# LIDDELL COAL OPERATIONS



## Proposed Modification to DA 305-11-01

# PRELIMINARY DOCUMENTATION

## EPBC Act Referral 2013/6908

Volume 1

## MAIN REPORT

June 2014

LIDDELL COAL
A GLENCORE MANAGED COMPANY

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EPBC Act Referral 2013/6908

June 2014

Prepared on behalf of:

Liddell Coal Operations Pty Limited

By:-

**SLR Consulting Australia Pty Ltd**

**Umwelt (Australia) Pty Ltd**

**Jacobs** (formerly Sinclair Knight Merz)

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**Appendix B** **Modification to Liddell Coal Mine (DA 305-11-01 Mod 5) - NSW Office of Water Submission**

**Appendix C** **Groundwater Impact Assessment, Liddell Coal Operations Modification 5 to Development Consent DA 305-11-01 (SKM 2014)**

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**Appendix J** **Liddell Coal Mine Extension Aquatic Ecology and Groundwater Dependent Ecosystem Assessment (Eco Logical Australia 2013)**

# LIDDELL COAL OPERATIONS

PART 1

## The Proposed Action

# 1.0 BACKGROUND INFORMATION

## 1.1 Introduction

Liddell Coal Operations (LCO) is an established open-cut mine located at Ravensworth, approximately 25 kilometres (km) north-west of Singleton in the Upper Hunter Valley of New South Wales. LCO is operated and managed by Liddell Coal Operations Pty Limited, a wholly owned subsidiary of Glencore Coal Pty Limited (Glencore), on behalf of a joint venture between Glencore (67.5 percent (%)) and Mitsui Matsushima Australia (32.5%). LCO is located within the Parish of Liddell, in the County of Durham, and lies within both the Singleton Local Government Area (LGA) and the Muswellbrook LGA. The locality of LCO is illustrated on **Figure 1.1**.

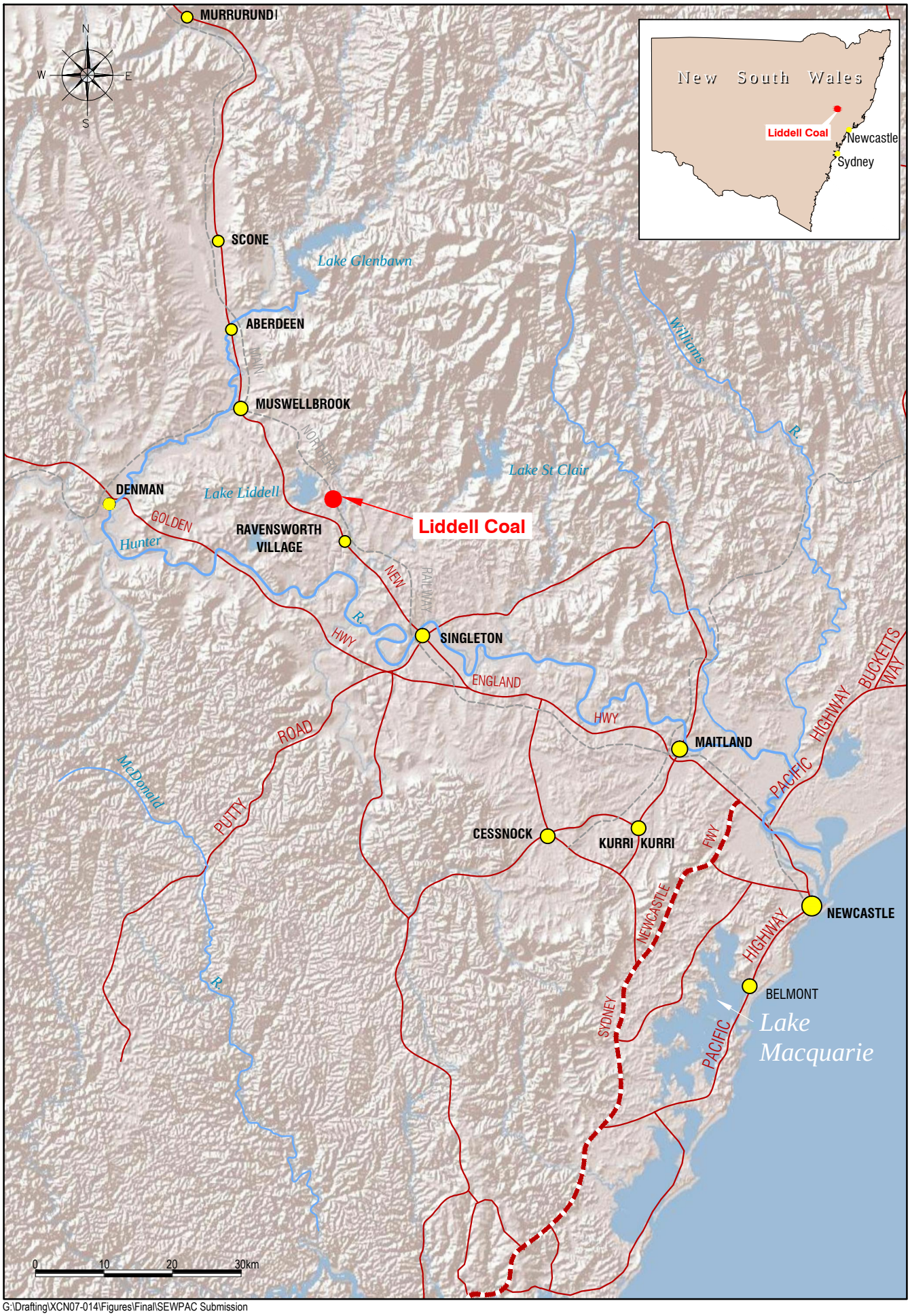
Mining at LCO has been continuous since the 1950s, during which time a number of underground and open cut coal mining operations have been developed on and under the site, subject to a number of mining leases and development consents. In 2001, a development application was lodged with Planning NSW (now the NSW Department of Planning and Environment (DPE)) to consolidate the development consents and to continue operations within the colliery holding. Development Consent DA 305-11-01 was granted by the Minister for Planning on 20 November 2002 for 21 years of continued mining operations at LCO. This DA remains the current development consent for LCO, and has since been modified on four separate occasions.

DA 305-11-01 allows for mining operations to occur at LCO until the end of 2023 within an approved mining footprint, as illustrated on **Figure 1.2**. However, current open cut mining activities will reach this approved footprint in 2014. Coal reserves have been identified outside of the existing approved mining area, within the development consent and mining lease boundaries, and LCO is therefore seeking to modify DA 305-11-01 to extend currently approved mining activities to include these additional resources so as to maximise coal recovery and maintain continuity of coal production until approximately 2028 (referred to herein as the 'Proposed Action'). The modification is sought under Part 3A section 75W of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). Mining at LCO is undertaken in accordance with NSW Mining Lease No 1597, issued under the NSW *Mining Act 1992*.

The Proposed Action will provide for continued open cut mining within the LCO development consent and mining lease boundaries through the extension of the existing South Pit and Entrance Pit, as well as mining of coal resources towards the end of mine life under the Mine Infrastructure Area (MIA), and maximising use of existing infrastructure. No changes to the mining method, production rates or operating hours are proposed under the Proposed Action. The Proposed Action is consistent with the objectives of the EP&A Act, as discussed further below in **Section 1.4**, and is permissible with development consent under the Singleton LEP and Muswellbrook LEP.

LCO Pty Limited referred the Proposed Action to the Department of the Environment (DoE) in June 2013. The Proposed Action in the referral relates only to areas of proposed additional disturbance due to the modification of the development consent within six non-contiguous areas separated by current mine infrastructure. These six areas are collectively described as the Referral Area, as illustrated on **Figure 1.2**. The Proposed Action which is the subject of the referral therefore does not relate to any works which are currently authorised by the existing development consent.

The existing LCO development consent, DA 305-11-01, was granted in 2002 for 21 years of continued mining operations. The proposed continued operations in the 2001 application were not considered to relate to any of the matters of national environmental significance (MNES) prescribed by the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and therefore the application was not the subject of an EPBC Act referral. DA 305-11-01 has been the subject of four subsequent modifications and none of these were considered to relate to any MNES either.

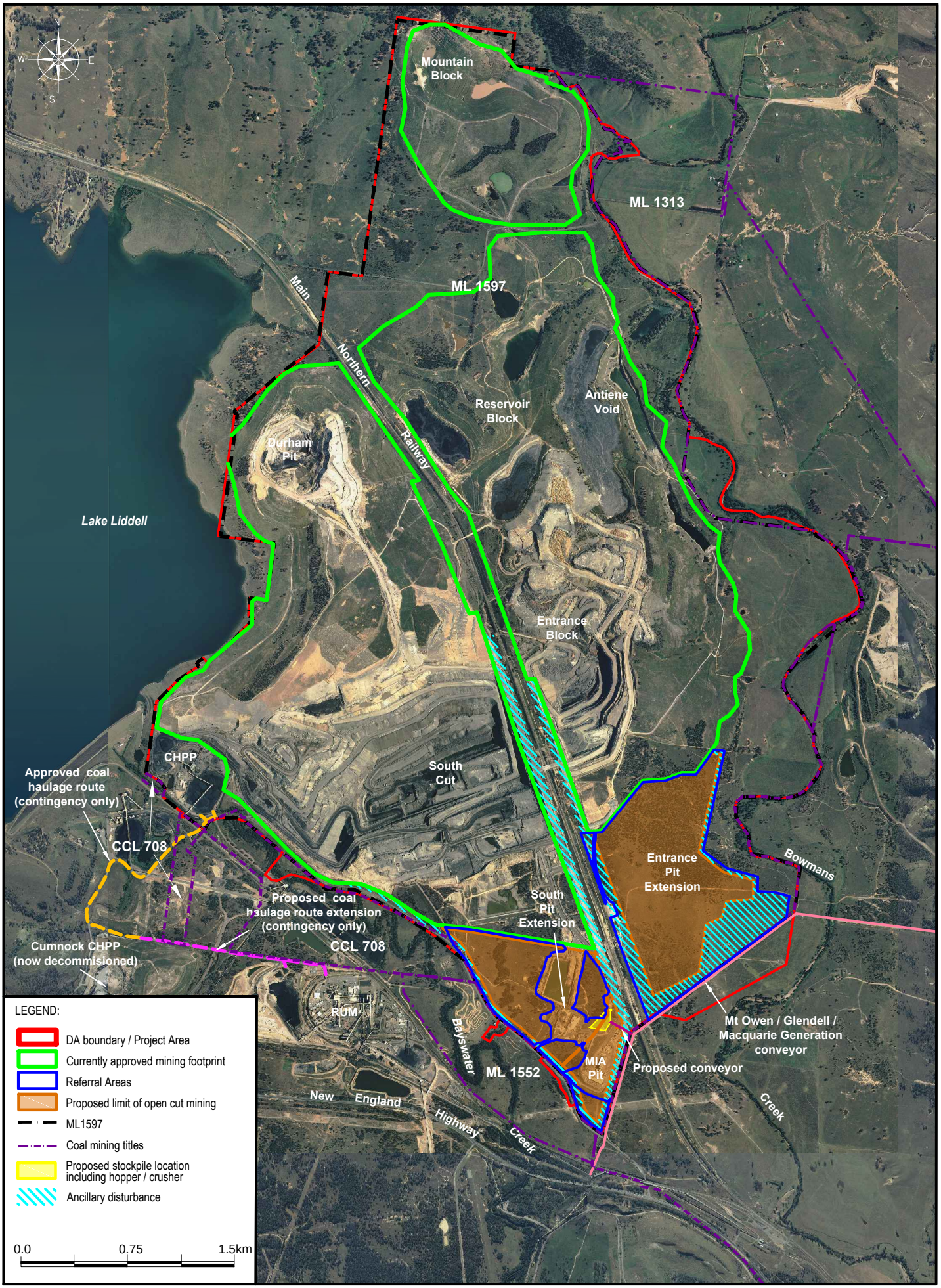



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Locality Plan

**FIGURE 1.1**




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Proposed Action and Referral Area

**FIGURE 1.2**

In a letter dated 21 October 2013, LCO were advised by DoE that the Minister's delegate determined the Proposed Action to be a controlled action, and as such requires assessment and a decision on approval under the EPBC Act before it can proceed. The Minister's delegate also decided that the project will need to be assessed through preliminary documentation. This report has been prepared to fulfil this requirement, with the additional information prepared in accordance with the *Guidelines for Preparation of Additional Information – Assessment by Preliminary Documentation – Extension to Liddell Coal Mining Operations (EPBC 2013/6908).*

At the state level, an Environmental Assessment (EA) has been prepared and submitted to the NSW DPE in support of the application to modify DA 305-11-01 to allow for the extension of mining at LCO. The EA was publicly exhibited in September 2013, and LCO has since provided a response to submissions received during this exhibition period to DPE. Further information on submissions received is provided in **Section 4.1.1.3**. The application is now under assessment by DPE.

## 1.2 Purpose and Need for the Proposed Action

Current open cut mining operations at LCO will reach the approved mining footprint within DA 305-11-01 in 2014. The Proposed Action involves extending the footprint of both the Entrance Pit and South Pit, and mining of the MIA Pit. This will enable the efficient recovery of additional coal reserves which have been identified within LCO's existing development consent and mining lease boundaries, totalling 38 Million tonnes (Mt) of Run-of-Mine (ROM) coal.

The Proposed Action will therefore enable optimisation of an existing mining operation, existing coal handling and preparation facilities, and existing transportation facilities to extract, process and transport additional coal resources to existing markets. Furthermore, if the additional 38 Mt of coal is not recovered by LCO as part of the existing operation, the likelihood of the resource being extracted in the future is considered low. The high cost of re-establishing mining operations within the site, compared to the additional coal quantity, would likely result in the resource being isolated and sterilised.

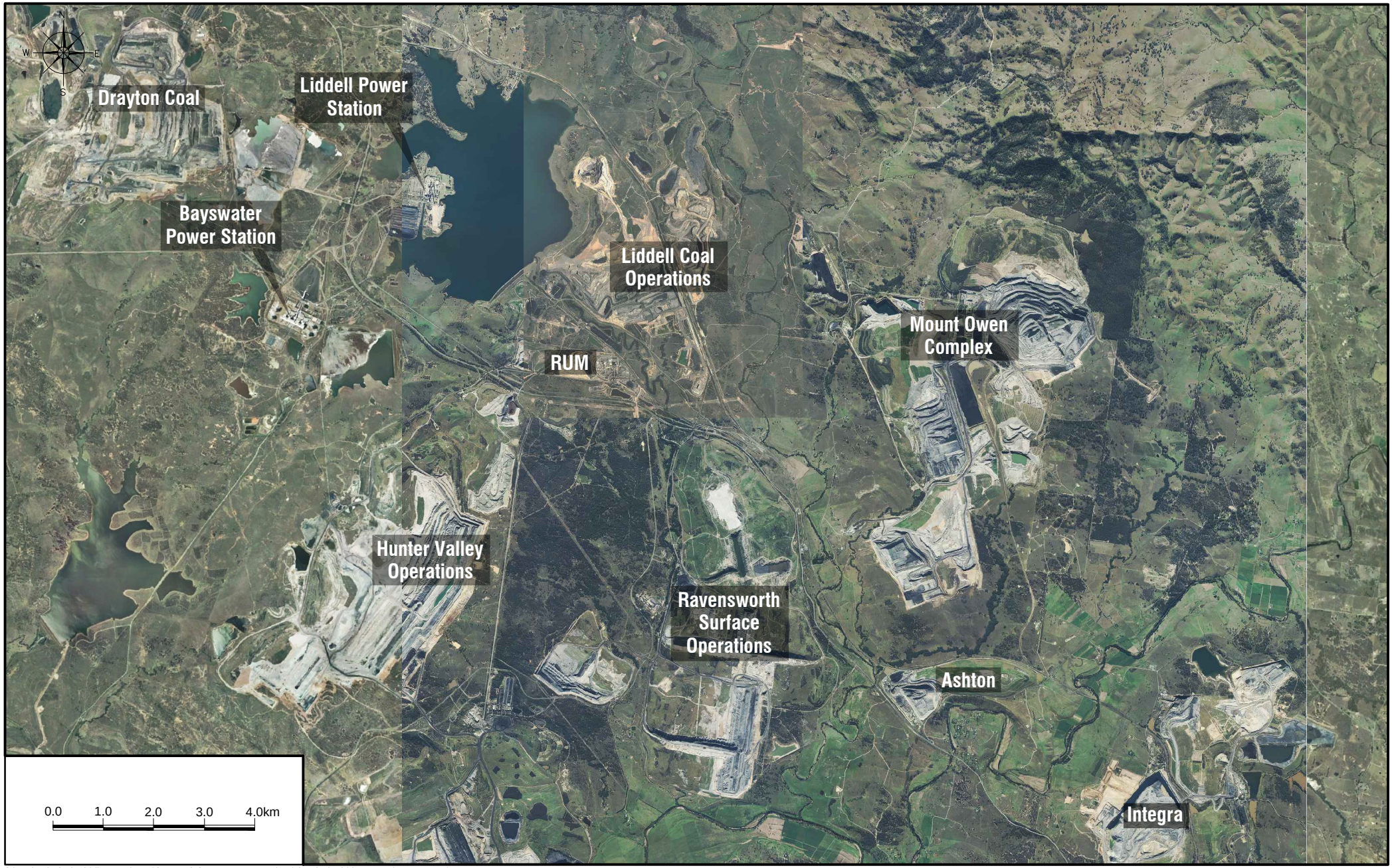
The Proposed Action involves an extension of the mine life by up to 5 years, sustaining the workforce at LCO and enabling the associated flow-on benefits to the local community as a result of continued employment.

The Proposed Action will therefore result in a number of benefits to both the local and regional community, as well as the State, which are summarised as follows:

- Maximising the recovery of resources within LCO's existing development consent and mining lease boundaries, a resource which is unlikely to be recovered in the future due to costs of mine re-establishment; and
- Enabling the efficient recovery of coal resources within the development consent and mining lease boundaries;
- Sustaining the current workforce at LCO;
- Associated flow-on benefits to the local community as a result of continued employment; and
- Broader benefits to the State in terms of royalty revenues and taxes.

## 1.3 Regional Context

Mining has been occurring in the LCO Project Area for 60 years. The area surrounding the Referral Area is heavily dominated by numerous mining and power generating activities, as illustrated on **Figure 1.3**. Surrounding current mining operations include Ravensworth Operations to the south, Ravensworth Underground Mine and the Ravensworth Central Coal Processing facility to the south west, and the Mt Owen Complex (incorporating Mt Owen, Ravensworth East and Glendell mining operations) to the east.




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Regional Locality and Surrounding Land Use

**FIGURE 1.3**

Other mines in the wider surrounding area include Ashton Coal, Integra, Hunter Valley Operations and Drayton Coal. Liddell and Bayswater Stations are located approximately 4 km and 6 km to the north west and west of LCO respectively. As illustrated in **Plate 1**, Lake Liddell, which is a constructed water storage, provides cooling water to the Liddell Power Station and is located immediately adjacent to LCO.

Proposed mining operations in the surrounding area include the Mount Owen Mining Complex Continued Operations Project. DGRs have been issued for this Project, which will seek approval to continue mining of the North Pit to the south of the current approved pit limit, extending the approved pit life from 2018 to 2026. Preparation of an Environmental Impact Statement to support the Mount Owen Continued Operations Project application is currently underway.



**Plate 1 – Adjacent land use - Bayswater and Liddell Power stations**

The Main Northern Railway line traverses LCO from northwest to southeast. The remaining land within the vicinity of LCO is characterised by traditional agricultural activities, mostly comprising low intensity grazing.

## 1.4 Objectives

As described above, the key objective of the Proposed Action is to enable optimisation of an existing mining operation, allowing the recovery of identified coal resources within an existing development consent and mining lease boundary, sustaining the current workforce and continuing the flow-on benefits to the local community.

The NSW EP&A Act is the principal piece of legislation overseeing the assessment and determination of development proposals in NSW. The objects of the EP&A Act, as set out in section 5 of the Act, are as follows:

*a) to encourage:*

*(i) the proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment,*

*(ii) the promotion and co-ordination of the orderly and economic use and development of land,*

*(iii) the protection, provision and co-ordination of communication and utility services,*

*(iv) the provision of land for public purposes,*

*(v) the provision and co-ordination of community services and facilities, and*

*(vi) the protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats, and*

*(vii) ecologically sustainable development, and*

*(viii) the provision and maintenance of affordable housing, and*

*(b) to promote the sharing of the responsibility for environmental planning between the different levels of government in the State, and*

*(c) to provide increased opportunity for public involvement and participation in environmental planning and assessment.*

The consistency of the Proposed Action with the objects of the EP&A Act is summarised in **Table 1.1**.

