
Singleton	0.03	0.13	0.08
Muswellbrook	0.02	0.08	0.04

2.4.3 Monetisation of incremental premature mortalities and uplift for morbidity impacts

Incremental premature mortalities associated with the change in exposure to $PM_{2.5}$ concentrations were projected using the method described in Section 4.1 of **Golder Associates** (**2013**). The method involves calculating the change in mortality rate based on existing mortality rates, change in pollutant concentrates and a 'Beta (β)' coefficient, which represents the sensitivity of health outcome incidence rates to changes in pollutant concentrations, known as a concentration response function (CRF). The changes in mortality rate are then applied to the total number of persons across the exposed population to estimate an absolute number of additional premature mortalities. As noted in **Section 2.4.2**, this produces a conservative upper bound result.

The CRF used for this study was the CRF used by Golder Associates to characterise the health risks of changes in annual average $PM_{2.5}$ concentrations, which in turn was based on recommendations by **Jalaludin and Cowie (2012)** *'as the most current and robust CRF for use in Australia'* (**Golder Associates, 2013**). This same approach has also been used in the report 'Economic Analysis to Inform a National Plan for Clean Air (Particulates)' (**Boulter and Kulkarni, 2013**).

The steps in projecting premature mortalities were:

- estimating the baseline incidence of all cause mortalities for the 30+ years age group (based on analysis of statistics for NSW and the Hunter New England Local Health District from HealthStats NSW[g]);
- applying a CRF, using a 'Beta Co-efficient' from **Jalaludin and Cowie (2012)** and population estimates for the exposed population centres (ABS 2011 Census[h] and AQIA modelling[i]);
- monetising the incremental projected premature mortalities using a Value of Statistical Life (VSL), based on **Boulter and Kulkarni (2013)**; and
- applying an uplift to account for morbidity impacts based on analysis by **Boulter and Kulkarni** (**2013**).

The assumptions are summarised in Table 2.3 below.

Table 2.3: Assumptions used to monetise health impacts

Assumption	Value	Source
Baseline incidence (All-cause mortality 30+)	1.2%	HealthStats NSW
Beta Co-efficient	0.006	Jalaludin and Cowie (2012)
Population of Camberwell Village cluster (30+)	56	AQIA modelling
Population of Middle Falbrook and Glennies Creek cluster (30+)	68	AQIA modelling
Population of northwest cluster (30+)	20	AQIA modelling
Population of Singleton (30+)	7,573	ABS 2011 Census
Population of Muswellbrook (30+)	6,779	ABS 2011 Census
Value of Statistical Life	$7.2 million [a]	Boulter and Kulkarni (2013)
Uplift for morbidity	0.05%	Boulter and Kulkarni (2013)

[a] In 2015 dollars (converting from $6.5 million in 2011 dollars to 2015 dollars using the mid-point of the Reserve Bank of Australia's target band for inflation)

[g] Centre for Epidemiology and Evidence. Health Statistics New South Wales. Sydney: NSW Ministry of Health. Available at: www.healthstats.nsw.gov.au. Accessed (accessed April 2016).

[h] Using Australian Bureau of Statistics 'TableBuilder' tool and data from the 2011 Census (http://www.abs.gov.au/websitedbs/censushome.nsf/home/tablebuilder?opendocument&navpos=240), accessed April 2016.

[i] The AQIA modelling allows for identification of properties within the selected clusters. Population (30+) for these clusters was estimated as two times the number of affected properties (assuming two 30+ adults per property).

3 RESULTS

Table 3.1 below compares the results from Method 1 and Method 2 using the central discount rate of 7 per cent and sensitivity analysis using alternative discount rates of 3 per cent and 10 per cent.

Table 3.1: Estimated incremental economic costs from the Project (2015 $ million)

Estimate	Method 1 – using Not in Any Significant Urban Area (NSW) unit damage cost	Method 1 – using Singleton unit damage cost	Method 2
Annual cost (2016-2018)	$0	$1.6	$0.2
Annual cost (2019-2022)	$0	$6.5	$0.8
Annual cost (2023-2030)	$0	$4.1	$0.5
PV using a 7% discount rate	$0	$39.9	$4.9
PV using a 4% discount rate	$0	$48.1	$5.9
PV using a 10% discount rate	$0	$33.6	$4.1

Note that Method 1 (using the Not in Any Significant Urban Area (NSW) unit damage cost) results in an estimated economic cost of $0. This is because the AQVW assigns a unit damage cost value of $0 per tonne of $PM_{2.5}$ to emissions originating from 'Not in in any Significant Urban (NSW)'[j].