**Table 1.1 – Consistency with objects of the EP&A Act**

| Objects of the EP&A Act | Consistency of the Proposed Action |
|---|---|
| *to encourage:* | |
| *the proper management, development and conservation of natural and artificial resources, including agricultural land, natural areas, forests, minerals, water, cities, towns and villages for the purpose of promoting the social and economic welfare of the community and a better environment,* | Specialist consultants have been engaged to assess and report on the potential for the Proposed Action to impact upon the natural and artificial resources within and in the vicinity of the Referral Area. Notably:<br>• The impacts on the natural environment have been addressed within Sections 7.3, 7.4, 7.5, 7.8, 7.9, and 7.13 of the EA submitted to the DPE, and on those relevant matters of national environmental significance in **Sections 6** and **10** of this document.<br>• The impacts on agricultural land have been addressed in Section 7.14 of the EA submitted to the DPE.<br>• The social and economic implications have been addressed in the EA and in **Section 3** of this document. |
| *the promotion and co-ordination of the orderly and economic use and development of land,* | The orderly and economic use of land is best served by development which is permissible under the relevant planning regime and predominantly in accordance with the prevailing planning controls. The Proposed Action comprises a permissible development which is consistent with the relevant NSW statutory and strategic planning controls. As detailed in this preliminary documentation, the Proposed Action will result in positive economic impacts, with appropriate mitigation measures and management strategy being proposed to reduce adverse environmental impacts. |
| *the protection, provision and co-ordination of communication and utility services,* | Refer to **Section 2.8**. |
| *the provision of land for public purposes,* | Not applicable to the Proposed Action. |
| *the provision and co-ordination of community services and facilities, and* | Not applicable to the Proposed Action. |

| Objects of the EP&A Act | Consistency of the Proposed Action |
|---|---|
| *the protection of the environment, including the protection and conservation of native animals and plants, including threatened species, populations and ecological communities, and their habitats, and* | Specialist consultants have been engaged to assess and report on the potential for the Proposed Action to impact upon the local environment. The impacts on flora and fauna have been addressed within Section 7.4 of the EA submitted to the DPE, and on listed threatened species and communities, and migratory species in **Sections 6** of this document. |
| *ecologically sustainable development, and* | The proposal is consistent with the principles of ecological sustainable development as outlined in **Section 4.5**, addressing both this object of the EP&A Act and clause 7(1)(f) in Schedule 2 of the EP&A Regulation. |
| *the provision and maintenance of affordable housing, and* | Not applicable to the Proposed Action. |
| *to promote the sharing of the responsibility for environmental planning between the different levels of government in the State, and* | The proposed modification to DA 305-11-01 is subject to the provisions of the NSW EP&A Act, where the Minister for Planning and Infrastructure (or his delegate) is the consent authority. |
| *to provide increased opportunity for public involvement and participation in environmental planning and assessment.* | LCO has undertaken consultation in relation to the proposed modification with government agencies, the local community and other stakeholders.<br>Any relevant public representations will need to be considered by the DPE during the assessment of the development application. |

At a local level, LCO is located within both the Singleton LGA and Muswellbrook LGA, in an area predominantly zoned RU1 Primary Production under the provisions of the *Singleton Local Environmental Plan 2013*. All of the open cut pit extension areas proposed as part of the Proposed Action are located within the Singleton LGA in this zone. The proposed mining activities are a permissible land use within this zone with development consent.

Whilst all of the proposed open cut pit extension areas are located within the Singleton LGA, a very small portion of the proposed ancillary disturbance area extends into the Muswellbrook LGA on land zoned RU1 Primary Production (Rural Zone). This component of the proposed project is not a component of the Controlled Action subject to referral. The proposed ancillary mining activities are permissible within this zone subject to the existing development consent. No coal resource will be extracted as part of the Proposed Action from areas located within the Muswellbrook LGA.

## 1.5 Document Structure and Project Team

This report has been prepared in accordance with the *Guidelines for Preparation of Additional Information – Assessment by Preliminary Documentation – Extension to Liddell Coal Mining Operations (EPBC 2013/6908,* and is divided into the three main parts, as follows:

- **PART 1 – The Proposed Action**: This part provides background information to the Proposed Action including the need for the proposal, objectives and contextual information, a description of the Proposed Action, describes social and economic impacts, and includes information on other local and state approvals and conditions that may apply to the Proposed Action.

- **PART 2 – Listed Threatened Species and Communities, and Migratory Species**: This part provides a description of these matters of national environment significance that may be affected by the Proposed Action, describes potential impacts, outlines proposed avoidance, management and mitigation measures, and presents the proposed offset strategy for the Proposed Action.

- **PART 3 – Water Resources and Water Related Assets**: This part provides a description of the existing environment relating to water resources in the region, a description of the numerical model developed for the Proposed Action, an assessment of the likely significant impacts on water resources and water related assets based on the outcomes of this model, and proposed safeguards and mitigation measures.

This preliminary documentation has been prepared on behalf of LCO Pty Ltd by the parties listed below in **Table 1.2**.

**Table 1.2 – Documentation Team**

| Section | Company | Team Member |
|---|---|---|
| **Part 1 – The Proposed Action** | | |
| **Section 1** Background | SLR Consulting | Nicole Armit |
| **Section 2** Description of the Action | SLR Consulting | Nicole Armit |
| **Section 3** - Social and Economic Considerations | SLR Consulting | Nicole Armit |
| **Section 4** Other Approvals and Conditions | SLR Consulting | Nicole Armit |
| **Part 2 – Listed Threatened Species and Communities, and Migratory species** | | |
| **Section 5** Existing Environment - Biodiversity | Umwelt (Australia) Pty Limited | Rebecca Vere, Chloe Parkins and Travis Peake |
| **Section 6** Potential Impacts - Biodiversity | Umwelt (Australia) Pty Limited | Rebecca Vere, Chloe Parkins and Travis Peake |
| **Section 7** Proposed avoidance, management and mitigation measures - Biodiversity | Umwelt (Australia) Pty Limited | Rebecca Vere, Chloe Parkins and Travis Peake |
| **Section 8** Proposed Offset Strategy | Umwelt (Australia) Pty Limited | Rebecca Vere, Chloe Parkins and Travis Peake |
| **Part 3 – Water Resources** | | |
| **Section 9** –Existing Environment – Water Resources and Water Related Assets | Jacobs (formerly SKM) | Richard Cresswell, Brian Rask and Chris Dusterberg |
| **Section 10** – Relevant Impacts – Water Resources | Jacobs | Richard Cresswell, Brian Rask and Chris Dusterberg |
| **Section 11** – Proposed safeguards and Mitigation Measures | Jacobs | Richard Cresswell, Brian Rask and Chris Dusterberg |

# 2.0 PROPOSED ACTION

## 2.1 Overview

LCO currently operates in accordance with NSW development consent (DA 305-11-01) and NSW Mining Lease 1597, and has approval to conduct mining operations within an approved mining footprint until 31 December 2023, producing up to 8 Mtpa of ROM coal. Product coal, both thermal and semi-soft, is delivered to export markets via the Hunter Valley Rail Loop, Main Northern Railway Line and Newcastle Port.

LCO currently employs approximately 360 full-time personnel and up to 100 contractors, with operations undertaken 24 hours a day, seven days a week.

The NSW development consent boundary encloses an area of 2108 ha, with the current approved mining footprint equating to 1374 ha. Key components of the existing operations can be seen in **Plate 2**.




**Plate 2 – Existing operations at LCO looking west**

Whilst LCO currently has approval to conduct mining operations until the end of 2023, at current extraction rates open cut mining activities will reach the approved mining footprint in 2014. Coal reserves have been identified outside of this footprint, within the NSW development consent boundary, and LCO therefore propose to extend the existing open cut mining operations outside the approved mining area to enable continuity of mining and maximise recovery of coal resources within the existing NSW development consent boundary.

LCO are therefore seeking approval to modify the NSW development consent to allow for this extension of mining activities, with the primary objectives of the Proposed Action to:

- Develop the on-going open cut mining operations with a focus on maximising resource recovery within the existing development consent and mining lease boundaries;
- Maintain continuity of coal production, and subsequently secure on-going employment opportunities and socio-economic flow-on benefits; and
- Continue to conduct mining at LCO in an environmentally responsible manner to minimise the potential for adverse impacts.

The key components of the Proposed Action, as illustrated on **Figure 1.2** and included in the Project EPBC Act Referral (2013/6908 - June 2013), include the following:

- **Expansion of the Open Cut Mining Footprint** - Extension of the South and Entrance Pits to the south east, and, upon completion of mining in these pits, the mining of coal resources under the existing MIA, during which time the MIA will be relocated to temporary facilities. The extension will expand the approved mining footprint by 255 hectares (ha) and will enable the recovery of an additional approximate 38 Mt of ROM coal.
- **Extension to the Life of Mine** – The extension of open cut mining activities will lead to an associated extension of the life of mine at LCO from 2023 to 2028.
- **Additional Tailings Emplacement Area** – A tailings emplacement area will be constructed within the final void of the South Pit to dispose of the additional tailings associated with the extension of open cut mining activities.
- **Minor Additional Infrastructure**:
    - Construction and commissioning of a transfer point and conveyor connected to the existing Mt Owen/Glendell/Macquarie Generation conveyor is proposed (refer **Figure 1.2**), enabling LCO to send coal to the RCCP facility, and receive coal and crushed gravel from Mt Owen, via the existing conveyor system. The new conveyor will deliver/take material to/from a new 50,000 tonne stockpile; and
    - Infrastructure and ancillary surface disturbance to support the new mining areas will be required, including but not limited to, powerlines, water management infrastructure and haul roads.

LCO proposes to continue to employ approximately 360 full time personnel and approximately 100 contractors as required.

The proposed works comprising the Proposed Action lie wholly within both the existing development consent boundary and the mining lease ML 1597 boundary. No changes are proposed to the approved operating hours, mining method, or mining equipment, which will remain as approved under DA 305-11-01, as modified. The Proposed Action the subject of the referral includes only those areas of additional disturbance shown in **Figure 1.2**.

**Table 2.1** summarises and compares the major components of the approved operations at LCO, and the proposal to further modify DA 305-11-01 (Mod 5).

**Table 2.1 - LCO Approved and Proposed Operations**

| Aspect | Existing Approved Operation | Proposed Extension Project (Mod 5) |
|---|---|---|
| Project Area | The Project Area, defined as the DA boundary, covers an area of 2108 ha. | No change proposed. |
| Open Cut Mining Area | Current approved mining footprint of 1374 ha. | Expansion of the open cut pits by approximately 171 ha, and an additional 84 ha of ancillary disturbance for infrastructure to support the new mining areas, is proposed, totalling 255 ha. |
| Production and Resource recovery | Extraction of up to 8 Mt of ROM coal per year.<br>The original EIS (Umwelt, 2001) estimated cumulative ROM production over a 21 year mine life of 90.8 Mt.<br>Extraction of up to 0.5 Mtpa of coal tailings with residual energy content for transport to Liddell and Bayswater power stations. | No change in annual production rates.<br>Estimated increase in the total resource recovered by 38 Mt.<br>No change is proposed to the recovery of tailings. |
| Mine Life | Mining operations approved to take place until 31 December 2023. However, available mining areas within approved mining footprint will be exhausted in 2014. | Extension of life of mining operations from 31 December 2023 to 31 December 2028. |
| Vegetation Removal | Progressive campaign approach, with the extent of clearing undertaken in each campaign just sufficient for the subsequent period of mine development. | No change proposed. |
| Soil Stripping and Stockpiling | Progressive campaign approach, with the extent of stripping undertaken in each campaign just sufficient for the subsequent year of mine development. | Methodology will generally remain the same with different varying depths of topsoil and subsoil suitable for stripping and different designated stockpile areas. |
| Overburden and Interburden Management | Overburden is blasted and loaded into trucks for transfer and placement in one of the out-of-pit emplacement areas or in-pit within completed sections.<br>No more than two blasts can be carried out per day. | No changes proposed to the method of overburden and interburden management. Minor variation to the mining footprint to achieve the additional coal reserves.<br>Up to three blasts to be carried out per day; however no change proposed to the total number of blasts carried out over a weekly period. |
| Mining Method | Open cut mining methods (truck and excavator); with limited highwall mining (auger or continuous miner) where open cut mining is not feasible. | No change proposed. |
| Coal Seams | Current mining targets Lemington, Pikes Gully, Arties, Liddell, Barrett and Hebden seams. | Mining will continue to target these seams. Additionally, mining of the Bayswater seam (above Lemington) has also been identified as being economically viable in exploration programs and will be extracted where practical. |
| Open Cut Area | Approved mining area at Liddell includes a number of open cut pits – Mountain Block, Antiene East Block, Railway Block, Reservoir Block, Entrance Pit, Barrier Pit, Ten North, Central Pit and South Pit. | Extension of the Entrance Pit and South Pit, and development of the MIA Pit, all within the DA and Mining Lease boundaries. |

| Aspect | Existing Approved Operation | Proposed Extension Project (Mod 5) |
|---|---|---|
| Coal Processing | Processing of up to 8 Mtpa at the LCO CHPP, including up to 1.5 Mtpa of ROM coal from Cumnock No. 1 Colliery<br>Up to 1.5 Mtpa of ROM coal may also be sent to Cumnock No.1 Colliery for processing as required. | Coal to continue to be processed at LCO, with no change proposed to the approved annual amount of coal processed at the CHPP. Coal will no longer be processed from Cumnock No. 1 Colliery as this mine is no longer in operation.<br>Up to 2 Mtpa of ROM coal may be processed at LCO CHPP from Mt Owen and despatched from LCO. The maximum processing rate of 8 Mtpa includes the option to process up to 2 Mtpa of ROM coal from the Mt Owen Complex.<br>The Cumnock CHPP is also no longer in operation, and therefore up to 1.5 Mtpa to be processed at RCCP facility instead of Cumnock CHPP when required, and despatched via the Ravensworth Coal Terminal (RCT).<br>It is noted that coal processing is not included in the Proposed Action. |
| Coal Transportation | Product coal from the LCO CHPP is to be transported by rail.<br>127 loading days permitted onto the Hunter Valley Rail Loop, up to a maximum of 220 loading days following completion of a study on the adequacy of the capacity, access to and safety of rail infrastructure to the satisfaction of the Director General.<br>Transport of ROM coal to and from Cumnock No.1 Colliery is permitted by truck via internal haul roads, Pikes Gully Road and Liddell Station Road. No more than 1.5 Mtpa of ROM coal to be transported to Cumnock for processing.<br>Transport of up to 0.5 Mtpa of coal tailings by truck along the New England Highway to Liddell and Bayswater Power Stations is restricted to 114 truck movements per day, five days per week. | All product coal from LCO CHPP (including any coal received and processed from Mt Owen) to continue to be transported by rail, with the ability to load trains on any day of the year as scheduled by the Hunter Valley Coal Chain.<br>Coal will no longer be transported to/from Cumnock for processing. Up to 1.5 Mtpa of ROM coal will instead be transported by truck to the RCCP, as per the approved route to the Cumnock CHPP via internal haul roads, Pikes Gully Road and further along Liddell Station Road (the extension to this haulage route is illustrated on **Figure 1.2**). In addition, LCO proposes a new connection to the existing overland conveyor to provide the option of transporting the above ROM coal to RCCP.<br>Construction and commissioning of a conveyor and transfer point from the existing Mt Owen/Glendell/Macquarie Generation conveyor, enabling LCO to send or receive coal to and from the existing conveyor system. This conveyor may also be used for the transport of crushed gravel from Mt Owen.<br>Coal transport is not included in the Proposed Action. |
| Tailings and rejects | Approval to dispose of tailings in the Antiene tailings dam, Reservoir Pit 1 (Reservoir West), Reservoir Pit 2 (Reservoir South), Reservoir Pit 3 (Reservoir North) and the Railway fines tailings facility.<br>Up to 0.5 Mtpa of tailings material can be transported via road to Bayswater and Liddell power stations. | Completion of the current approved tailings emplacement areas and the proposed development of a tailings emplacement area within the final void of the South Pit to dispose of the additional tailings associated with the extension of open cut mining activities.<br>Continuation of the option to transport up to 0.5 Mtpa of tailings material via road to Bayswater and Liddell power stations. |

| Aspect | Existing Approved Operation | Proposed Extension Project (Mod 5) |
|---|---|---|
| Coal Storage | Coal is stockpiled in a ROM coal stockpile with an approximate capacity of 100,000 tonnes. Coal is also stockpiled in a supplementary stockpile with a capacity of up to 450,000 tonnes. | Increase in the storage capacity of the ROM coal stockpile to 200,000 tonnes.<br>A new 50,000 tonne ROM coal stockpile is also proposed near the MIA, from which the new conveyor will take/deliver ROM coal.<br>The total ROM coal storage capacity will therefore be increased to a total of 700,000 tonnes. |
| General Infrastructure | Primary infrastructure includes, but is not limited to the following:<br>• site offices and site services;<br>• workers amenities,<br>• workshop,<br>• fuel farm,<br>• CHPP,<br>• truck loading bin,<br>• weighbridge,<br>• car parks,<br>• surface water management system,<br>• RO plant. | No additional buildings are proposed other than the relocation of the MIA to temporary facilities to allow mining underneath the existing MIA. The surface water management system will be updated to effectively cater for the expanded operations, and will continue to use voids for water storage.<br>New dewatering and monitoring bores will be required. These are expected to be in (but may not be limited to) the Hazeldene workings, Entrance Pit and South Pit.<br>Other associated infrastructure will be required to support the new mining areas, including powerlines, pipelines, water truck fill points conveyor, coal storage stockpiles and access roads. |
| Closure and Rehabilitation | Approved Conceptual Mine Closure Plan based on the rehabilitation criteria established in the approved Mining Operations Plan. The plan is reviewed and updated on a three-yearly basis, with a detailed closure plan required five years prior to closure. | Change to the final landform to incorporate additional open cut mining areas and waste quantities.<br>Some areas of rehabilitation will form habitat corridors and are proposed as a component of the ecological offsets for the project. |
| Operating hours | Mining operations are undertaken 24 hours per day, 7 days per week. | No change proposed. |
| Environmental Management | A comprehensive set of environmental management plans are in place. These plans are backed by an environmental monitoring network including meteorological, air quality, water quality, noise and subsidence monitoring. | The current environmental management plans and monitoring programs will be reviewed and updated as required to incorporate the modification. |

The Proposed Action is described in more detail in the sections below to provide an overall understanding of the nature and extent of the works proposed over and above what is currently approved at LCO. Detail has not been provided in this section with regards to a number of aspects relating to the existing mining operation such as vegetation removal, coal extraction methods, hours of operation, site servicing and general waste management, given that these will continue to be undertaken on site as approved under DA 305-11-01, as modified.

## 2.2 Mine Extension and Conceptual Mine Plan

LCO currently has approval to conduct open cut mining operations within a number of pit areas, totalling approximately 1374 ha. The Proposed Action involves an expansion of the approved mining footprint by 255 ha, primarily involving the extension of the existing Entrance Pit and South Pit. Both of these pits are currently approved, and the extension involves a continuation of mining in these two pit areas beyond the approved mining footprint, as illustrated on **Figure 1.2** and **Plate 3**.

Upon completion of open cut mining in the Entrance and South Pits, coal resources will then be extracted from beneath the existing MIA. The presence of the MIA currently constrains the south easterly extent of the South Pit. Coal resources in the southern most corner of the LCO DA boundary are now proposed to be extracted via a separate pit. Mining in this MIA Pit will be conducted towards the end of the mine life, and hence no permanent relocation of the MIA is planned, with mining of coal in this pit to be undertaken following the removal of surface infrastructure, during which time the MIA will be relocated to temporary facilities.



**Plate 3 – The Referral Area, Looking Towards the Existing MIA**

The proposed extension of the mining footprint associated with the Entrance Pit is approximately 96 ha, whilst the South Pit extension totals approximately 58 ha, and the MIA Pit approximately 16 ha. An additional approximate 84 ha of ancillary disturbance associated with the open cut pit extensions is also proposed for support infrastructure such as access tracks, water pipelines and powerlines, comprising an increase in the approved mining footprint at LCO in the order of 255 ha. Of this 255 ha, approximately 56 ha are already disturbed as a result of approved mining related infrastructure, such as water management infrastructure, roads, powerlines and the MIA. The Proposed Action therefore involves disturbance of an additional 199 ha (the Referral Area) over and above land already disturbed or approved to be disturbed as part of existing operations approved at LCO. All additional areas of disturbance are within the current NSW development consent boundary and Mining Lease boundary.

The proposed sequence and approximate timing of mining is illustrated on **Figures 2.1a, b** and **c**. It is noted however that mining operations are dependent on economic considerations, and as such the conceptual mine plan, mine sequence and timing of mining activities may be subject to changes due to operational requirements or as additional geological data is gathered. On this basis, approval is sought for the general mining footprint, schedule and extent of associated activities presented in this preliminary documentation and in the Environmental Assessment submitted to the NSW DPE.

Mining activities associated with the extension will initially concentrate in the South Pit. However, to enable this extension to progress, excavation of a new mine water storage void will first be required to replace the current primary mine water storage, the Raw Water Transfer Void (RWTV), which is within the footprint of the extended South Pit.

Proposed extension activities outside the current approved mining footprint will therefore commence with the development of a replacement water storage void. A conceptual layout is provided on **Figure 2.1a**. This is proposed to take place in approximately 2014, or Year 1 of approval of the Proposed Action, in preparation for open cut mining outside the current approved footprint in around 2015.

Coal extraction will then commence in the South Pit extension area around 2015, or Year 2 of the Proposed Action. Mining will continue predominantly in the South Pit until around Year 4 to 5, when mining activities start to increase again in the Entrance Pit and the commencement of the extension there. Mining will continue predominantly in the Entrance Pit until resources are exhausted around Year 10. Mining will continue in the South Pit until approximately Year 7 or 8.

Following completion of coal extraction within the South and Entrance Pits, extraction of coal resources will take place in the MIA pit from around Year 10, after the removal of the surface infrastructure. Operation of the MIA pit will be undertaken utilising minimal temporary surface facilities, and permanent relocation of the MIA is therefore not included as part of this application.