Costs estimated using Method 2, which provides a more accurate but conservative estimate of the economic costs of air quality impacts, are less than the costs estimated from Method 1 (using the unit damage cost corresponding to the Singleton SUA). The results for Method 2 are arrived at by approximating the impact pathway approach and are based primarily on the increase in premature mortality. For example, the projected economic cost in 2020 ($0.8 million) is based on a projected increase of the mortality rate from 1.1966 per cent to 1.1974 per cent (or an increase of 0.0008 per cent).

[j] The unit damage cost values have been derived from work undertaken by PAEHolmes (**PAEHolmes al, 2013**). PAEHolmes recommended a value of $360 per tonne of $PM_{2.5}$ for emissions originating from 'Not in in any Significant Urban (NSW)'. The AQVW rounds off all unit damage values to the nearest $1,000, resulting in a unit damage value of $0 per $tPM_{2.5}$ for emissions originating from 'Not in in any Significant Urban (NSW)'. Retaining the original unit damage value ($360 per tonne of $PM_{2.5}$ in 2011 prices), results in an estimated $0.04 million economic costs in 2025, and $0.4 million, $0.5 million and $0.4 million in total PV costs (using a 7 per cent, 3 per cent and 10 per cent discount rate respectively).

4 CONCLUSION

Pacific Environment has undertaken an assessment of the economic costs of air quality impacts from the Project, using two methods (damage cost and an approximation of an impact pathway). The damage cost approach (Method 1), either significantly understates or overstates the economic costs of air quality impacts (depending on which unit damage cost value is used). The base assumptions behind Method 1 also do not apply to the Project. The approximation of the impact pathway approach (Method 2) provides a more accurate estimate of the economic costs of air quality impacts, however it is noted that several inputs to Method 2 include conservative assumptions to ensure it produces an upper bound result.

Using the approximated impact pathway approach (Method 2), the economic costs of air quality impacts are estimated to be **$4.9 million** in Present Value (PV) terms (2015 dollars using a 7 per cent real discount rate), or **$5.9 million** or **$4.1 million** (using a 4 per cent or 10 per cent discount rate respectively).

Given that Method 2 is still an approximation of the impact pathway approach, the estimates from application of Method 2 should also be considered conservative approximations (with an associated margin of uncertainty). The most notable data limitation in this analysis was that predictions were not available for the major exposed population centres of Singleton and Muswellbrook. In the absence of these data the analysis adopted conservative assumptions and therefore the estimates should be considered as an upper bound on the likely economic costs of health impacts associated with the Project.

5 REFERENCES

Boulter P and Kulkarni K (2013). "Final Report – Volume 1: Main Report. Economic Analysis to Inform the National Plan for Clean Air (Particles)". Prepared by Pacific Environment Limited and Marsden Jacob Associates for NEPC Service Corporation, August 2013.

Deloitte Access Economics (DAE) (2014). Mount Owen Continuation Operations Project Environmental Impact Statement, Appendix 17 Cost Benefit Analysis and Economic Analysis. Available at: https://majorprojects.affinitylive.com/public/90e8e023258ddc533e414fa75c8a31d7/20.%20MOCO%20Project%20-%20EIS%20-%20Appendix%2017%20-%20Cost%20Benefit%20Analysis%20and%20Economic%20Impact%20Analysis.pdf

Golder Associates (2013). Exposure Assessment and Risk Characterisation to Inform Recommendations for Updating Ambient Air Quality Standards for PM2.5, PM10, O3, NO2, SO2. Golder Associates Report Number 127643066-001-R-Rev0.

Jalaludin B and Cowie C (2012). Health Risk Assessment – Preliminary Work to Identify Concentration-Response Functions for Selected Ambient Air Pollutants. Report prepared for EPA Victoria. Respiratory and Environmental Epidemiology, Woolcock Institute of Medical Research. 30 June 2012.

NSW Department of Planning and Environment (2015a) "Guidelines for the economic assessment of mining and coal seam gas proposals – Draft for consultation". October 2015. Available at: http://planspolicies.planning.nsw.gov.au/index.pl?action=view_job&job_id=7312

NSW Department of Planning and Environment (2015b). "Guidelines for the economic assessment of mining and coal seam gas proposals". December 2015. Available at: http://www.planning.nsw.gov.au/Policy-and-Legislation/Mining-and-Resources/Integrated-Mining-Policy

Pacific Environment (2014). Mount Owen Continuation Operations Project Environmental Impact Statement, Appendix 6 Air Quality Impact Assessment. Available at: https://majorprojects.affinitylive.com/public/eda975895d033f8a85756d26ad7eb38e/07.%20MOCO%20Project%20-%20EIS%20-%20Appendix%206%20-%20Air%20Quality%20Impact%20Assessment.pdf

PAEHolmes (2013). Methodology for valuing the health impacts of changes in particle emissions – Final Report. PAEHolmes Report 6695.

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