LCO currently has approval to mine all seams from the Lemington to Hebden seams; however, the Bayswater seam (above the Lemington) has been identified in recent exploration programs as being economically viable for extraction and will be mined. Mining in the Referral Area will therefore include all seams from the Bayswater to Hebden seams.

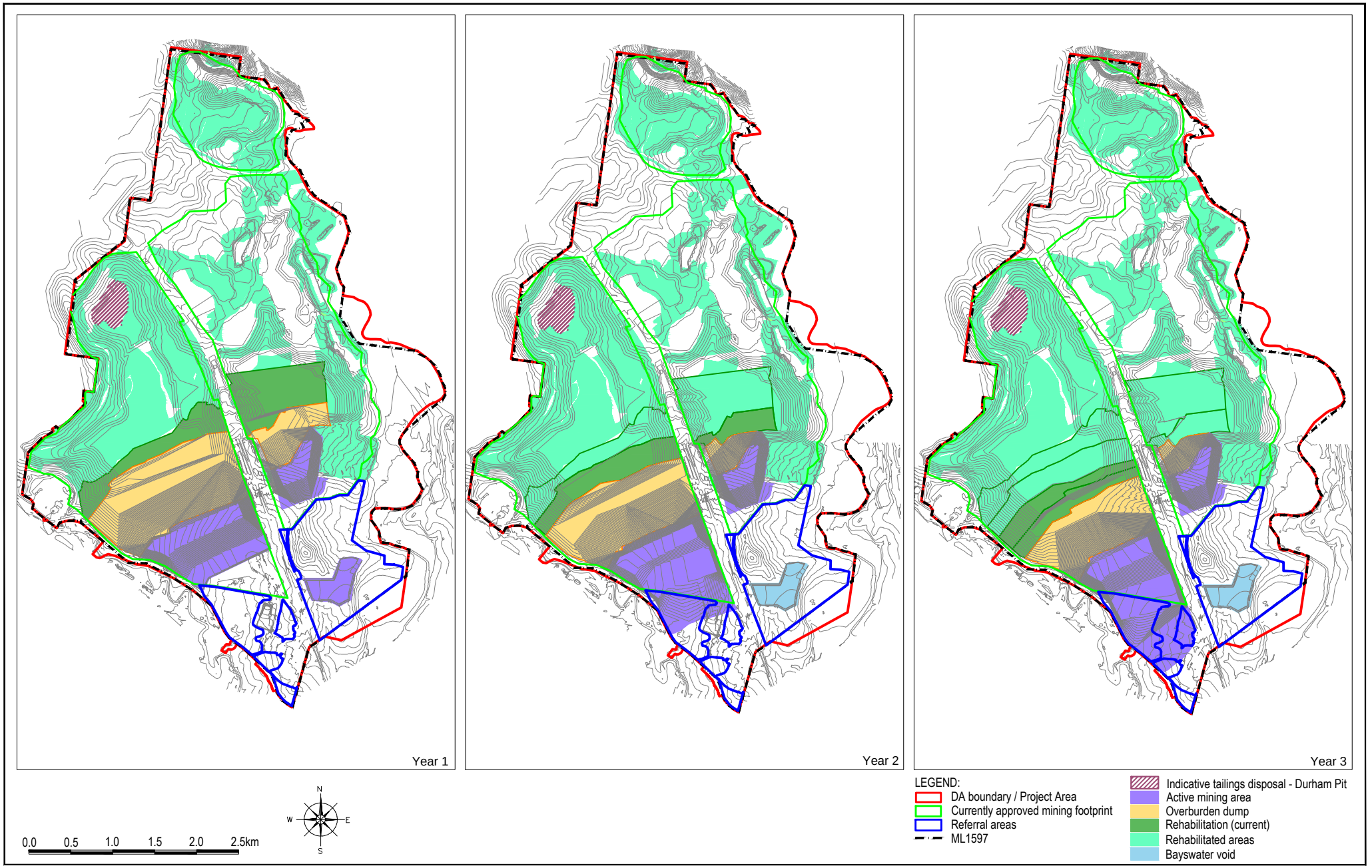
## 2.3 Coal Production and Mine Life

LCO propose to expand open cut mining operations to access an additional 38 Mt of ROM coal from within the existing NSW development consent and Mining Lease boundaries.

The currently approved annual ROM coal production rate of up to 8 Mt will remain unchanged. With the Proposed Action commencing in approximately 2014 (Year 1), it is anticipated that the Proposed Action will enable open cut mining to continue to around the Year 2025. However, as noted above mining operations are dependent on economic considerations, and a reduction in open cut coal production in any year, due for example to unfavourable mining or economic conditions, would most likely extend the mine life. As such, approval is sought for mining operations to continue to 2028 to account for such circumstances, representing an increase in the life of the current NSW development consent by five years. Any required refinements to the conceptual mine plan and schedule will be addressed as part of the ongoing MOP process administered by the DRE.

## 2.4 Overburden and Interburden Management

No changes are proposed to the current approved method of overburden and interburden management, with blasted overburden to continue to be loaded into rear dump trucks and transported to either out-of-pit emplacement areas or to be back-filled in-pit in completed mining sections.



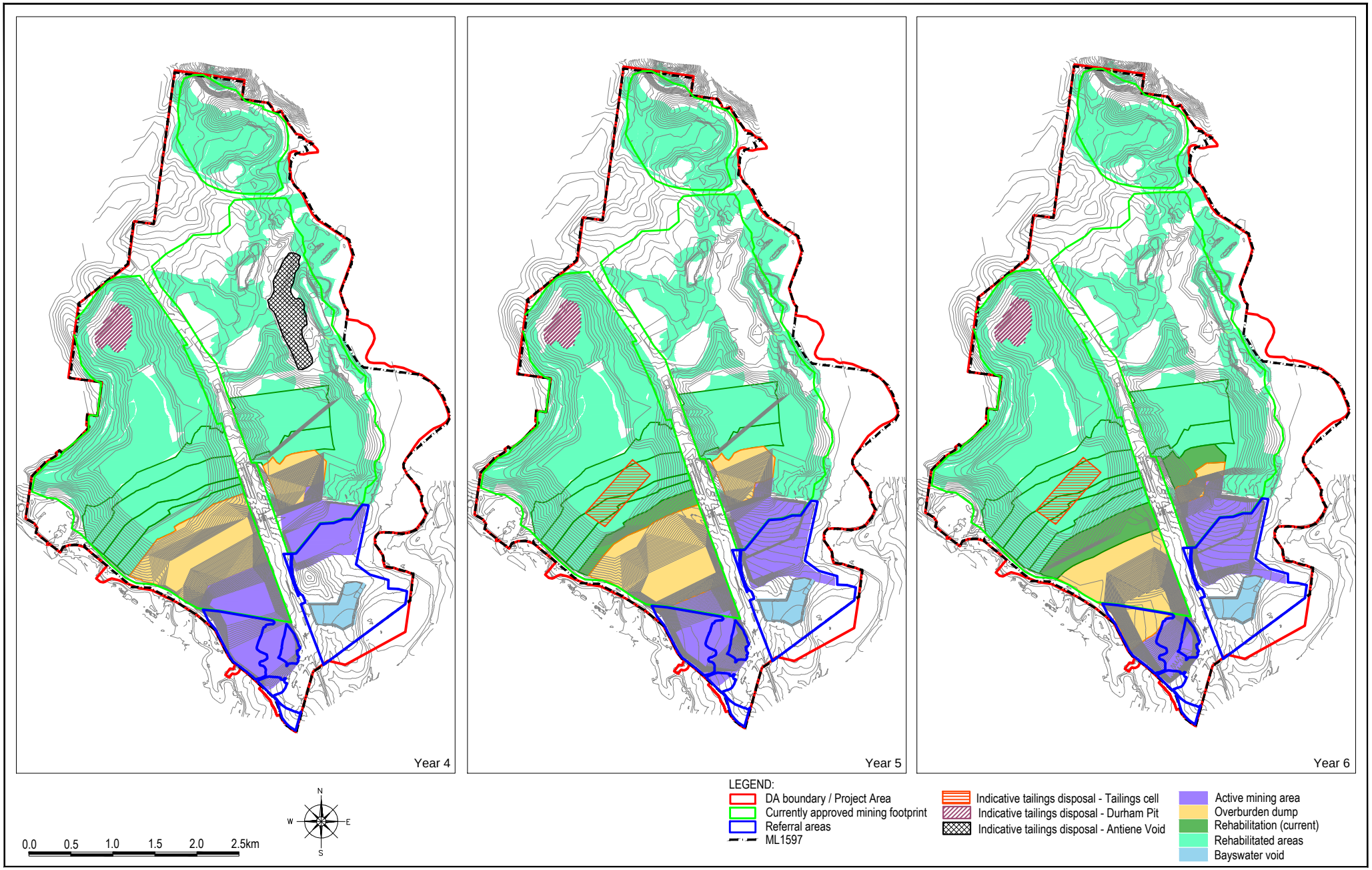

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Proposed Sequence of Mining and Rehabilitation

**FIGURE 2.1a**



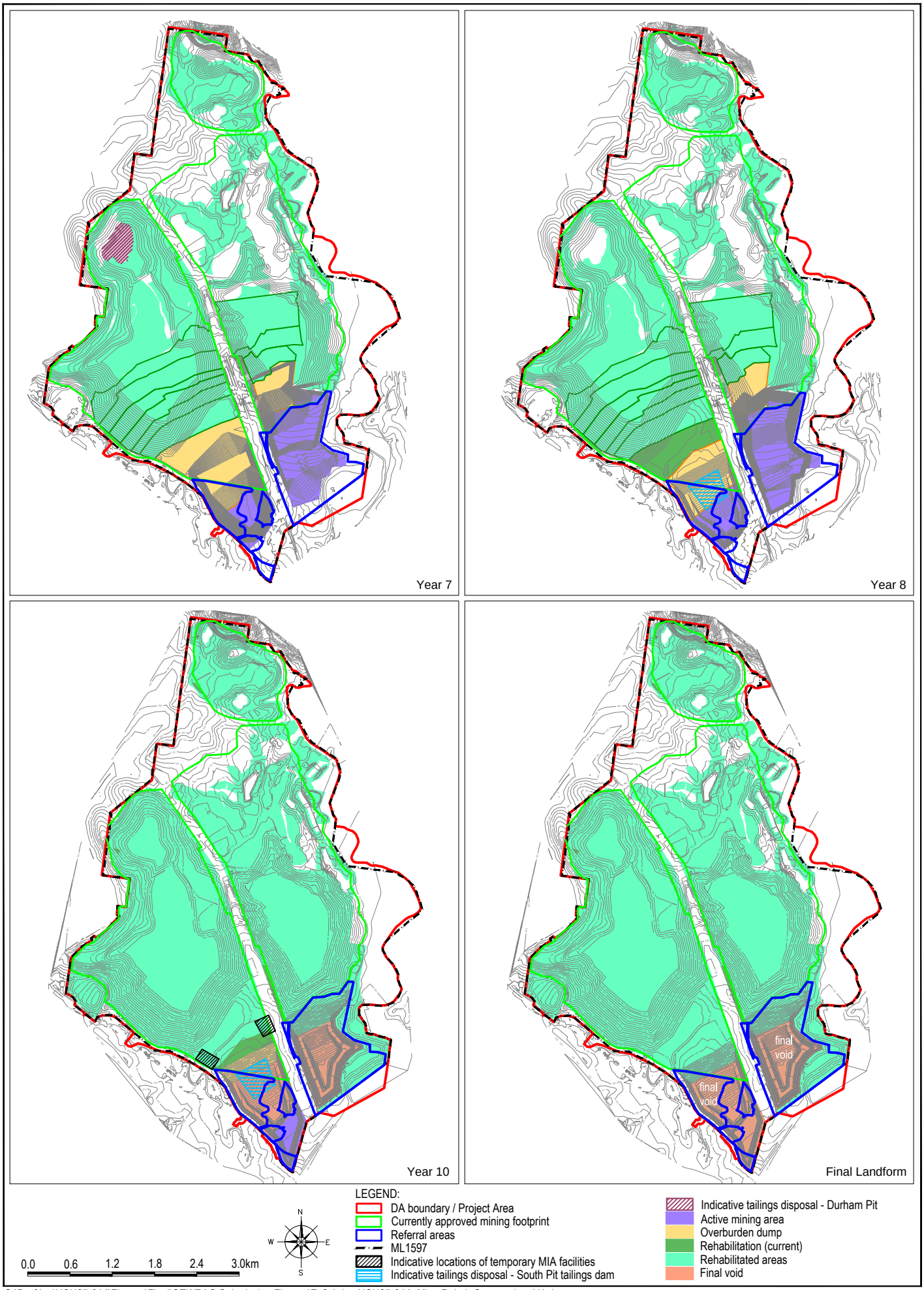

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Proposed Sequence of Mining and Rehabilitation

**FIGURE 2.1b**




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Proposed Sequence of Mining and Rehabilitation

**FIGURE 2.1c**

## 2.5 Blasting

NSW development consent Schedule 3 Condition 10 allows LCO to carry out up to two blasts per day. As can be seen on **Figure 1.2**, the open cut extension areas become narrower towards the DA boundary, and LCO therefore propose to increase the number of blasts that can be fired from two to three per day. This is to allow greater flexibility as the pit becomes smaller and tighter to fire more blasts in one day in some areas to ensure continuous productivity. Importantly, no increase in the total number of blasts that would be fired over a weekly period is proposed.

## 2.6 New ROM coal stockpile

LCO seek to modify DA 305-11-01 to allow for the transport of up to 1.5 Mtpa ROM coal to the RCCP facility for processing. It is also proposed to receive up to 2 Mtpa of ROM coal from the Mt Owen Complex for processing and despatch. This ROM coal will be transported via a conveyor, and approval is therefore sought for the construction and commissioning of a conveyor and transfer point from the existing Mt Owen/Glendell/Macquarie Generation conveyor, which travels through the south eastern section of the LCO development consent boundary, illustrated on **Figure 1.2**. In addition to ROM coal, this conveyor may also be used to transport crushed gravel from Mt Owen.

Associated with this new conveyor and transfer point will be a 50,000 tonne ROM coal stockpile, as shown on **Figure 1.2**.

## 2.7 Tailings and Rejects Disposal

### 2.7.1 Overview

LCO currently have approval to dispose of tailings within a number of areas, including the Antiene, Reservoir West, Reservoir South and the Durham Tailings Emplacement Areas.

Tailings produced from the extended mining footprint will continue to be disposed of in these approved disposal areas until they are exhausted. Further tailings storage will be required to accommodate much of the tailings produced as a result of the extraction of additional coal reserves from the extension areas. The approximate volume of tailings and coarse rejects produced will equate to approximately 9% and 26% of ROM coal respectively.

LCO propose to develop a tailings emplacement area in the northern section of the final void of the South Pit to dispose of the additional tailings. This void is not anticipated to be available for tailings emplacement until mining is completed in the South Pit. Further detail on the planned management of tailings is provided below in **Section 2.7.2**. The disposal of coarse rejects will continue as per current approved operations.

### 2.7.2 Tailings Strategy

From 2014 to approximately 2018 (Year 5 of the Proposed Action), tailings will be primarily directed to the Durham Tailings Emplacement Area (DTEA). The DTEA is estimated to have a capacity for 3.85 million $m^3$ of tailings with a potential additional 2 million $m^3$ available within the existing void from 2019 to 2020, subject to further detailed design. Concurrently, to assist in the timely decommissioning and capping of the Antiene Tailings Dam, LCO propose to place a highly consolidated layer of tailings over the existing tailings surface, in effect creating a more stable platform to commence rehabilitation works. This additional layer will be achieved through modified practices including flocculation and central discharge disposal techniques, and will also provide for an additional 1 million $m^3$ of capacity.

The South Pit Tailings Dam will be located within the upper levels of the South Pit, which will be isolated from the final void water storage by a confining embankment.

Tailings produced from approximately 2021 through to the end of the mine life will be stored in the South Pit Tailings Dam, which will have a capacity of approximately 1.34 million $m^3$.

Tailings are also proposed to be placed on the advancing overburden dumps of the South Pit between 2018 and 2019 in a series of emplacement cells. These cells will enable sufficient tailings disposal capacity but may require rehandling following reasonable desiccation and final co-disposal with coarse rejects within the overburden emplacements.

LCO anticipate that the tailings storages are likely to be fully rehabilitated within five years of the cessation of tailings placement, dependent on climatic conditions and operational needs.

## 2.8 General Infrastructure and Site Services

Construction of additional ancillary infrastructure to support the new mining areas will be undertaken within the LCO development consent boundary, including but not limited to, powerlines, water management infrastructure, haul roads, light vehicle access roads, coal storage facilities and water truck fill points. No additional off-site infrastructure will be required.

**Site Services**

Site services which currently exist within the Referral Area are illustrated on **Figure 2.2**. As shown, an existing 11 kV powerline owned by Ausgrid passes though the very southern end of the LCO development consent boundary and Referral Area. However, this area is not planned to be disturbed as part of the Proposed Action until towards the end of mine life as part of the MIA Pit extraction; the exact timing of which will depend on mine planning as the mine progresses southeast. LCO will continue to consult with Ausgrid should relocation or termination of this powerline be required in the future, as per the current Statement of Commitments in DA 305-11-01.

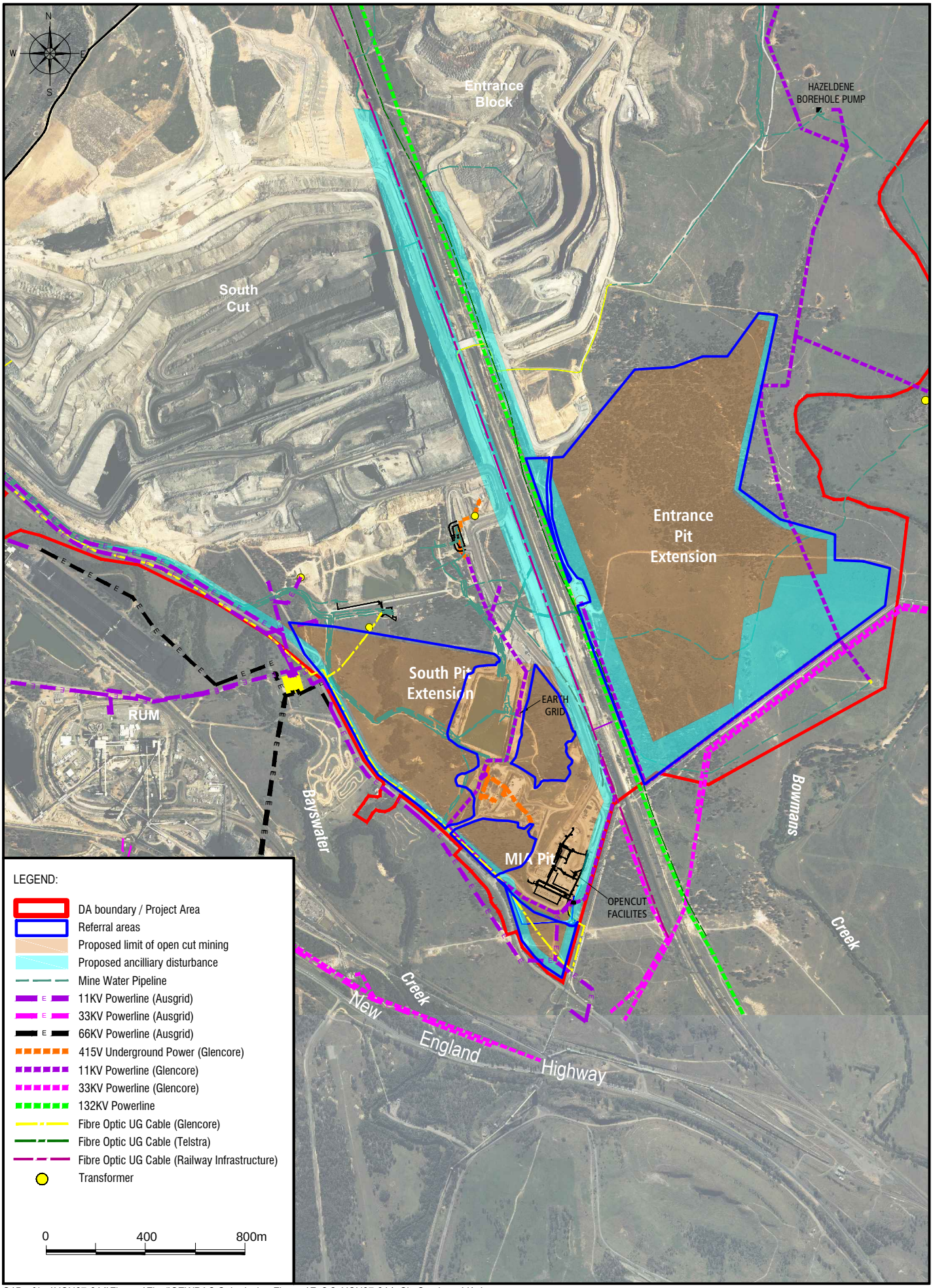
A further Glencore owned 11 kV powerline located near the MIA will need to be relocated to allow for the construction of the new conveyor and transfer point. This powerline will be relocated in accordance with the current commitments in DA 305-11-01 regarding the relocation of services, and will be undertaken in consultation with Ausgrid as required.

**The Main Northern Railway Line**

The Main Northern Railway Line is a major infrastructure feature dissecting the LCO DA boundary. LCO has operated in close proximity to the railway line without hindrance for a couple of decades. In consideration of the Main Northern Railway Line, mining operations have been designed to protect the integrity of the railway by limiting mining to the land outside the zone adjacent to the railway enclosed by an angle of draw of 35 degrees from the vertical plane of the boundary parallel, to a thirty metre horizontal offset distance from either side of the railway lands.

LCO has implemented an extensive geotechnical monitoring program to monitor the integrity of the buttress separating the South Pit and the Entrance Pit upon which the Main Northern Railway Line operates. The monitoring program includes:

- The installation and monitoring of inclinometers;
- The installation and monitoring of vibrating wire piezometers; and
- The installation of survey monitoring monuments to monitor the integrity of the buttress by closed traverse.




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Existing Sites Services

**FIGURE 2.2**

Monitoring intervals are stipulated by an independent Geotechnical Engineer. Results from each of the monitoring processes are reviewed by the Geotechnical Engineer for advice on the condition of the buttress. To date LCO has not had any issues relating to the integrity of the buttress and subsequently the Main Northern Railway Line.

The proposed extension of mining in the Entrance and South Pits will involve a continuation of mining in parallel with the railway line, as per existing approved operations, which have a proven track record of successfully coexisting with the railway. The existing management procedures in relation to the Main Northern Railway Line with therefore continue within the Referral Area.

## 2.9 Water Management

The Proposed Action will require some changes to the existing water management system, with the water management system to be updated to effectively cater for the expanded operations. The key changes proposed are as follows:

- The establishment of a temporary mine water storage to replace the current primary mine water storage, which is located within the footprint of the South Pit extension. The new water storage will be established and used until the South Pit final void becomes available for water storage.
- New dewatering bores for mine water will be required as mining progresses, including in the Hazeldene and Liddell underground workings. These will be located outside the Referral Area and therefore are not included in the Proposed Action.

These changes to water management, as well as the associated impacts and mitigation measures, are discussed in further detail in **Sections 10** and **11**.

Other aspects relating to water management at LCO will remain unchanged and do not form part of the Proposed Action.

## 2.10 Closure and Rehabilitation

A rehabilitation strategy has been developed for the proposed extension of the existing mining area, which aims to emulate the pre-mining grazing areas and enhance local and regional ecological linkages.

Disturbed areas at LCO will continue to be progressively rehabilitated throughout the life of the mine to achieve a self-sustaining landform. The key objectives of the final landuse, rehabilitation and landform design will be as follows (Umwelt, 2013a):

- To provide opportunities for future sustainable agricultural activities such as grazing;
- To contribute towards effective habitat corridors through the area which promote regional fauna movements between the neighbouring Ravensworth Operations, Mt Owen Complex, Lake Liddell and the Ravensworth Operations Hillcrest Offset Area, which is located immediately north of LCO;
- To maintain and provide additional suitable habitat for the spotted-tailed quoll, which is listed as Endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), particularly around the Bowmans Creek area; and
- To improve the visual amenity of the area.

Revegetation of the extension areas will include the establishment of a surface cover of grasses and legumes and the planting of trees in habitat corridors. LCO propose to establish the vegetation community Grey Box - Narrow-leaved Ironbark shrubby woodland, an Endangered Ecological Community (EEC) identified within the Referral Area, in these wildlife corridors. The re-establishment of this endangered community forms part of an offset strategy developed for the Proposed Action, as discussed further in **Section 8**. In addition, these corridors have been designed to link in with habitat

corridors already established in rehabilitated areas at LCO, as well as existing bushland to the north of LCO and habitat corridors proposed as part of the rehabilitation of the Ravensworth Operation, to the south.

In addition to rehabilitation works, habitat enhancement works of non-mined lands along Bowmans Creek within the LCO DA boundary will be undertaken, with the specific purpose of enhancing existing habitat, and providing additional habitat for the spotted-tailed quoll (*Dasyurus maculatus maculatus*). The spotted-tailed quoll is listed as an endangered species under the EPBC Act. Further detail on this habitat corridor, as well as proposed closure and rehabilitation works, is provided in **Sections 7** and **8**.

## 2.11 Environmental Management

The environmental management plans and monitoring programs currently employed at LCO will continue to remain in place. These management plans and monitoring programs are designed to demonstrate environmental due diligence and to implement procedures that provide on-going management and monitoring of the mining operation in line with the objectives of sustainable development.

The existing environmental management plans and monitoring programs will be reviewed and updated, as required, to incorporate the Proposed Action, commitments made in the EA for the modification and any additional consent conditions.

The results of the various environmental monitoring activities will continue to be reported externally on an annual basis in the LCO Annual Environmental Management Report (AEMR) and on the LCO website www.liddellcoal.com.au.

# 3.0 SOCIAL AND ECONOMIC IMPACTS

## 3.1 Economic Assessment

An Economic Assessment of the Proposed Action was prepared by Gillespie Economics (2013). A description of the assessment undertaken and findings is presented below. The full report prepared by Gillespie Economics is attached as **Appendix A**.

### 3.1.1 Methodology

In conducting the assessment, Gillespie Economics (2013) gave consideration to the relevant aspects of the DPE's *Draft Guideline for Economic Effects and Evaluation in EIA,* (James and Gillespie, 2002) and the *Draft Guideline for the use of Cost Benefit Analysis in mining and coal seam gas proposals* (NSW Government 2012).

According to Gillespie Economics (2013) there are two important aspects of the Proposed Action that can be considered from an economic perspective:

- The economic efficiency of the Proposed Action (i.e. consideration of the economic costs and benefits of the Proposed Action); and
- The economic activity impacts of the Proposed Action (i.e. the economic activity that the Proposed Action will provide to the local, regional or NSW economy).

The DPE's draft guideline on economic evaluation in environmental impact assessment (James and Gillespie, 2002) identifies economic efficiency as the key consideration of economic analysis. Benefit Cost Analysis (BCA) is the method used to consider the economic efficiency of proposals.

The economic assessment therefore included two types of analyses of the Proposed Action:

- BCA ; and
- An economic impact assessment.

**Benefit Cost Analysis**

The BCA is concerned with the net benefits from the Proposed Action, whilst the economic impact assessment focuses on indicators of economic activity i.e. direct and indirect output (expenditure/revenue), value-added, income and employment, in a specific region. While BCA can provide qualitative and quantitative information on how economic efficiency costs and benefits are distributed, welfare economics and BCA are explicitly neutral on intra and intergenerational distribution of costs and benefits. Decision-makers therefore need to consider the economic efficiency implications of a Proposed Action, as indicated by BCA, alongside the performance of a project in meeting other conflicting goals and objectives of the EP&A Act and government (Gillespie Economics, 2013).

The BCA of the Proposed Action involves the following key steps:

- Identification of the base case (without the Proposed Action, defined as the currently approved operations over time);
- Definition of the "with" Proposed Action case;
- Identification and valuation of the incremental benefits and costs associated with the Proposed Action relative to the base case;
- Consolidation of value estimates using discounting to account for temporal differences;

- Application of decision criteria;
- Sensitivity testing; and
- Consideration of non-quantified benefits and costs.

Under the base case, LCO would continue its current mining operations in accordance with DA 305-11-01. LCO has approval to conduct mining operations until 2023, and whist it is noted above in **Section 2** that the current mine plan would reach the approved mine footprint in 2014, with some major adjustments to the mine plan the open cut activities could continue until 2019 under the current development consent, extracting the remaining coal reserves from within the approved mining footprint. Therefore, to ensure an accurate comparison between approved and proposed operations, the base case assumes mining is able to continue until 2019.

In contrast, the key components of the Proposed Action as described in **Section 2** include:

- Expansion of the open cut mining footprint;
- Recovery of an additional approximate 38 Mt of ROM coal;
- Additional tailings emplacement area in the South Pit void;
- Minor additional infrastructure, including but not limited to, a conveyor, powerlines, water management infrastructure and haul roads; and
- Extension to the operation of the mine to 2025. Note end of mining in 2025 is based on the optimal proposed mine plan, however the mine sequence and timing of mining activities may be subject to changes due to operational requirements or as additional geological data is gathered. On this basis, approval is sought for mining activities to continue until 2028 to allow for some changes to the mine schedule which, should it be required, would be addressed as part of the MOP process managed by the DRE.

The BCA was undertaken in real values with discounting at 7%, and sensitivity testing at 4% and 10%, in accordance with the NSW Treasury guidelines (2007), NSW DPE guidelines (James and Gillespie, 2002) and the NSW government draft guidelines (2012). Environmental, cultural and social impacts were initially left unquantified and interpreted using the threshold value method. This method uses the value of quantified net production benefits as the amount that unquantified environmental, social and cultural costs would need to exceed to make a project questionable from an economic efficiency perspective (Gillespie Economics, 2013). Where possible, the main environmental, cultural and social impacts were also quantified using market data and benefit transfer (borrowing economic values that have been determined for other study sites). The values of impacts remaining unquantified were interpreted using the threshold value method.

**Economic Impact Assessment**

The Economic Impact Assessment looks at the impact of the Proposed Action in terms of a number of economic indicators as follows:

- Gross regional output – the gross value of business turnover;
- Value-added – the difference between the gross regional output and the costs of the inputs of raw materials, components and services bought in to produce the gross regional output;
- Income – the wages paid to employees including imputed wages for self-employed and business owners; and
- Employment – the number of people employed (including full-time and part-time).

The economic impacts were estimated for two regions; the regional economy, comprising the LGAs of Singleton, Muswellbrook and the Upper Hunter Shire, and the NSW economy.

The economic impact assessment conducted by Gillespie Economics (2013) used an input-output model in accordance with the DPE's draft guideline (James and Gillespie, 2002). Input-output analysis involves two main steps:

- Construction of an appropriate input-output table (regional transaction table) that can be used to identify the economic structure of the region and multipliers for each sector of the economy; and
- Identification of the initial impact or stimulus of a project (construction and/or operation) in a form that is compatible with the input-output equations so that the input-output multipliers and flow-on effects can then be estimated (West, 1993).

The key assumptions used in the input-output analysis are presented in Attachment 3 of the Economic Assessment (refer **Appendix A**).

### 3.1.2 Benefit Cost Analysis

The present value of costs and benefits associated with the Proposed Action is presented in **Tables 3.1** to **3.3** (Gillespie Economics, 2013), including a description of these costs and benefits were evaluated. The potential environmental, social and cultural costs listed in the tables below are only economic costs to the extent that they affect individual and community well-being through direct use of resources by individuals or non-use. If the potential impacts do not occur, or are mitigated to the extent where community wellbeing is insignificantly affected (i.e. those bearing the costs are fully compensated), then no environmental, social or cultural economic costs are included in the BCA.

When impacts accrue globally, the numbers in brackets in **Table 3.1** relate to the level of impact estimated to accrue to Australia.

**Table 3.1 - Costs of the Proposed Action (Present Values @7% discount rate)**

| | Cost | Description | Value ($M) |
|---|---|---|---|
| Production | Opportunity cost of capital | No opportunity capital costs are associated with the Proposed Action apart from that reflected in prices paid for machinery which is reflected in development costs. | $0 |
| | Opportunity cost of land | Based on the market value of the land, and is the cost associated with using the land in LCO ownership for the Proposed Action instead of its next best use. | $10 |
| | Development costs | Costs associated with the purchase of new equipment, new infrastructure (e.g. new dewatering boreholes), acquisition of land for ecological offsets and labour costs during development of the Proposed Action. | $46 |
| | Operating costs | Costs associated with the actual mining operation, CHPP operations, coal delivery (rail freight and port handling and loading), general costs (overheads and administration), and labour costs. | $853 |
| | Decommissioning and rehabilitation costs | A provision for final site decommissioning and rehabilitation works. Note annual progressive rehabilitation costs are included in the operating costs above. | $19 |
| | **Total** | | **$928** |

| | Cost | Description | Value ($M) |
|---|---|---|---|
| Environmental, cultural and social impacts | Greenhouse gas impacts | The Proposed Action is predicted to generate 4.4 Mt of direct (Scope 1) emissions, 0.2 Mt of Scope 2 and 0.6 Mt of Scope 3 (not including the burning of coal which is beyond the scope of BCA for a mining Proposed Action).<br>A shadow price of AUD$23/t CO2-e rising at 2.5% per year in real terms for three years and then remaining constant was used to estimate the global social cost of CO2-e emissions from the Proposed Action. | $38 ($0.4) |
| | Agricultural impacts | The value of any foregone agriculture. | Included in opportunity cost of land and capital costs (land acquisitions) |
| | Noise impacts | Minor potential exceedances (1-2 dB of the PSNC) are predicted to only occur under enhanced meteorological conditions, and therefore the impact on private receivers is likely to be negligible. | Insignificant* for private receptors. |
| | Blasting | Infrequency of historical exceedances i.e. less than once a year, with this trend declining, suggests impacts would be insignificant. | Insignificant* |
| | Air quality impacts | No exceedances are predicted of the annual average $PM_{10}$, TSP or dust deposition criteria as a result of the Proposed Action for LCO alone, or cumulatively.<br>Predicted 24-hour and annual average PM2.5 levels are well below the relative advisory standards for both 24-hour and annual averaging periods. | Insignificant* |
| | Surface water | 277ML/yr of surface water licences will continue to be held for an additional 5 yrs. Opportunity cost calculated by applying market value of water of $2000/ML. The cost of purchasing an additional 128 ML of water access licences has also been included. | $0.6 |
| | Groundwater | 5ML/yr of groundwater licences (relating to Bowmans Creek Alluvials) that could otherwise be used for irrigation purposes will continue to be held for an additional 5 yrs. Opportunity cost calculated by applying market value of water of $2000/ML.<br>No impact predicted on any privately owned bores. | $0.01 |
| | Ecology | The Proposed Action will result in the clearing of 188 ha of native vegetation including 56 ha of EECs listed under the NSW TSC Act. Biodiversity Offset Strategy proposed. | Some loss of values but offset. Cost of biodiversity offset included in capital costs and operating costs |
| | Road transport impacts | Negligible traffic impacts associated with the Proposed Action. | Insignificant* |
| | Aboriginal heritage | No highly scientific significant Aboriginal heritage sites are predicted to be directly or indirectly impacted by the Proposed Action. | Insignificant* |

| | Cost | Description | Value ($M) |
|---|---|---|---|
| | Non-Aboriginal heritage impacts | A Blast Impact Strategy has been developed to ensure that the potential for impacts on the State heritage listed Chain of Ponds Inn as a result of blasting are minimised. Stabilisation works will have minimal impact on the aesthetics, function of historical significance of the Inn. Costs of mitigation measures are included in the capital and operating costs above. | Insignificant* |
| | Visual impacts | Negligible visual impacts associated with the Proposed Action. | Insignificant* |
| | **Non-market impacts total** | | **$39 ($1)** |

*from an aggregate economic efficiency perspective
Source: Gillespie Economics, 2013

**Table 3.2 - Benefits of the Proposed Action (Present Values @7% discount rate)**

| | Benefit | Description | Value ($M) |
|---|---|---|---|
| Production | Residual value of capital | This is the residual value that could be realised by alternative use or sale of equipment at the end of the Proposed Action. | $7 |
| | Residual value of land | This is the residual value that could be realised by alternative use or sale of land at the end of the Proposed Action. | $7 |
| | Value of coal | Based on production of 38 Mt of ROM coal as a result of the Proposed Action at a peak production rate of 8 Mtpa. | $1,633 |
| | Rehabilitation and decommissioning costs | Avoided decommissioning and rehabilitation costs in 2020. | $23 |
| | **Total** | | **$1,670** |
| Environmental, cultural and social impacts | | Non-market values of employment | $46 |
| | **Total** | | **$46** |

**Table 3.3 - Benefit Cost Analysis Results (Present Values @7% discount rate)**

| | Costs ($M) | Benefits ($M) |
|---|---|---|
| Production | $928 | $1670 |
| **Net production benefit** | **$742 ($316)** | |
| Non-market impacts | $39 ($1) | $46 |
| **Net social benefit (including non-market value of employment)** | **$750 ($362)** | |
| **Net social benefit (excluding non-market value of employment)** | **$703 ($315)** | |

Note: totals may have minor discrepancies due to rounding.

Source: Gillespie Economics (2013)

As can be seen in **Table 3.3**, the Proposed Action is estimated to have a net production benefit of $742M.

Assuming 100% foreign ownership, $316M of this would accrue to Australia, which in accordance with the threshold value method, is the price the community must value any residual environmental impacts of the Proposed Action to justify not proceeding with it in economic efficiency terms.

Instead of leaving the analysis as a threshold value exercise, Gillespie Economics (2013) also qualitatively considered, and where possible quantified, the main environmental, cultural and social impacts associated with the Proposed Action. As is evident in **Table 3.3**, the main potential impacts of the Proposed Action are internalised into the production costs of the Proposed Action through mitigation measures and compensation costs.

Costs not included in the production costs are those associated with the opportunity cost of water and greenhouse gas costs, however as is evident in **Table 3.1** these costs are small and considerably less than the estimated net production benefits of the Proposed Action to Australia.

Overall, the Proposed Action is estimated to have net social benefits to Australia of $315M, and up to $362M if non-market benefits from employment are included. While the major environmental, cultural and social impacts have been quantified and included in the BCA, any other residual environmental, cultural or social impacts that remain unquantified would need to be valued at greater than between $315M and $362M for the Proposed Action to be questionable from an Australian economic efficiency perspective. The Proposed Action is therefore desirable and justified from an economic efficiency point of view (Gillespie Economics, 2013).

**Distribution of Costs and Benefits**

BCA is only concerned with economic efficiency. BCA and welfare economics provide no guidance on what is a fair, equitable or preferable distribution of costs and benefits. Nevertheless, BCA can provide qualitative and quantitative information for the decision-maker on how economic efficiency costs and benefits are distributed (Gillespie Economic, 2013), as discussed below.

The net production benefit of the Proposed Action will be distributed amongst a full range of stakeholders as follows:

- On a national level to the Commonwealth Government in the form of company tax ($182M present value). This will then be subsequently used to fund government infrastructure and services.
- On a state level to the NSW Government via royalties ($134M present value), which will then be subsequently used to fund government infrastructure and services.
- LCO shareholders in the form of after tax (and after voluntary contributions) profits; and
- The local community in the form of any voluntary contributions to community infrastructure and services.

**Table 3.4** presents how the benefits and costs of the Proposed Action will be distributed on a local, state, national or global level.

**Table 3.4 - Distribution of Benefits and Costs (Present Values at 7% Discount Rate)**

| Value ($M) | | Distribution | | | |
|---|---|---|---|---|---|
| | | Local | State | National | Global |
| **Net Production Benefits** | | | | | |
| Net production benefits to proponent | $426 | ✓ | ✓ | ✓ | ✓ |
| Net production benefits to Commonwealth Government – Company tax | $182 | ✓ | ✓ | ✓ | - |
| Net production benefits to NSW Government – Royalties | $134 | ✓ | ✓ | - | - |
| Net production benefits to local and regional community in the form of voluntary contributions | Unquantified | ✓ | - | - | - |
| ***Total*** | ***$742*** | | | | |
| **Non-market Costs and Benefits** | | | | | |
| ***Benefits*** | | | | | |
| Non-market benefit of employment | $46 | ✓ | ✓ | - | - |
| ***Total*** | ***$46*** | | | | |
| ***Costs*** | | | | | |
| Greenhouse gas emissions rest of the world[1] | $38 | - | - | - | ✓ |
| Greenhouse gas emissions Australia[2] | $0.4 | ✓ | ✓ | ✓ | |
| Agricultural impacts | Included in opportunity cost of land and capital costs (land acquisitions) | ✓ | - | - | - |
| Noise impacts | Insignificant* for private receptors. | ✓ | - | - | - |
| Blasting | Insignificant* | ✓ | - | - | - |
| Air quality impacts | Insignificant* | ✓ | - | - | - |
| Surface water | $0.6 | ✓ | - | - | - |
| Groundwater | $0.01 | ✓ | - | - | - |
| Ecology | Some loss of values but offset. Cost of biodiversity offset included in capital costs and operating costs | ✓ | ✓ | ✓ | - |
| Road transport impacts | Insignificant* | ✓ | - | - | - |
| Aboriginal heritage | Insignificant* | ✓ | ✓ | ✓ | - |
| Non-Aboriginal heritage impacts | Insignificant* | ✓ | ✓ | ✓ | - |
| Visual impacts | Insignificant* | ✓ | - | - | - |
| ***Total*** | ***$39*** | | | | |
| **Net Social Benefits** | **$750** | | | | |

*from an aggregate economic efficiency perspective
Source: Gillespie Economics (2013)

The residual non-market costs that have been quantified and accrue to NSW are estimated at less than $1M, as seen in **Table 3.4**, which is significantly less than the net production benefits that directly accrue to NSW through royalties ($134M) from the Proposed Action. The State and the local community will obtain additional benefits through voluntary contributions to the local and regional community and infrastructure and services provided with a share of Commonwealth Government Company tax. There will also be additional benefits to NSW from the potential non-market employment benefits ($46M). Therefore, as well as resulting in net social benefits to Australia the Proposed Action would result in net social benefits to NSW and the local community.

**Sensitivity Analysis**

The results of the BCA were tested for ± 20% changes to a number of variables at a 4%, 7% and 10% discount rate as follows:

- Opportunity costs of land;
- Capital costs;
- Operating costs;
- Decommissioning and rehabilitation costs;
- Value of coal;
- Greenhouse costs;
- Surface and groundwater impacts;
- Residual value of capital and land; and
- Non-market employment impacts.

The sensitivity analysis shows that the results of the BCA of the Proposed Action are not sensitive to changes in assumptions regarding these variables. Results were most sensitive to potential decreases in the sale value of coal; however a sustained reduction in coal price of 60% would be required to make the Proposed Action economically unviable. The Proposed Action's desirability from an economic efficiency therefore remains the same.

### 3.1.3 Economic Impact Assessment

**Economic Structure of the Region**

A 2012 input-output table of the local and regional economy was developed by Gillespie Economics (2013) using the Generation of Input-Output Tables (GRIT) procedure (provided in Attachment 4 of the Economic Assessment). The regional economy was aggregated to 30 sectors and six sectors for the purpose of describing the economy.

The economic structure for the regional economy and the NSW economy is presented on **Figures 3.1** and **3.2**.

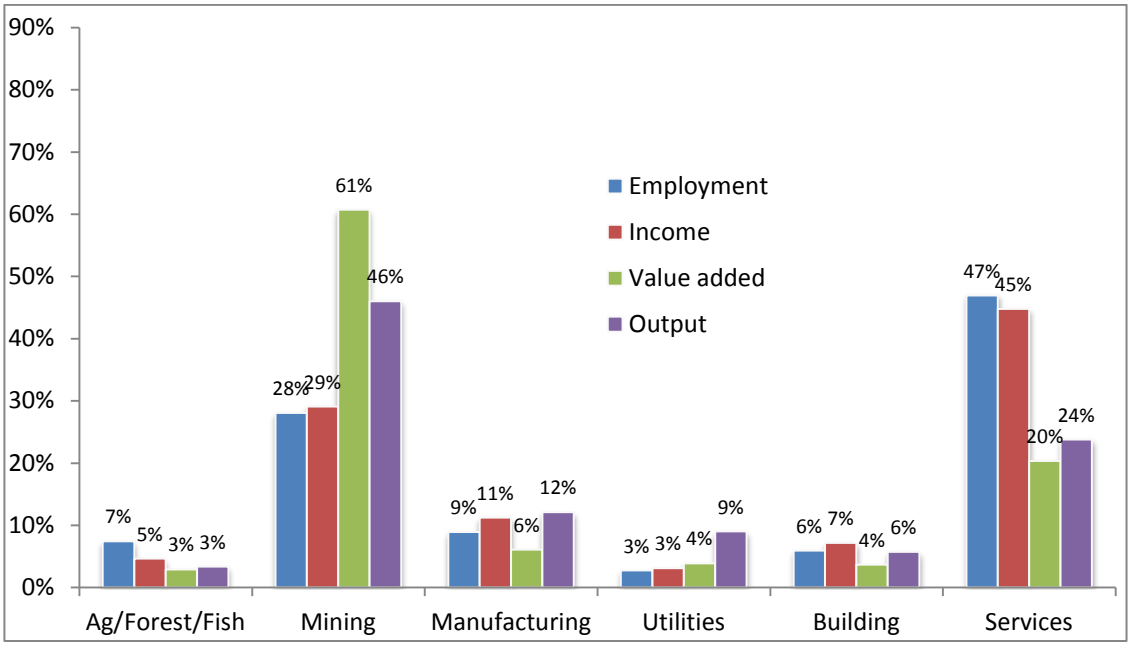



**Figure 3.1 - Summary of Aggregated Sectors: Regional Economy (Gillespie Economics, 2013)**

As illustrated in **Figure 3.1**, the coal mining sector is by far the most significant sector in the regional economy for output, value-added, income, and employment imports and exports, and is of much more importance to the regional economy at a regional level compared to at a State level (refer **Figure 3.2**).

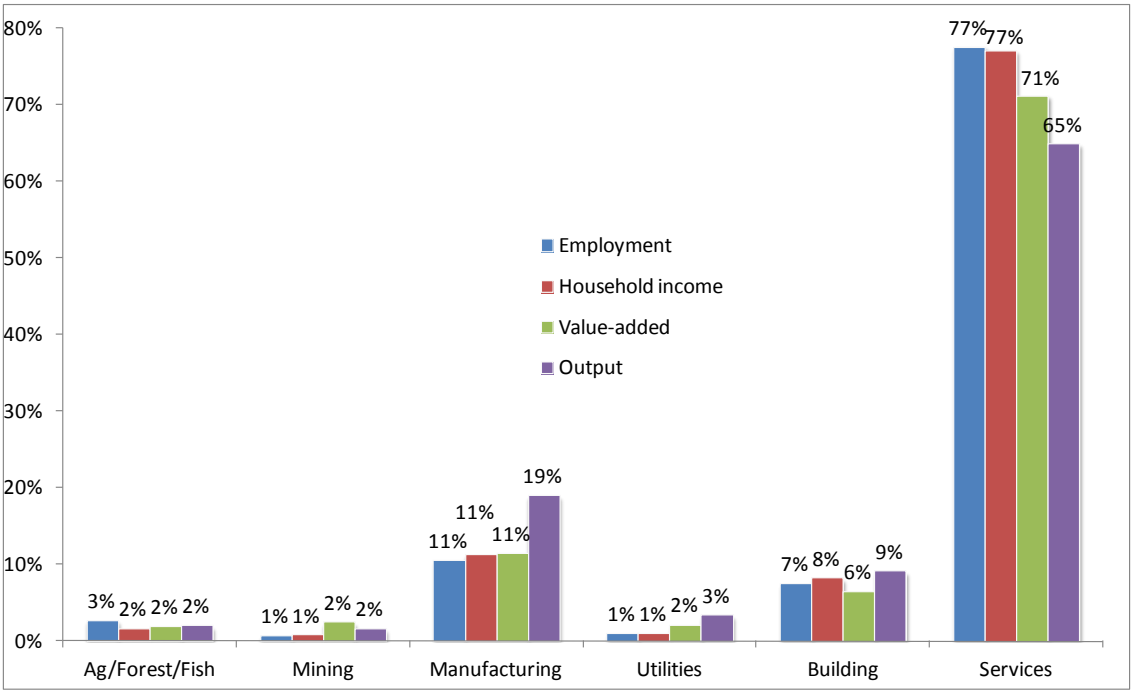



**Figure 3.2 - Summary of Aggregated Sectors: NSW Economy (Gillespie Economics, 2013)**

**Impacts on the Regional Economy**

The estimated direct and indirect average annual contribution of the Proposed Action to the regional economy for a period of seven years is as follows, with lesser contributions as the incremental production associated with the Proposed Action is ramping up or down:

- $458M in annual direct and indirect regional output or business turnover;
- $283M in annual direct and indirect regional value added;
- $37M in annual direct and indirect household income; and
- 469 direct and indirect jobs.

**Impacts on the NSW Economy**

The Proposed Action is estimated to make up to the following direct and indirect average annual contribution to the NSW economy for 7 years, with lesser impacts when the incremental production associated with the Proposed Action is ramping up and ramping down:

- $657M in annual direct and indirect regional output or business turnover;
- $374M in annual direct and indirect regional value added;
- $113M in annual direct and indirect household income; and
- 1,128 direct and indirect jobs.

The contributions to the NSW economy are considerably greater than for the regional economy, as the NSW economy is able to capture more mine and household expenditure, and there is a greater level of intersectoral linkages in the larger NSW economy. At the NSW level, there is greater scope for labour and resources required for the Proposed Action to be diverted from other sectors of the economy, particularly in times of near full employment of the economy, and hence for there to be some partially offsetting reduction in economic activity (Gillespie Economics, 2013).

**Mine Closure**

The Proposed Action will extend the mine life at LCO by a minimum of 5 years, providing continued economic activity to the regional and State economy during this time, and delaying the contraction of these economies associated with the cessation of mining. The magnitude of impacts on the regional economy as a result of mine closure would depend on a number of interrelated factors at the time including:

- The movements of workers and their families;
- Alternative development opportunities; and
- Economic structure and trends in the regional economy at the time.

The impact of cessation of mining at LCO would primarily depend on whether workers and their families leave the regional area, and ultimately on the economic structure and trends in the regional economy at the time. Given the uncertainty as to what this would be at the time of closure of LCO, it is not possible to foresee the likely circumstances, and hence associated impacts, in which mining at LCO would cease.

## 3.2 Social Considerations

LCO operates under the LCO Social Involvement Plan (SIP), which sets out how LCO will consult with the local community and other stakeholders, and also details the donations/contributions LCO makes each year to the local community.

Given that the Proposed Action involves a continuation of existing operations at LCO, and will not result in any change to annual production rates or operating hours, it is not anticipated to have adverse impacts upon the social and/or economic fabric of the local area or the wider Hunter Valley. Importantly, the Proposed Action will allow for an extension of the mine life at LCO of up to 5 years, resulting in the positive social and economic benefits associated with continued employment at the mine. Failure to obtain approval for the Proposed Action will result in a shorter life of mine, with adverse socio-economic impacts associated with failure to recover coal resources, loss of jobs and reduction in flow-on benefits.

The output of LCO, in terms of direct and indirect employment and flow-on benefits, is anticipated to make a significant contribution to the local and regional economy. A discussed above in **Section 3.1** LCO also indirectly generates employment opportunities through requirement for ancillary services to the mine and general stimulus to the local economy.

In addition to the direct and indirect employment opportunities, the Proposed Action will potentially result in the following positive social impacts:

- Reduction of social stress through employment in the mining and related industry. The Proposed Action will enable the current 360 full-time employees and 100 contractors to be maintained for up to an additional 5 years. Furthermore there will be additional indirect employment benefits through service and supply from local businesses;
- Continuation of training opportunities for local people, including young people and indigenous people, in a growth industry;
- Stimulus to local businesses, particularly in Singleton and Muswellbrook, including motel and hotel trade, cafes and restaurants, mining-related servicing and engineering business, and general surplus spending activity such as gyms, cinemas, recreational goods and services, and other local businesses; and
- Maintenance of the population to participate in locals clubs, sporting groups, cultural activities, and organisations, therefore contributing to stronger social networks and social capital.

Potentially adverse social impacts primarily relate to environmental emissions, such as air quality, noise, blasting and visual related impacts. Each of these issues has been appropriately addressed within the EA, with no significant or limiting factors over and approve that currently approved under DA 305-11-01 identified. In addition, the Proposed Action will not adversely impact the local road network. Where impacts have been identified, appropriate mitigation and management measures have been proposed. No changes to existing operating hours or production levels are proposed as part of the Proposed Action, and the impact to the social amenity is therefore anticipated to be minimal.

LCO also provides regular contributions to local community projects. In recent years LCO have made donations to a number of organisations and charities such as Lake Liddell Trust, Lifeline Muswellbrook, Hebden Rural Fire Brigade, Special Children's Christmas Parties, and end of year presentation funding for local schools. Community-based and charitable contributions such as these will be continued as part LCOs on-going commitment to ensuring the economic benefits of the Proposed Action are not restricted to the company, employees and various levels of government.

Glencore's coal assets in Australia contribute significantly to community organisations in the Hunter Valley through its Corporate Social Involvement (CSI) Program, particularly to organisations based in the Singleton and Muswellbrook LGAs.

Glencore's CSI investment gives communities access to skills and infrastructure that will endure beyond the lifespan of its operations, improve employment opportunities and attract other businesses to these regions. Examples of investments made in the local region and of benefit to the communities of LCO over recent years are as follows:

- $1.5M over four years 2011-2014 to the Hunter Central Rivers Catchment Authority;
- $500,000 over 2 years 2005-2006 to Singleton Council to construct a new Singleton Youth Venue;
- $600,000 over 2 years 2007-2008 to purchase and refurbish a new building for the Singleton Neighbourhood Centre;
- $500,000 over 2 years 2007-2008 for Healthy Waterways project to restore a 6.5km length of the Hunter River in Singleton;
- $380,000 over 4 years 2007-2010 for the Dads Take Home Reading program for Singleton district primary schools;
- $450,000 over 3 years 2009-2011 to the Singleton Indigenous Regeneration Support team. Includes training of indigenous people to a certificate 2 level in conservation and land management and to implement these skills on the Hunter River Regeneration Project in Singleton;
- $460,000 in 2009 to Singleton Council for the construction of the Singleton Visitors info Centre;
- $200,000 to Singleton Council for an All Abilities Playground over 2 years 2009-2010;
- $170,000 in 2011 to Hunter Prelude Singleton for facility upgrades for a centre that provides services for developmentally delayed children.
- $178,000 in 2012-2013 to Singleton Junior sports clubs;
- $240,000 over 3 years 2012-2014 ($80,000 in 2012) to Singleton Primary schools as part of a three year program for IT equipment;
- $54,800 over two years 2012-2013 to Singleton schools for an Educational support fund;
- $27,800 in 2012-2013 to Hunter Prelude for Child Psychology Services; and
- Funding for the Muswellbrook Women's and Children's refuge.

LCO is committed to on-going community consultation and will continue to engage the community in consultation for the purposes of providing information relating to the Proposed Action and Glencore operations in general. This will also enable the community to provide feedback to LCO and raise any issues or concerns. Consultation will continue to include the following:

- Circulation of information and newsletters, as required, relating to mining activities; and
- Continuation of the LCO CCC, established under DA305-11-01 for the existing LCO operation. This CCC comprises representatives from local government and the community, and meets on a bi-annual basis.

Further, LCO is committed to responding to any community complaints within 24 hours of receipt. All complaints will be investigated and the results of the investigation reported to the complainant in a timely manner. LCO operates a 24 hour complaints hotline to ensure that any community concerns can be captured and responded to as soon as possible. The 24 hour contact telephone number for the hotline is 1800 037 317.

# 4.0 OTHER APPROVALS AND CONDITIONS

This section describes the local and state government statutory planning instruments relevant to LCO and the Proposed Action, and assesses their implications in relation to the approval process.

## 4.1 Primary Approvals

### 4.1.1 Environmental Planning and Assessment Act 1979

#### 4.1.1.1 State Approval Pathway

The EP&A Act is the principal piece of legislation overseeing the assessment and determination of development proposals in NSW. It aims to encourage the proper management, development and conservation of resources, the protection of the environment and ecologically sustainable development (ESD). As confirmed by the DPE in a letter dated 15 February 2012, the proposed modification is to be considered pursuant to Part 3A, section 75W of the EP&A Act.

Although Part 3A was repealed on 1 October 2011, Schedule 6A of the EP&A Act provides savings provisions whereby section 75W of Part 3A continues to apply to modifications of Part 4 development consents referred to in clause 8J(8) of the EP&A Regulation.

Clause 8J(8) of the EP&A Regulation provides a mechanism whereby major projects approved under Part 4 of the EP&A Act can be modified under section 75W, stating that:

*(8) For the purposes only of modification, the following development consents are taken to be approvals under Part 3A of the Act and section 75W of the Act applies to any modification of such a consent:*

*(a) a development consent granted by the Minister under section 100A or 101 of the Act,*

*(b) a development consent granted by the Minister under State Environmental Planning Policy No 34 - Major Employment-Generating Industrial Development,*

*(c) a development consent granted by the Minister under Part 4 of the Act (relating to State significant development) before 1 August 2005 or under clause 89 of Schedule 6 to the Act,*

*(d) a development consent granted by the Land and Environment Court, if the original consent authority was the Minister and the consent was of a kind referred to in paragraph (c).*

*The development consent, if so modified, does not become an approval under Part 3A of the Act.*

The existing development at LCO was originally assessed as State Significant Development, with DA 305-11-01 granted by the Minister under Part 4 of the EP&A Act and before 1 August 2005. Accordingly, this modification is sought under section 75W, and the proposal will be subject to assessment by the Director-General of the NSW DPE and determination by the NSW Minister for Planning and Infrastructure in accordance with Part 3A of the EP&A Act. The development consent, if modified, will not become an approval under Part 3A of the Act, but will remain a Part 4 consent.

As outlined in **Section 2.0**, the Proposed Action would primarily comprise an increase in the open cut mining footprint of LCO by approximately 19%, within the existing DA and mining lease boundaries. Importantly, no changes are proposed to the approved annual rate of ROM production from the mine. In addition, no changes are proposed to the mining method, mining equipment, operating hours, and coal handling techniques from those for which development consent has already been granted.

#### 4.1.1.2 Environmental Assessment Director General's Requirements

A Briefing Paper for the proposed development consent modification at LCO and request for Director General's Requirements (DGRs) was submitted to the DPE in September 2011. The DGRs were issued in February 2012. **Table 4.1** provides a summary of the general requirements and key issues to be addressed in the EA in accordance with the DGRs.

**Table 4.1 – NSW DPE Director General's Requirements**

| Development Issue / Assessment Requirement |
|---|
| **NSW Department of Planning and Infrastructure (Director-General's Requirements)** |
| **General Requirements:** |
| The Environmental Assessment for the modification must include: |
| • An executive summary |
| • A detailed description of<br>- Historical operations<br>- Existing and approved mining operations/facilities<br>- Existing environmental management and monitoring regime |
| • A detailed description of the modification, including the |
| - need for the modification<br>- alternatives considered, including a justification for the proposed mine plan and coal rejects disposal strategy on economic, social and environmental grounds<br>- likely interactions between existing and approved mining operations<br>- likely staging of the modification<br>- plans of any proposed building works |
| • A risk assessment of the potential environmental impacts of the modification, identifying key issues for further assessment. |
| • A detailed assessment of the key issues specified below, and any other issues identified in the risk assessment, which includes;<br>- A description of the existing environment, using sufficient baseline data<br>- An assessment of the potential impacts of all stages of the modification, including any cumulative impacts;<br>- A description of the measures that would be implemented to avoid, minimise, mitigate and/or offset the potential impacts of the modification, including detailed contingency plans for managing any significant risks to the environment. |
| • A statement of commitments, outlining all the proposed environmental management and monitoring measures. |
| • A conclusion justifying the modification on economic, social and environmental grounds, taking into consideration whether the modification is consistent with the objects of the EP&A Act; and |
| • A signed statement from the author of the EA, certifying that the information contained within the document is neither false nor misleading. |
| **Key Issues:** |
| Soil and Water – including:<br>• A detailed assessment of the potential impacts of the modification, using appropriate quantitative modelling on:<br>- The quantity of both surface and ground water resources, with particular reference to the Hunter River, alluvial groundwater resources and the evaporative sink extension;<br>- Ground and surface water users , both in the vicinity of and downstream of the proposal;<br>- The riparian and ecological values of the watercourses both on site and downstream of |

| Development Issue / Assessment Requirement |
|---|
| the proposal;<br>- Environmental flows; and<br>- Flooding;<br>• A comparison of these impacts predictions against those associated with the existing mine plan, including detailed explanations for any differences;<br>• Plans for the proposed tailing dam, including detailed design and completion criteria;<br>• A detailed assessment of the environmental, hydro-geological, hydrological and geomorphic considerations of the final drainage alignments; and<br>• A revised site water balance for the mine; |
| Noise & Blasting – including:<br>• A quantitative assessment of the potential construction and operational noise impacts, in conjunction with the cumulative noise impacts from other sources, including the surrounding mines and other operations at the mine;<br>• Noise modelling based on applicable meteorological and stability category temperature inversion conditions to be developed in consultation with OEH; and<br>• Potential blasting impacts of the project on people, livestock, property and roads. |
| Air Quality – including:<br>• a detailed consideration of the potential construction and operational impacts on the local air shed, in conjunction with the cumulative air impacts from other sources, including the surrounding mines and other operations at the mine; |
| Biodiversity – including:<br>• Accurate estimates of any vegetation clearing or other impacts;<br>• An assessment of the potential impacts of the project on any terrestrial or aquatic threatened species or populations and the habitats, endangered ecological communities, riparian vegetation or groundwater dependent ecosystems; and<br>• A description of the measures that would be implemented to maintain or improve the biodiversity values of the surrounding region in the medium to long term; |
| Heritage – including the potential impacts of the project on Aboriginal and non-Aboriginal heritage; |
| Greenhouse Gas – including:<br>• A quantitative assessment of the potential scope 1, 2 and 3 greenhouse gas emissions of the project, and qualitative assessment of the potential impacts of these emissions on the environment; and<br>• A detailed description of the measures that would be implemented to minimise, reuse, recycle and dispose of any waste produced on site to ensure that the project is energy efficient; |
| Visual – including a detailed description of the measures that would be implemented to minimise the potential visual impacts of the Project; |
| Transport – including a detailed assessment of any potential impacts of the project on the safety and performance of the road network; |
| Waste – including:<br>• Estimates of the quantity and nature of the potential waste streams of the project; and<br>• A detailed description of the measures that would be implemented on site to ensure that the project is energy efficient; |
| Hazards – paying particular attention to public safety; |
| Social and Economic – including:<br>• An assessment of the potential impacts of the project on the local and regional community; and<br>• A detailed assessment of the costs and benefits of the project as a whole, and whether it would result in a net benefit for the NSW community; and |
| Rehabilitation – including a description of the proposed rehabilitation strategy for the mine, taking into consideration relevant strategic land use planning or resource management plans or policies. |

Following receipt of the DGRs in February 2012, supplementary DGRs were issued by the DPE on 30 April 2012 requiring the preparation of an Agricultural Impact Statement (AIS) as part of the EA. This requirement was as a result of the release of the *Draft Upper Hunter Strategic Regional Land Use Plan* (Department of Planning & Infrastructure, 2012a) for public exhibition in March 2012, which states that the EA must include:

*"an Agricultural Impact Statement that includes a specific focused assessment of the impacts of the proposal on strategic agricultural land, having regard to the draft gateway criteria in the draft Upper Hunter Strategic Regional Land Use Plan."*

Accordingly, an AIS has been prepared for the Project.

Further environmental assessment requirements were also received from the NSW Office of Water in a letter dated 28 June 2012 (refer **Section 4.2.2** below).

An Environmental Assessment addressing the DGRs presented in **Table 4.1** has been completed and submitted to the NSW DPE. Following review, the DPE deemed the EA to be adequate for exhibition, and the EA was placed on public exhibition for a period of four weeks, ending on 18 October 2013.

#### 4.1.1.3 Submissions Received

Following public exhibition of the EA, 14 submissions were received. Of these, 11 submissions were from government agencies, three from special interest groups, and one was a submission received from the general public in support of the Project. All submissions can be viewed on the DPE's website at the following address:

http://majorprojects.planning.nsw.gov.au/index.pl?action=view_job&job_id=5165

Submissions were received from the NSW Office of Water and NSW Office of Environment and Heritage in relation to water and biodiversity matters respectively, and are therefore relevant to the referral. A submission was also received in relation to the Economic Assessment of the Proposed Action from Economists at Large. These submissions are discussed below.

**NSW Department of Primary Industries – Office of Water**

The NSW Office of Water provided an overall comment that:

*"The NSW Office of Water has reviewed the proposal and is supportive of the water management measures proposed by LCO in their Statement of Commitments. Based upon the impact assessment and predictive model results, an adaptive management strategy is appropriate for the monitoring and mitigation of any potential water management impacts to the Bowman's Creek alluvial system. In addition to the management measures outlined in LCO's Statement of Commitments the Office of Water provides the following comments for consideration in the development of conditions of approval."*

The Office of Water submission is attached in **Appendix B**, and the recommendations provided by the Office of Water (presented in italics) and LCO's responses are provided below.

***1. Groundwater***

*That the groundwater model and groundwater assessment is independently reviewed to be robust and reliable prior to commencement of the proposal.*

Dr Noel Merrick of HydroAlgorithmics Pty Ltd was engaged by LCO to undertake an independent peer review of the groundwater model and groundwater assessment prepared by SKM for the Proposed Action. The Groundwater Impact Assessment (SKM, 2014) and the peer review report are attached in **Appendix C** and **D** respectively.

***2. Water licences under the Water Management Act 2000 and Water Act 1912***

*That LCO be required to liaise with the Office of Water and ensure that the maximum expected take of alluvial groundwater associated with mine dewatering activities (270ML) is fully accounted for by way of water access licences or any applicable exemptions.*

As a result of the peer review process, a number of parameters used in the groundwater model have been refined. The outputs of the model have subsequently been revised and the model is now predicting reduced impacts on groundwater resources compared to those presented in the EA. As discussed in the original Groundwater Impact Assessment (SKM, 2013) and in the EA, a precautionary approach was adopted in developing the regional groundwater model for the Proposed Action, resulting in a conservative prediction of potential groundwater impacts of the Project. Further work and refinement of the model has therefore reduced the level of predicted impacts.

The revised groundwater model and Groundwater Impact Assessment (SKM 2014, refer **Appendix C**) now predicts that the estimated leakage rates from the alluvial aquifer as a result of the Proposed Action will peak at approximately 65 ML/year at the end of mining, less than the initial prediction of 270 ML. The alluvium groundwater and surface creek flows are considered a connected resource under the Water Sharing Plan and constitute the Jerrys Water Source. This peak predicted demand is within the licence allocation of 142 ML currently held by LCO for this water source.

*That LCO nominate the appropriate licence(s) held to cover peak model demand of 4000 ML/yr from the hard rock aquifers associated with the Liddell Coal Operation and demonstrate that sufficient unattributed entitlements are available to account for the take prior to commencement of the proposal.*

All licence entitlements for the hard rock aquifer are available to account for the take of water associated with LCO's operations. None of the licence entitlements (totalling 27,000ML) are currently attributed to offset the take of groundwater from adjacent mines.

**3. Contingencies**

*It is recommended that a Surface and Groundwater Response Plan is prepared and implemented prior to the commencement of the proposal.*

LCO will update the existing Surface and Groundwater Response Plan to incorporate the Proposed Action.

**Office of Environment and Heritage**

OEH submitted that issues relating to threatened biodiversity have not been adequately resolved and will need to be addressed within the conditions of approval.

The Ecological Assessment of the Proposed Action was carried out by Umwelt (2013b), who have provided a response to all of the issues relating to threatened biodiversity raised by OEH in their submission. This response is attached in **Appendix E**, along with the submission from OEH.

**Economists at Large**

Economists at Large provided a submission relating to the Economic Assessment prepared for the Project by Gillespie Economics (2013). The submission raised a number of issues including the transparency of the Benefit Cost Analysis, the scope of the assessment, external costs, and the use of input-output modelling. Gillespie Economics prepared a response to each of the issues raised by Economists at Large in their submission, and both this response and the Economists at Large submission is attached in **Appendix F** of this document.

### 4.1.2 Mining Act 1992

The objects of the NSW *Mining Act 1992*, as provided in section 3A of the Act, are to:

*"encourage and facilitate the discovery and development of mineral resources in New South Wales, having regard to the need to encourage ecologically sustainable development"*

The Proposed Action is consistent with the objective of the *Mining Act 1992*, involving extending the footprint of two existing open cut pits currently being mined at LCO and enabling the efficient recovery of additional coal reserves which have been identified within LCO's existing development consent and mining lease boundaries, totalling 38 Mt of ROM coal.

The Proposed Action will therefore enable optimisation of an existing mining operation, existing coal handling and preparation facilities, and existing transportation facilities to extract, process and transport additional coal resources to existing markets. Furthermore, if the additional 38 Mt of coal is not recovered by LCO as part of the existing operation, the high cost of re-establishing mining operations within the site, compared to the additional coal quantity, would likely result in the resource being isolated and sterilised.

LCO operates under the mineral authorities illustrated on **Figure 1.2**. The Proposed Action will not extend mining or mining-related activities outside the bounds of the current mining authorities, and therefore the Proposed Action should not necessitate any variation to existing authorities or the issue of new authorities under the *Mining Act 199*2.

Statutory mining documents, such as the Mining Operations plan (MOP) would need to be revised as necessary to incorporate the scope of Proposed Action, commitments made in the EA prepared to support the modification application, and any additional consent conditions.

### 4.1.3 State Environmental Planning Policies

SEPPs are legal Environmental Planning Instruments (EPIs) prepared by the Minister to address issues significant to NSW. The SEPPs relevant to the Proposed Action are outlined in the below sub-sections.

**SEPP No. 33 – Hazardous and Offensive Development**

*SEPP No. 33 - Hazardous and Offensive Development* links the permissibility of industrial development proposals to their individual safety and environmental performance.

Certain activities may involve handling, storing or processing a range of materials which, in the absence of location, technical and/or operational controls, may create an off-site risk or offence to people, property or the environment. Such activities would be defined as 'potentially hazardous industry' or 'potential offensive industry'.

Hazardous industry is limited to industrial developments which, after all measures proposed to reduce or minimise its impact have been employed, would still pose a significant risk to the surrounding populace and/or biophysical environment. With the continued implementation of best management practices for

hydrocarbons used on–site, as well as effective implementation of the approved environmental management plans and occupation health and safety management systems, the Proposed Action would not pose any significant risk to the people, property or environment over and above the currently approved operations at LCO.

Furthermore, in determining whether an industrial development proposal has the potential to be offensive, the level of offence would not be considered significant if the relevant authority is willing to issue a licence under its environment and/or pollution control legislation. In this case, if the OEH considers that the conditions of LCO's EPL 2094 can be met, then the proposal is highly unlikely to be offensive.

**SEPP No. 44 – Koala Habitat Protection**

*SEPP No. 44 – Koala Habitat Protection* provides for the protection of koala habitat by ensuring that areas subject to development proposals are considered for their value as 'core' or 'potential' habitat for koalas. Any development application in a SEPP No. 44 specified LGA, affecting an area of 1 ha or greater, must be assessed under SEPP No. 44. Both the Singleton LGA and Muswellbrook LGA are listed under Schedule 1 of SEPP No. 44 as areas to which the SEPP applies.

No potential koala habitat was recorded within the Referral Area during preparation of the Ecological Assessment for the Proposed Action (Umwelt, 2013b). Tree species listed under Schedule 2 of the SEPP were either not recorded or recorded in densities less of than 15% of all overstorey species within each community. Furthermore, no koalas were identified during extensive walking and driving spotlight searches in the Referral Area, and the species has not been recorded at LCO during annual fauna monitoring surveys. The preparation of a Koala Plan of Management is therefore not required.

**SEPP No. 55 – Remediation of Land**

*State Environmental Planning Policy No. 55 – Remediation of Land* (SEPP 55) provides a state-wide planning approach to the remediation of contaminated land. SEPP 55 requires consent authorities to consider contamination and remediation in zoning/rezoning proposals as well as when determining development applications. Whilst SEPP 55 applies to development applications and not Part 3A major projects, it is noted that the Proposed Action would not pose any additional risk with regard to land contamination.

The Proposed Action is an expansion of the existing approved operation. With continued implementation of the storage and handling procedures and management practices for hydrocarbons and explosives used on-site, the potential for contamination is considered low. Furthermore, the potential for acid generation from regolith material (topsoil and subsoil) and overburden is considered low. The Proposed Action would therefore not pose any additional risk with regard to land contamination.

Land contamination will be considered and addressed during the preparation of the next MOP or MOP variation.

**SEPP (Mining, Petroleum Production and Extractive Industries) 2007**

*SEPP (Mining, Petroleum Production and Extractive Industries) 2007* (Mining SEPP) aims to provide for the proper management and development of mineral, petroleum and extractive material resources for the social and economic welfare of NSW. The Mining SEPP provides that development for the purpose of underground mining may be carried out with development consent on any land (and overrides anything to the contrary contained in a Local Environmental Plan), and defines mining developments that are prohibited, exempt or complying development.

The provisions of the SEPP requiring specified matters to be taken into account have been drafted using the language of Part 4 of the EP&A Act and do not expressly apply to Part 3A. However, given that the development consent pertaining to LCO, if modified, will not become an approval under Part 3A, but will remain a Part 4 consent, the Mining SEPP has been considered.

Part 3 of the SEPP discusses matters a consent authority must consider when assessing development applications. Specifically, clauses 12AA and 12AB require that the primary consideration of the consent authority should be the significance of the resource, and clause 12AB which sets out non-discretionary development standards for mining which operate to prevent the consent authority from requiring more onerous standards for those matters. Further, clauses 12 to 17 (inclusive) require consideration to be given to the compatibility of projects with other surrounding land uses, compatibility with proposed mining, petroleum production or extractive industries, natural resource and environmental management, resource recovery, transport considerations, and rehabilitation, respectively. The information presented in this EA addresses each of these matters. The assessment has been multi–disciplinary and involved consultation with various government agencies and stakeholders. Emphasis has been placed on anticipation and prevention of potential environmental and social impacts, with appropriate management strategies, mitigation measures and monitoring activities identified. Each of these matters as they relate to the Proposed Action is discussed below.

In relation to compatibility with surrounding land uses, open cut and underground coal mining projects have been developed on a broad scale in the Upper Hunter Area for over 40 years. Mining at LCO has been continuous since the 1950s, and has therefore been coexisting with surrounding land uses for over 60 years. The mining operations in the immediate vicinity of LCO (Mount Owen Complex and Ravensworth Operations) are all owned and operated by Glencore, which assists in ensuring compatibility of operations, particularly in relation to aspects such as water management and rehabilitation through providing the opportunity for shared water management infrastructure as well as enhancing rehabilitation outcomes through common rehabilitation planning, including identifying opportunities for the establishment of wildlife corridors across the operations.

The Proposed Action's predicted impacts on natural resources, and proposed environmental management and mitigation measures are discussed in detail in the EA submitted to the NSW DPE. Potential significant impacts on matters of national environmental significance that are protected under Part 3 of the EPBC Act are specifically addressed in this preliminary documentation, namely in **Sections 5-11**. Environmental management plans and monitoring programs currently in place at LCO will be reviewed and updated as required to incorporate the Proposed Action, commitments made in the EA and any additional consent conditions.

In relation to resource recovery, the Proposed Action would enable the recovery of an additional 38 Mt of coal. The Proposed Action would therefore enable LCO to optimise the recovery of coal reserves within its existing development consent and mining lease boundaries, utilising current infrastructure and mining equipment, thereby ensuring efficient recovery.

With regards to the transport of coal from LCO, all product coal would be transported by rail to the Port of Newcastle for export. Up to 1.5 Mtpa of ROM coal may be transported to RCCP for processing by road, and to enable this LCO propose to extend the length of the current approved haulage route by approximately 1.5 km further east on Liddell Station Road, a road that is closed to vehicular traffic from the Old New England Highway and does not provide any access to private properties or residences.

Finally, with regard to rehabilitation, the SEPP requires the consent authority to consider whether specific conditions should be imposed relating to rehabilitation of land affected by the development.

The proposed extension areas would be progressively rehabilitated, as is current practice at LCO, and completely rehabilitation as part of the closure process at the cessation of mining.

## 4.2 Secondary Approvals - Other NSW State Legislation

A summary of NSW legislation in addition to the EP&A Act and *Mining Act 1992* which may relate to the Proposed Action is presented in **Table 4.2** and described in the sub-sections below.

**Table 4.2 – Relevant NSW Legislation**

| Planning Provision | Comments | Further Approval Required? |
|---|---|---|
| *Coal Mine Health and Safety Act 2002* (CMHS Act) | The principal aim of the CMHS Act is to secure the objectives of the *Occupational Health and Safety Act 2000* in relation to coal operations. It achieves this by imposing certain specific safety requirements on coal mines. This includes the requirement to obtain consent from the Minister for Mineral Resources for the establishment of emplacement areas. | LCO currently holds all necessary approvals under the CMHS Act. |
| *Roads Act 1993* (Roads Act) | A permit is required to impact on a public road. | No |
| *Crown Lands Act 1989* (Crown Lands Act) | The Crown Lands Act provides for the administration and management of Crown land in the eastern and central divisions of NSW. Crown land may not be occupied, used, sold, leased, dedicated, reserved or otherwise dealt with unless authorised by this Act or the *Crown Land (Continued Tenures) Act 1989*.<br>There is no crown land within the Referral Area. The Proposed Action does however involve the transport of coal along Liddell Station Road which is a crown public road. LCO's existing development consent DA 305-11-01 allows for up to 1.5 Mtpa of ROM coal to be sent from LCO to the Cumnock Coal Handling and reparation Plant by truck via internal haul roads, Pikes Gully Road and Liddell Station road for processing as required. The Cumnock CHPP is no longer in operation and therefore LCO propose instead to transport up to 1.5 Mtpa of ROM coal by truck to the Ravensworth Coal Handling and Preparation Plant to maintain this processing flexibility. This would extend the current approved haulage route by approximately 1.5 km along Liddell Station Road. | No |
| *Water Management Act 2000 (WM Act)* | The Hunter Unregulated and Alluvial Water Sources Water Sharing Plan (WSP) (in force under the WM Act) applies to the surface waters and alluvial groundwater of Bowmans Creek (Jerrys Water Source).<br>Relevant consideration is required for impacts on surface water in particular Bowmans Creek, which is regulated within the framework of the WM Act.<br>The WSP means that water extraction and interference licensing is required to account for any assessed baseflow loss over the life of the mine and until such time as those losses are negated. | Yes - predicted losses of baseflow from Bowmans Creek will need to be adequately accounted for in accordance with the requirements of the WM Act and the Water Sharing Plan for the Hunter Unregulated and alluvial Water Sources (2009). |

| Planning Provision | Comments | Further Approval Required? |
|---|---|---|
| *Water Act 1912 (Water Act)* | Certain licensing provisions of the Water Act administered by the NSW Office of Water (NOW) still apply. | No |
| *National Parks & Wildlife Act 1974* | The National Parks & Wildlife Act provides for the management of Aboriginal Heritage and the protection of native flora and fauna. Approval is not required under the Act for impacting on native flora or fauna where that activity is carried out in accordance with a development approval granted under the EP&A Act. | Yes - the Proposed Action will require an Aboriginal Heritage Impact Permit (AHIP) under Section 90 of the NPW Act 1974 |
| *Threatened Species Conservation Act 1995 (TSC Act)* | Under the EP&A Act impacts on threatened species listed under the TSC Act are required to be assessed. | No. |
| *Fisheries Management Act 1994 (FM Act)* | Under the EP&A Act impacts on threatened species listed under the FM Act are required to be assessed. | No. |
| *Dams Safety Act 1978 (Dams Safety Act)* | This Act requires that the NSW Dams Safety Committee (DSC) periodically review large dams that may constitute a hazard to human life and property. These dams are known as prescribed dams and are listed in Schedule 1 of the Dams Safety Act. Any new prescribed dams are to be designed to the satisfaction of the DSC. | Tailings emplacements within the South Pit void required to be constructed may be subject to assessment in accordance with the DSC requirements. |
| *Protection of Environment Operations Act 1997 (POEO Act)* | The POEO Act is administered by Office of the Environment and Heritage (OEH) and requires licences for environmental protection including waste, air, water and noise pollution control. | Yes – LCO currently operates under Environment Protection Licence No.2094, which may require a variation to incorporate relevant aspects of the Proposed Action. |
| *Mine Subsidence Compensation Act 1961* | This Act makes provision for and in respect of a scheme for the payment of compensation where improvements on the surface or household effects are damaged by subsidence following the extraction of coal or shale. | No - As the Proposed Action is for open cut operations, this act is not applicable. |
| *Aboriginal Land Rights Act 1983* | Under Sections 34 and 35 of the Aboriginal Land Rights Act 1983 Land Rights claims can also be lodged by the New South Wales Local Aboriginal Land Council (LALC) or by the LALC over any Crown Lands. | No - There is no crown land within the Referral Area. |
| *Heritage Act 1977* | This Act provides for the protection of heritage items and places. Approval must be obtained from the Heritage Branch of the NSW OEH before an activity can be carried out that may damage a protected item or place. | Yes.<br>Chain of Ponds Inn, which is a State Heritage listed item, is located in proximity to the Referral Area, and approval may be required under section 60 of the Act to allow for proposed stabilisation works to the Inn. |

### 4.2.1 Protection of the Environment Operations Act 1997

The POEO Act establishes the State's environmental regulatory framework and includes licensing requirements for certain activities.

Section 43(b), 48 and 55 of the POEO Act requires that an EPL be issued prior to carrying out a scheduled activity. LCO currently holds EPL 2094, which will be varied as required upon approval.

### 4.2.2 Water Management Act 2000 and Water Act 1912

The *Water Management Act 2000* (WM Act) and the *Water Act 1912* (Water Act) contain provisions for the licensing, allocation, capture and use of water resources, and are administered by the NSW Office of Water (Office of Water). The WM Act has been progressively replacing the Water Act as relevant Water Sharing Plans (WSPs) are introduced for each water source. Generally, where a WSP under the WM Act applies to the water sources in an area, the provisions of the Water Act are ousted.

WSPs establish rules for sharing water between the environmental needs of a river or aquifer and water users, and also between different types of water use such as town supply, rural domestic supply, stock watering, industry and irrigation. These plans protect the health of our rivers and groundwater while also providing water users with perpetual access licences, equitable conditions, and increased opportunities to trade water through separation of land and water.

The WSP relevant to operations at LCO is the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*. This WSP commenced in 2009, and includes unregulated rivers and creeks, highly connected alluvial groundwater, and tidal pool areas within the Hunter regions. The WSP covers a total of 39 different water sources, nine of which are further sub-divided into management zones.

LCO is bounded to the east by Bowmans Creek and its associated alluvial aquifer, which falls within the Jerrys Water Source under the WSP. This water source is separated into two management zones; Jerrys Management Zone and Appletree Flat Management Zone, with the water resources affected by the Proposed Action falling within the Jerrys Management Zone. Water Sharing rules for the Jerrys Water Source are governed by the Hunter WSP, which includes access and trading rules, and requires accounting of water taken from water sources regulated by the WSP. Further discussion of the implications of the Proposed Action in relation to the WSP is provided in **Section 9**.

LCO holds a number of surface water and groundwater extraction licences under the WM Act, which are summarised in **Tables 4.3** and **4.4**.

**Table 4.3 – LCO Surface Water Extraction Licences**

| Surface Water Extraction Licences | | | | | | |
|---|---|---|---|---|---|---|
| **Locality** | **Licence No.** | **Holder** | **Use** | **Water Source/ Management Zone/Type** | **Annual Use (ML)** | **Annual Allocation (ML)** |
| Bowmans Creek | WAL 18320 | Enex Foydell Pty Ltd | Irrigation | Jerrys Water Source/ Jerrys Management Zone/ Unregulated River | Nil | 50 |
| Bowmans Creek | WAL18304 | Enex Foydell Pty Ltd | Irrigation | Jerrys Water Source/ Jerrys Management Zone/ Unregulated River | Nil | 32 |
| Bowmans Creek | WAL18318 | Enex Foydell Pty Ltd | Irrigation | Jerrys Water Source/ Jerrys Management Zone/ Unregulated River | Nil | 55 |
| Bayswater Creek | WAL 18306 | Mitsushima Australia Pty Ltd<br>Enex Liddell Pty Ltd<br>Gabume Pty Ltd | Industrial (coal mining) | Jerrys Water Source/ Jerrys Management Zone/ Unregulated River | Nil | 100 |
| Hunter River via Macquarie Generation | WAL7815 | Liddell Tenements Pty Ltd | Industrial | Hunter Regulated River Water Source/ Zone 1B Regulated River | Nil | 20 |
| Swamp Creek | 20SL042837 | LCO Pty Ltd | Monitoring | | Nil | N/A – Diversion Works |

**Table 4.4 – LCO Groundwater Licences**

| Groundwater Licences | | | | | |
|---|---|---|---|---|---|
| **Locality** | **Licence No.** | **Holder** | **Lot/DP** | **Purpose** | **Annual Extraction Allocation (ML)** |
| Haz 6 | 20BL168066 | Liddell Tenements Pty Ltd | 81/607296 | Monitoring | N/A |
| Dur 3 | 20BL168065 | Liddell Tenements Pty Ltd | 31/837350 | Monitoring | N/A |
| LC1 | 20BL168064 | Liddell Tenements Pty Ltd | 353/867083 | Monitoring | N/A |
| Durham 1 | 20BL168063 | Liddell Tenements Pty Ltd | 33/862516 | Industrial | 6000 |
| 8 South 3 & 4 | 20BL168062 | Liddell Tenements Pty Ltd | 32/870789 | Industrial | 6000 |
| Durham 2 & 4 | 20BL168061 | Liddell Tenements Pty Ltd | 3/237654 | Industrial (2 bores) | 1000 |
| Haz 2 | 20BL168060 | Liddell Tenements Pty Ltd | 81/607296 | Industrial (2 bores) | 5500 |
| ALV1, ALV2, ALV3, ALV4, ALV7, ALV8 | 20BL168053 | LCO Pty Ltd | 43/654013<br>201/848078<br>4/255403<br>81/607296<br>6/255403<br>32/545601 | Test bore/ Monitoring | N/A |
| Bowmans Creek Alluvial | WAL18302 | Liddell Southern Tenements Pty Ltd | 32/545601 | Irrigation | 5 |
| | 20BL017861 | Enex Foydell Limited | 6/1077004 | Irrigation | 5 |
| M49 | 20BL172293 | Liddell Southern Tenements Pty Ltd | 32/545601 | Dewatering | 2500 (Combined with 20BL168209) |
| Mt Owen 1 | 20BL168209 | Mt Owen Pty Ltd | 353/867083 | Stock, domestic, farming and test purposes | 2500 (Combined with 20BL172293) |
| Mt Owen 2 | 20BL169544 | Mt Owen Pty Ltd | 353/867083 | Dewatering | 2500 |
| Middle Liddell | 20BL172588 | LCO Pty Ltd | 1/237766 | Dewatering | 6000 |

Extensive consultation was conducted throughout the preparation of the environmental assessment of the Proposed Action with the Office of Water. An initial meeting was held on 1 May 2012 to provide an overview of the Proposed Action, to discuss the proposed methodology for the groundwater modelling and assessment, and to seek any further assessment requirements the Office of Water may have. The proximity of LCO and the proposed open cut extension to Bowmans Creek was discussed, as well as acknowledgement of the long history of operations at LCO. Following the meeting, the Office of Water sent a letter dated 28 June 2012 to LCO detailing specific assessment requirements. These requirements related to three primary issues raised at the meeting on 1 May, and are summarised below in **Table 4.5**.

A second meeting was held with the Office of Water in Newcastle on 19 October 2012, and a third in Sydney on 22 November 2012. The primary purpose of these meetings was to keep the Office of Water informed on the progress of the groundwater model development and to discuss preliminary outcomes. The key discussion points at these meetings are also summarised in **Table 4.5**. At both meetings the extensive groundwater modelling work being conducted for the Proposed Action was acknowledged, noting the conservative nature of the model. Office of Water suggested a fourth meeting with the Office of Water hydrogeologists to discuss specifics of the model setup. This meeting was held on 17 December 2012.

**Table 4.5 – Office of Water Assessment Requirements**

| Office of Water requirement/key issues raised | LCO response and how addressed in the EA |
|---|---|
| **Meeting on 1 May 2012 and Letter dated 28 June 2012** | |
| Any interference with either alluvial or surface waters associated with Bowmans Creek requires accounting in accordance with the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009.* This requires clear identification of the alluvial boundary. | • Light Detection and Ranging (LiDAR) flown to identify alluvial boundary.<br>• Detailed soil survey conducted to ground-truth alluvial boundary (GSSE, 2013a).<br>• Development of a groundwater model to predict any interference with Bowmans Creek and its associated alluvial system (refer **Section 9** and **10** in this document).<br>• Investigation into accounting mechanisms and options based on predictions of the groundwater model (refer **Sections 9** and **10**). |
| Investigation into the history of impacts on Bowmans Creek, and interactions with existing old underground workings, and investigate risks associated with further interaction with the flooded underground workings. | • Groundwater model developed to simulate historical mine workings at LCO. |
| Development of a regional-scale groundwater model, requiring significant calibration and sensitivity modelling to understand in-situ and mining-affected groundwater regimes, as well as surface/groundwater interaction for the site. Additional consultation requested regarding development of the model. | • Development of a groundwater model (refer **Section 9** and **10** in this document). The calibration process and sensitivity analysis is discussed in detail in Appendix B of the Groundwater Impact Assessment, refer **Appendix C**.<br>• Further meetings were held with Office of Water on 19 October 2012, 22 November 2012 and 17 December 2012 to discuss development of the model. |
| **Meeting on 19 October 2012** | |
| Calibration of the model and the use of stream gauge data in this calibration. | • Calibration is summarised in **Section 10**, including the use of stream gauge data. |
| Understanding of the current and future dewatering regime of underground workings, and associated impacts. | • Historical dewatering regime replicated in the groundwater model, refer **Section 9** and **10**. |
| Accounting of impacts | • Investigation into accounting mechanisms and options based on predictions of the groundwater model (refer **Section 10**). |

| Office of Water requirement/key issues raised | LCO response and how addressed in the EA |
|---|---|
| **Meeting on 22 November 2012** | |
| Groundwater modelling must be undertaken in accordance with the *Australian Groundwater Modelling Guidelines* (National Water Commission, June 2012). | • Model developed accordingly. |
| Surface water/groundwater assessment must:<br>• Identify affected water sources<br>• Quantify impacts<br>• Fully account for these impacts | • Refer **Sections 9** and **10.** |
| Acknowledgement of long history of mining at LCO, and that operations pre-dated commencement of the WSP. Sustainable allocations specified in the WSP were estimated through consideration of agricultural, industrial and stock and domestic use at time of WSP commencement, with no provision for water use by mining activities. | • Historical impacts and licencing implications are discussed in **Section 9** and **10**. |

### 4.2.3 Coal Mine Health and Safety Act 2002

LCO currently holds all necessary approvals under the *Coal Mine Health and Safety Act 2002*. LCO will ensure that any further approvals required for the Proposed Action are obtained in consultation with the DTIRIS Mineral Resources and Energy Division.

### 4.2.4 Dams Safety Act 1978

The *Dams Safety Act 1978* requires that the Dams Safety Committee (DSC) periodically review large dams that may constitute a hazard to human life and property. These dams are known as prescribed dams and are listed in Schedule 1 of the *Dams Safety Act 1978.*

Two prescribed dams under Schedule 1 of the Act are relevant to the Proposed Action. The first, Lake Liddell, bounds the LCO development consent boundary to the west. However, the proposed extension of open cut mining at LCO would involve an extension of mining in a south easterly direction away from the Lake. The second dam, Antiene Tailings Dam, would continue to be managed as per the existing approval. In addition, no changes are proposed to the mining method or mining equipment. The Proposed Action would therefore not result in any changes with respect to interaction with prescribed infrastructure. LCO will however continue to consult with Macquarie Generation in relation to Lake Liddell and the DSC in relation to both dams as required.

### 4.2.5 National Parks and Wildlife Act 1974

The *National Parks and Wildlife Act 1974* (NPW Act) contains provisions for the protection and management of national parks, historic sites, nature reserves and Aboriginal heritage throughout NSW, as is administered by the Office of Environment and Heritage.

The *Aboriginal and Historic Heritage Assessment* (OzArk, 2013) prepared for the Proposed Action identified a number of Aboriginal heritage sites within the Referral Area that would be impacted by the Proposed Action.

On this basis, management of these sites would be undertaken through application to the OEH for an Aboriginal Heritage Impact Permit (AHIP) under section 90 of the NPW Act for the destruction and salvage of the sites. The AHIP would be prepared in consultation with the Aboriginal community stakeholders.

### 4.2.6 Heritage Act 1977

Historical archaeological relics, buildings, structures, archaeological deposits and features are protected under the *Heritage Act 1977*. The Chain of Ponds Inn, which is a State Heritage listed item, is located in proximity to the Referral Area. Approval may be required under Part 4 Division 3 of the Act to allow for proposed stabilisation works to the Inn to ensure potential impacts from blasting activities at LCO are minimised.

### 4.2.7 Threatened Species Conservation Act 1995

The TSC Act is administered by the OEH and includes provisions to declare and protect threatened species, populations and ecological communities in NSW. The TSC Act also provides a framework for the assessment of a development's impacts on threatened species and ecological communities. A detailed assessment of the Proposed Actions impacts in this regard is presented in **Section 6**.

### 4.2.8 Roads Act 1993

The *Roads Act 1993* is administered by the NSW Roads and Maritime Services (RMS) as well as local road authorities (generally local Councils). Under this Act, LCO must obtain the consent of the appropriate roads authority to:

a. erect a structure or carry out a work in, on or over a public road;
b. dig up or disturb the surface of a public road;
c. remove or interfere with a structure, work or tree on a public road;
d. pump water into a public road from any land adjoining the road; or
e. connect a road (whether public or private) to a classified road,

The Proposed Action will not involve any of the actions listed above, and approval is therefore not anticipated to be required under the Act. The Proposed Action involves one aspect relating to road transportation, being the transport of coal via road to the neighbouring Glencore RCCP facility. DA 305-11-01 currently allows for the transport of up to 1.5 Mtpa of ROM coal to and from Cumnock No. 1 Colliery for processing. The coal is transported generally by road trucks via private haul roads, Pikes Gully Road and Liddell Station Road.

ROM coal will no longer be sent to, or received from, Cumnock following closure of the Colliery. LCO now propose to instead transport up to 1.5 Mtpa to RCCP by road as per the existing approved route, with the only change being transport further along Liddell Station Road, which is a local road, past the Cumnock CHPP site to the RCCP facility, as illustrated on **Figure 1.2**.

## 4.3 Local Environmental Plans

Local Environmental Plans (LEPs) are EPIs that guide planning decisions for local government areas. They allow Councils to supervise the ways in which land is used through zoning and development consents.

Importantly, sub-clause 7(1) of the Mining SEPP states that development for the purpose of mining may be carried out with development consent on land where development for the purposes of agriculture or industry (with or without development consent) may be carried out. In relation to any inconsistency between the SEPP and a LEP, sub-clause 5(3) of the SEPP states that if the SEPP is inconsistent with any other EPI, whether made before or after the SEPP, the SEPP prevails to the extent of the inconsistency.

LCO is located within both the Singleton LGA and Muswellbrook LGA (refer **Figure 4.1**), in an area predominantly zoned RU1 Primary Production under the provisions of the *Singleton Local Environment Plan 2013* (Singleton LEP). All of the open cut pit extension areas proposed as part of the Proposed Action are located within the Singleton LGA in this zone. The proposed mining activities are a permissible land use within this zone with development consent.

Whilst all of the proposed open cut pit extension areas are located within the Singleton LGA, a very small portion of the proposed ancillary disturbance area extends into the Muswellbrook LGA on land zoned RU1 Primary Production (Rural Zone). The proposed mining activities are permissible within this zone with development consent. This component of the proposed project is not a component of the Proposed Action subject to referral. No coal resource will be extracted from areas located within the Muswellbrook LGA.

## 4.4 Other Considerations

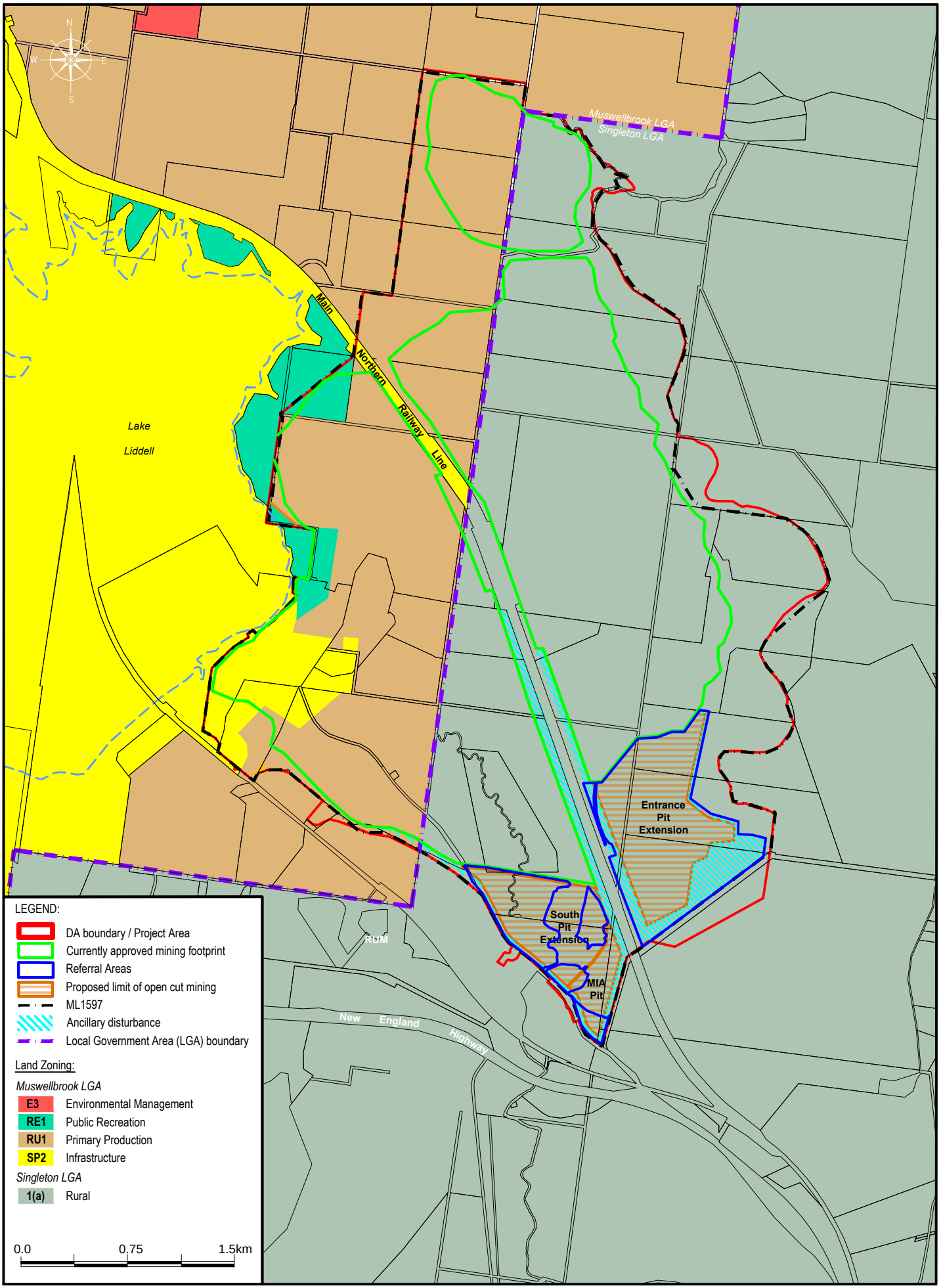
### 4.4.1 Upper Hunter Strategic Regional Land Use Plan

The Upper Hunter Strategic Regional Land Use Plan (SRLUP) is intended to provide a framework for resolving potential land use conflict issues between mining and coal seam gas proposals and strategic agricultural land within the Upper Hunter region, including the Referral Area. The key policy response for resolving land use conflict between mining and coal seam gas proposals and agricultural land is a gateway process. Under this process, a panel of independent experts assess proposals involving mining or coal seam gas development on strategic agricultural land at an early stage to determine whether the proposal is considered suitable on the subject land and whether it can progress to the development application stage.

The SRLUP and the gateway process only applies to new State Significant development applications or modifications (under Part 4 of the EP&A Act) for mining projects located outside of existing mining lease areas. On this basis the SRLUP does not apply to the Proposed Action, which is a modification of an existing approved development under Part 3A, section 75W of the EP&A Act and is within existing mining lease boundaries. However, matters relating to land use impacts, agricultural suitability and soils have been dealt with in Section 7.13 of the EA submitted to the DPE.

In addition, as discussed in **Section 4.1.1**, supplementary DGRs requiring the preparation of an AIS were received in April 2012 from the DPE. Accordingly, an AIS has been prepared and is discussed in detail in Section 7.14 of the EA submitted to the DPE. With regard to Biophysical Strategic Agricultural Land (BSAL), the Referral Area contains approximately 2.8 ha of land which has been mapped as BSAL by the Upper Hunter SRLUP, located along Bowmans Creek to the east of the Entrance Pit. As the proposed extent of open cut mining does not include this land mapped as BSAL, the Proposed Action is not expected to impact the land through surface area disturbance. Therefore there is not expected to be any impact on soil fertility, rooting depth, profile, microrelief, salinity of pH.

The verification process undertaken by GSSE (2013a) in accordance with the *Interim Protocol for Site Verification and Mapping of Biophysical Strategic Agricultural Land – V7* (OEH 2013) confirmed that the alluvial soil identified within the Referral Area is not considered to be BSAL.




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Zoning

**FIGURE 4.1**

### 4.4.2 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (AIP) is a key component of the NSW Government's Strategic Regional Land Use Policy. The AIP details how potential impacts to aquifers should be assessed by the government agencies, advisory bodies and consent authorities involved in the planning approval process. The AIP also clarifies the requirements for obtaining water licences for aquifer interference activities and defines the considerations for assessing potential impacts to key water-dependent assets.

The WM Act defines an aquifer interference activity as one which involves the following:

- The penetration of an aquifer;
- The interference with water in an aquifer;
- The obstruction of the flow of water in an aquifer;
- The taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; and
- The disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.

The WM Act includes the concept of ensuring "no more than minimal harm" for both the granting of water access licences and approvals. The Office of Water and the relevant Minister are required to ensure that when granting aquifer interference approvals, adequate arrangements are in place to ensure that no more than minimal harm will be done to any water source as a result of the proposed interference activities.

In addition, to ensure that extraction limits set by the relevant WSP are complied with, the AIP notes the importance of ensuring that the volumetric take of water by aquifer interference activities is appropriately licensed and accounted for (Office of Water, 2012). In this regard, a groundwater model has been developed to model predicted impacts of the Proposed Action. The outcomes of this model and the licensing implications are discussed in detail in **Section 10**.

The alluvial systems of the Hunter River and its tributaries, which include Bowmans Creek, are mapped as BSAL in the Upper Hunter SRLUP. Site verification and mapping of BSAL within the Referral Area has also been conducted as part of the soils assessment for the Proposed Action, the alluvial land within the Referral Area is not BSAL.

## 4.5 Ecologically Sustainable Development

### 4.5.1 Overview

Prior to any development taking place in NSW, a formal assessment is required to be made of the proposed development to ensure it addresses the relevant planning controls and, according to its nature and scale, confirm that it is environmentally, socially and economically sustainable.

The EP&A Act provides the framework for the assessment of development proposals and allows for community participation in the decision making process that would determine future land uses.

Ecologically sustainable development (ESD) is a primary objective of environmental protection in NSW. The objects of the EP&A Act adopt the principles of ESD and it is defined under section 6(2) of the *Protection of the Environment Administration Act 1991* as:

*(2) For the purposes of subsection (1)(a), ecologically sustainable development requires the effective integration of economic and environmental considerations in decision-making processes.*

*Ecologically sustainable development can be achieved through the implementation of the following principles and programs:*

*(a)* ***the precautionary principle*** *- namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation...*

*(b)* ***inter-generational equity*** *- namely, that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations,*

*(c)* ***conservation of biological diversity and ecological integrity*** *- namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration,*

*(d)* ***improved valuation, pricing and incentive mechanisms*** *- namely, that environmental factors should be included in the valuation of assets and services such as:*

*(i) polluter pays - that is, those who generate pollution and waste should bear the cost of containment, avoidance or abatement,*

*(ii) the users of goods and services should pay prices based on the full life cycle of costs of providing goods and services, including the use of natural resources and assets and the ultimate disposal of any waste,*

*(iii) environmental goals, having been established, should be pursued in the most cost effective way, by establishing incentive structures, including market mechanisms, that enable those best placed to maximise benefits or minimise costs to develop their own solutions and responses to environmental problems*

The overall objectives of ESD are to use, conserve and enhance natural resources. This ensures that ecological processes are maintained facilitating improved quality of life, now and into the future.

LCO is committed to the principles of ESD, and understands that social, economic and ecological objectives are independent. LCO also acknowledges that a well-designed and effectively managed operation would avoid significant environmental impact or degradation. The Proposed Action design and commitments have therefore been developed to appropriately identify, avoid, mitigate and manage environmental risk. In addition, the suite of environmental management plans and monitoring programs in place at LCO are designed to demonstrate environmental due diligence and to implement procedures that provide on-going management and monitoring of the operation in-line with the objectives of ESD, as outlined in the below sub-sections.

### 4.5.2 The Precautionary Principle

The Precautionary Principle, as defined in Principle 15 of the *Rio Declaration on Environment and Development* (United Nations, 1992), holds that where there are threats of serious or irreversible environmental damage, the lack of full scientific certainty should not be used as a reason for postponing cost-effective measures to prevent environmental degradation. When an activity raises the risk of harm to the environment, precautionary measures should be taken even if there is a lack of scientific evidence regarding the cause and effect.

LCO is an existing underground coal mine with a very long history of mining at the site. Mining has been in continuous operation at LCO since the 1950s, and Development Consent DA 305-11-01 was granted in 2001 for continued operations under Part 4 of the EP&A Act for a period of 21 years. The proposed modification 5 to DA 305-11-01 is a proposed continuation and extension of the approved mining operations. The current open cut operations have been in operation since 1990, and since this time LCO has gained an extensive understanding of the environment in which it operates and the potential for impacts as a result of the mining activities. The information gained during the mine's history has been used as a basis for the mine design in the Referral Area, as well as identifying appropriate management and mitigation measures.

Extensive consultation with government agencies, the community and other stakeholders has been undertaken throughout preparation of the EA to identify potential impacts, issues or concerns and ensure these matters have been taken into consideration through the mine planning and environmental assessment process.

The potential environmental impacts associated with the Proposed Action have been identified and quantified via qualitative risk assessment, stakeholder consultation and assessment. Specialist impact assessments, including the use of engineering and scientific modelling, have been undertaken in accordance with current best practice for environmental impacts relating to groundwater, terrestrial and aquatic ecology, agricultural resources, groundwater, surface water, flora and fauna, Indigenous and non-Indigenous heritage, surface water, air quality, greenhouse gas, noise, blasting, soil and land capability, impacts on agricultural resources, and traffic. Assessments have also been undertaken for visual amenity and economic and social implications.

These studies, combined with stakeholder consultation and input, have enabled LCO to understand the impacts of its operations on environmental and social factors. Where the potential for adverse environmental impact is predicted, LCO has adopted the recommendations of the specialist impact assessments and committed to the implementation of the operational mitigation measures, monitoring activities and adaptive management strategies.

An example of how the precautionary principle has been applied throughout the environmental impact assessment process can be found in the ecological assessment. The precautionary principle was applied particularly in the development of the mitigation and Biodiversity Offset Strategies, to ensure that uncertainties were compensated for with more robust mitigation or more substantial offset outcomes (Umwelt, 2013b). With regards to potential impacts of the Proposed Action on several threatened fauna species, including the federally listed spotted-tailed quoll, Umwelt (2013b) found that the potential for a significant impact could not be ruled out based on current knowledge and therefore, following application of the precautionary principle, these species are considered to be potentially significantly impacted by the Proposed Action, and were therefore considered in the development of the Biodiversity Offset Strategy.

Another example is in the development of the groundwater numerical model and groundwater impact assessment of the Proposed Action. Given the extent and complexity of the model and the amount of data available, substantial assumptions and simplifications were required to facilitate model construction and development. In keeping with standard practice, SKM adopted conservative values for model parameters for which reliable data was either unavailable or unknown. In particular the precautionary principle was applied in relation to the possible presence of cracks in the strata, and the subsequent leakage of water from the alluvials as a result of previous underground mining at LCO. Whilst previous environmental assessments have suggested that the cracking above the former Liddell underground workings have healed, in the absence of site specific data demonstrating such cracking has healed, SKM adopted a precautionary approach for the representation of these cracking and fracture areas within the regional groundwater model. The predictive model results presented are therefore considered conservative estimates of potential impacts to the overlying alluvial aquifer due to the incorporation of these fracture zones (SKM, 2014).

### 4.5.3 Intergenerational Equity

Intergenerational equity is centred on the concept that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations. There is a moral obligation to ensure that today's economic progress, which will benefit both current and future generations, is not offset by environmental deterioration.

The primary objective of the Proposed Action is to maximise resource recovery and maintain continuity of coal production from the existing LCO operations beyond the current life of mine in an environmentally responsible manner. The management strategies, mitigation measures and monitoring programs have been identified to minimise adverse impact upon the local environmental and surrounding populace. Emphasis has been placed on anticipation and prevention of potential impacts, as opposed to undertaking later remedial action.

These actions and initiatives will assist in ensuring that there are no significant effects on the environment that will diminish the social, environmental and economic resources available for future generations originating from the Referral Area.

### 4.5.4 Conservation of Biological Diversity and Ecological Integrity

This principle holds that the conservation of biological diversity and ecological integrity should be a fundamental consideration for development proposals.

The potential impacts on vegetation communities, habitat availability and endangered species, has been investigated by Umwelt (2013b) as part of the specialist Ecological Assessment of the Proposed Action. LCO has sought to avoid and minimise potential impacts on ecological values, as well as cultural heritage values, through the reduction of the original disturbance footprint proposed.

The ecological assessment concluded that, without mitigation and offsetting, the Proposed Action has the potential to have a significant impact on the spotted-tailed quoll (*Dasyurus maculatus maculatus*) and four threatened woodland birds.

A comprehensive mitigation strategy is proposed to reduce the level of impacts, including a robust tree-felling procedure to minimise impacts of clearing on native fauna and flora, fencing and access control, and weed and feral animal control. The rehabilitation strategy has been designed in a manner which will assist in recreating linkages and corridors in the landscape, and will importantly create a corridor assisting in the connection of remnant vegetation to both the north and south of LCO. This will particularly aim to provide interconnected foraging (and potentially denning) habitat for the spotted-tailed quoll. And finally a Biodiversity Offset Strategy has been developed to compensate for the likely residual impacts.

Implementation of the rehabilitation strategy will result in the establishment of 839 ha of woodland both in post-mined areas and also adjacent to Bowmans Creek (183 ha). Together, the rehabilitation of the Proposed Action areas, the offsite biodiversity offset proposed at Mountain Block, and the proposed mitigation measures, ensure that the residual ecological impacts of the Proposed Action are adequately mitigated, offset and counterbalanced (Umwelt, 2013b).

### 4.5.5 Improved Valuation, Pricing and Incentive Mechanisms

The principle of “improved valuation, pricing and incentive mechanisms” deems that environmental factors should be included in the valuation of assets and services. The cost associated with using or impacting upon an environmental resource is seen as a cost incurred to protect that resource.

The economic assessment prepared by Gillespie Economics (2013) and summarised in **Section 3.1** provides an analysis of the potential environmental and social costs and benefits of the Proposed Action. In this assessment, estimates were made of the main environmental, cultural and social impacts using market data and benefit transfer (borrowing economic values that have been determined for other study sites). Where some impacts remain unquantified, they were interpreted by Gillespie Economics (2013) using the threshold value method; a method which uses the value of quantified net production benefits as the amount that unquantified environmental, social and cultural costs would need to exceed to make a project questionable from an economic efficiency perspective.

Economic and social aspects that may impose costs and benefits on the local, state, national or global community, including greenhouse gas emissions, agriculture, water resources, biodiversity, noise, blasting, air quality, biodiversity, heritage, traffic and visual amenity have been evaluated by Gillespie Economics (2013), as presented in **Section 3**.

LCO will implement appropriate mitigation and management measures to ensure the avoidance, minimisation, offsetting and management of potential environmental and social impacts.

# LIDDELL COAL OPERATIONS

PART 2

## Listed Threatened Species and Communities and Migratory Species

# 5.0 EXISTING ENVIRONMENT – THREATENED SPECIES AND COMMUNITIES AND MIGRATORY SPECIES

Information regarding the existing environment in relation to threatened species and communities, and migratory species is provided in the sections below. The information presented is in accordance with the requirements set out in Section 4 of the "Guidelines for Additional Information – Assessment by Preliminary Documentation" (DoE).

## 5.1 Existing Land Use

As described above in **Section 1.3** and illustrated on **Figure 1.3**, the area within and surrounding LCO is dominated by mining and power generating activities. The region has been subject to extensive underground and open-cut coal mining since the early 20th century which has extensively altered the area's physical features and setting. There is a long history of mining in particular at the LCO site, where mining operations have been in continuous operation since the 1950s. The current open cut operations have been in operation since 1990, and since this time LCO has gained an extensive understanding of the environment in which it operates and the potential for impacts as a result of the mining activities.

Numerous mining operations surround LCO, and include Ravensworth Operations to the south, Ravensworth Underground Mine and the Ravensworth Central Coal Processing facility to the south west, and the Mt Owen Complex (incorporating Mt Owen, Ravensworth East and Glendell mining operations) to the east. Other mines in the wider surrounding area include Ashton Coal, Integra, Hunter Valley Operations and Drayton Coal. Bayswater and Liddell Power Stations are located to the west and north west of LCO respectively.

Lake Liddell lies immediately adjacent to LCO to the west, with the Main Northern Railway line traversing LCO from northwest to southeast. The remaining land within the vicinity of LCO is characterised by traditional agricultural activities.

## 5.2 Topography

The area surrounding LCO is characterised by two distinct areas; the gently undulating plain associated with the Hunter River Valley, and the steeper, elevated ranges in the north delineating the flank of the valley. Within the valley, ground elevations generally range between 50 and 150 m AHD, rising to elevations up to 500 m AHD along the northwest to southeast trending ridgeline of the Hunter Thrust. The Hunter Thrust is associated with outcropping of carboniferous rocks and marks the northern catchment boundary of the Hunter River Valley (SKM, 2014).

The topography of the Referral Area is characterised by gently undulating hills with local relief of up to 90 metres. The Referral Area includes very gently inclined alluvial fans (1-3%), bordered by gently inclined rises (3-10 per cent) at elevations ranging from 100 m AHD to 185 m AHD. The proposed Entrance Pit Extension area is flanked by nearby Bowmans Creek, a southerly flowing drainage line along the eastern boundary of the current LCO development consent boundary. Bayswater Creek flows adjacent to the proposed South Pit Extension Area and is a highly modified water system, flowing from Lake Liddell along the south western LCO development consent boundary to its confluence with the Hunter River, approximately 9 km downstream from LCO.

## 5.3 Matters of National Environmental Significance that may be Affected by the Action, including at Off-site Locations

A protected matters database search was undertaken (within a 10 km radius from the Referral Area) to identify the range of EPBC Act MNES that are predicted to potentially occur within the Development Consent boundary (including the Referral Area). An assessment of the potential for each of those MNES to occur within the habitats of the Referral Area is provided in **Appendix G**, as well as the potential for impact on each MNES.

Records from this database search were combined with records derived through literature reviews, field surveys and professional opinion to identify the range of recorded or potentially occurring MNES that may occur (refer to **Appendix G**). The identification of potentially occurring MNES was then used to assist in the development of appropriate field survey methods to be used to determine those MNES that would be subject to an Assessment of Significance as part of the Referral process.

Detailed and targeted surveys in the Referral Area have been supplemented by the results of annual ecological monitoring surveys that have been undertaken at LCO (including parts of the Referral Area) from 2001 onwards.

Based on previous survey results and ecological monitoring at LCO, and targeted surveys within the Referral Area undertaken as part of the Proposed Action, only one MNES (being the rainbow bee-eater (*Merops ornatus*)) has been recorded within the Referral Area. A number of other MNES have been recorded either within the broader LCO site, or within the nearby surrounds, such as from the nearby Mount Owen Complex.

**Table 5.1** lists those MNES that have been identified as occurring, or having potential to occur, within the Referral Area or within a 10 km radius from the Referral Area (refer **Figure 5.1**).

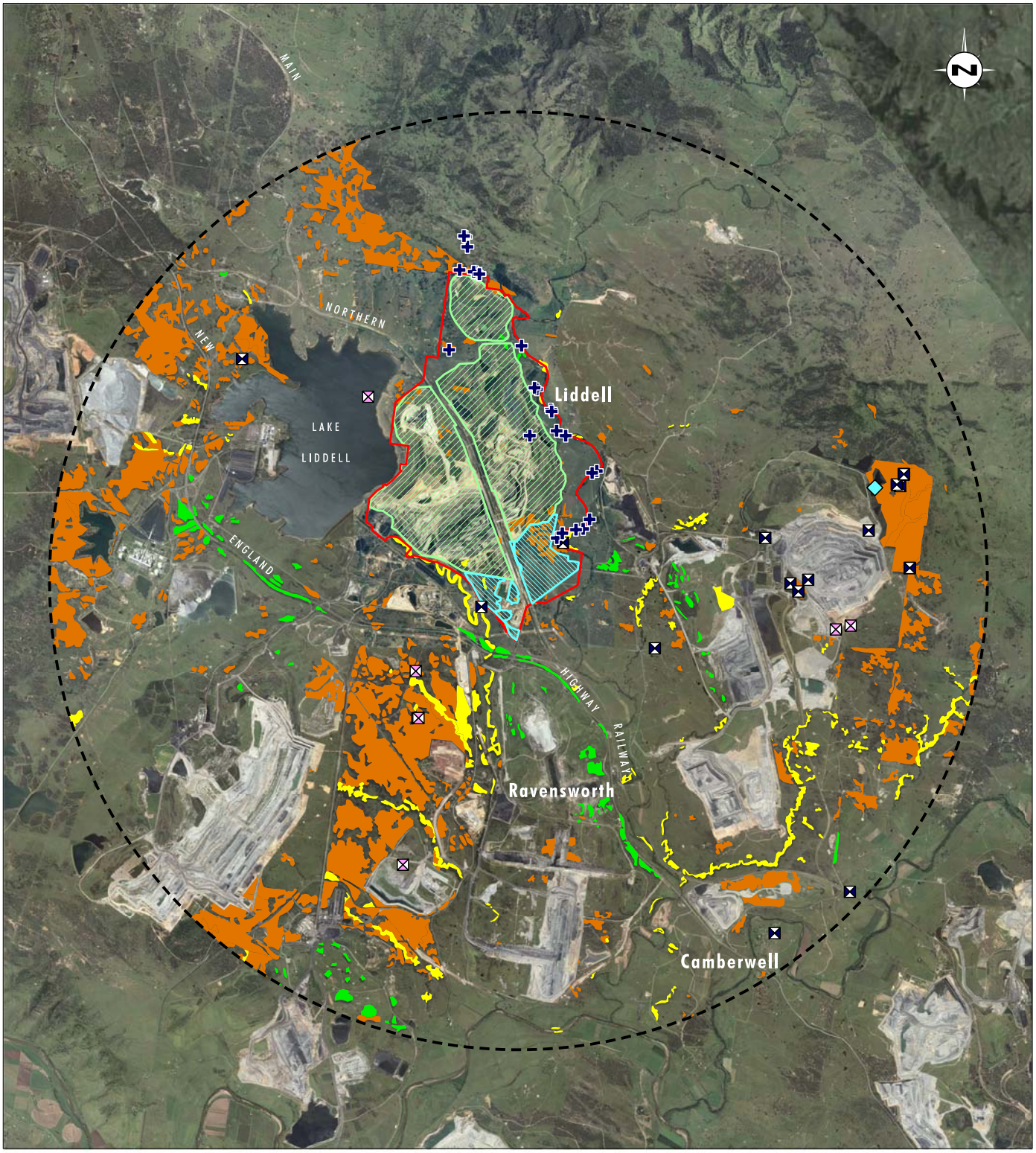



Image Source: Xstrata (2013), AAM (2012), Google Earth
Data Source: Xstrata (2012), Peake (2006)

0 2.0 4.0 6.0km
1:120 000

## Legend

- Liddell Coal Operations Approved DA Boundary
- Approved Mining Footprint
- Referral Area
- 10 Kilometer Radius of the Referral Area
- Green and Golden Bell Frog
- Other Spotted-tailed Quoll Records
- NPWS Atlas Spotted-tailed Quoll Records
- Swift Parrot
- Rehabilitation/Plantings
- Riparian Woodland/Forest (including Bullook Forest)
- Eucalypt-dominated Woodland/Forest

FIGURE 5.1

**Records of Matters of National Environmental Significance and Potential Habitat Within 10 Kilometres of Referral Area**

File Name (A4): R06/3122_075.dgn
20131204 13.59

**Table 5.1 – Protected Matters Summary Table – Matters of National Environmental Significance Recorded within a 10 Kilometre Radius of the Referral Area**

| **Threatened Ecological Communities (TECs)** | | | | | |
|---|---|---|---|---|---|
| **TECs** | **Name** | | **Status** | **Recorded in Referral Area?** | ***Recorded at LCO?** |
| | Lowland Rainforest of Subtropical Australia | | CE | No | No |
| | White Box-Yellow Box-Blakely's Red Gum Grassy Woodland and Derived Native Grassland | | CE | No | No |
| | Weeping Myall – Coobah – Scrub Wilga Shrubland | | CE | No | No |
| **Threatened Species** | | | | | |
| | **Scientific Name** | **Common Name** | **Status** | **Recorded in Referral Area?** | ***Recorded at LCO?** |
| **Flora** | **Species or Species Habitat Likely to Occur** | | | | |
| | *Eucalyptus glaucina* | Slaty red gum | V | No | No |
| | *Prasophyllum* sp. Wybong (C. Phelps ORG 5269) | A leek-orchid | CE | No | No |
| | *Thesium australe* | Austral toadflax, toadflax | V | No | No |
| | **Species or Species Habitat May Occur** | | | | |
| | *Euphrasia arguta* | | CE | No | No |
| | *Pterostylis gibbosa* | Illawarra greenhood, rufa greenhood, pouched greenhood | E | No | No |
| | *Streblus pendulinus* | Siahs backbone | E | No | No |
| | **Species Added Based on Local Records or Professional Opinion** | | | | |
| | *Bothriochloa biloba* | Lobed blue-grass | V | No | No |
| | *Ozothamnus tesselatus* | | V | No | No |
| | *Cryptostylis hunteriana* | Leafless tongue-orchid | V | No | No |
| | *Digitaria porrecta* | Finger panic grass | E | No | No |
| **Fauna** | **Species or Species Habitat Known to Occur within Area** | | | | |
| | *Erythrotriorchis radiatus* | Red goshawk | V | No | No |
| | *Petrogale penicillata* | Brush-tailed rock-wallaby | V | No | No |
| | *Phascolarctos cinereus* | Koala | V | No | No |
| | *Pseudomys novaehollandiae* | New Holland mouse | V | No | No |
| | **Foraging, Feeding or Related Behaviour known to Occur Within Area** | | | | |
| | *Pteropus poliocephalus* | Grey-headed flying-fox | V | No | No |
| | **Species or Species Habitat Likely to Occur within Area** | | | | |
| | *Lathamus discolor* | Swift parrot | E | No | No |

| | | | | | |
|---|---|---|---|---|---|
| **Threatened Ecological Communities (TECs)** | | | | | |
| | *Litoria aurea* | Green and golden bell frog | V | No | No |
| | *Pseudomys oralis* | Hastings River mouse | E | No | No |
| | **Species or Species Habitat may occur within Area** | | | | |
| | *Anthochaera phrygia* | Regent honeyeater | E/Mig | No | No |
| | *Botaurus poiciloptilus* | Australasian bittern | E | No | No |
| | *Leipoa ocellata* | Malleefowl | V/Mig | No | No |
| | *Rostratula benghalensis australis* | Australian painted snipe | E/Mig | No | Yes – Records from 2012 within 1 km of Referral Area along Bowmans Creek |
| | *Litoria booroolongensis* | Booroolong frog | E | No | No |
| | *Chalinolobus dwyeri* | Large-eared pied bat, large pied bat | V | No | No |
| | *Dasyurus maculatus maculatus* (SE mainland population) | Spot-tailed quoll, spotted-tail quoll, tiger quoll (south-eastern mainland population) | E | No | Yes – Records from 2012 within 200 m of Referral Area along Bowmans Creek. Den site also recorded in 2012, within 2 km from Referral Area along Bowmans Creek. Ongoing records in vicinity of Bowmans Creek. |
| | *Nyctophilus corbeni* (south-eastern form) | Greater long-eared bat, south-eastern long-eared bat | V | No | No |
| | **Species Added Based on Local Records or Professional Opinion** | | | | |
| | *Mixophyes balbus* | Stuttering frog | V | No | No |
| | *Mixophyes iteratus* | Giant barred frog | E | No | No |
| | *Hoplocephalus bungaroides* | Broad-headed snake | V | No | No |
| **Migratory Species** | | | | | |
| | *Ardea modesta* | Eastern great egret | Mig | No | No |
| | *Ardea ibis* | Cattle egret | Mig | No | No |
| | *Haliaeetus leucogaster* | White-bellied sea-eagle | Mig | No | No |
| | *Hirundapus caudacutus* | White-throated needletail | Mig | No | No |
| | *Apus pacificus* | Fork-tailed swift | Mig | No | No |
| | *Gallinago hardwickii* | Lathams snipe, Japanese snipe | Mig | No | No |
| | *Merops ornatus* | Rainbow bee-eater | Mig | Yes | Yes |
| | *Symposiachris trivirgatus* | Spectacled monarch | Mig | No | No |
| | *Monarcha melanopsis* | Black-faced monarch | Mig | No | No |
| | *Myiagra cyanoleuca* | Satin flycatcher | Mig | No | No |
| | *Rhipidura rufifrons* | Rufous fantail | Mig | No | No |

*Note: Recorded as part of surveys for current Proposed Action.
Status (EPBC Act): CE, Critically Endangered, E – Endangered, V, Vulnerable, MIG – Listed migratory species under the EPBC Act.

The rainbow bee-eater (*Merops ornatus*) is the only MNES that has been recorded within the Referral Area. An Assessment of Significance was completed for this species as part of the Referral process, and this concluded that the Proposed Action is unlikely to result in a significant impact on this species. This species was not specifically mentioned by DoE in their Guidelines (dated 21 October 2013) as requiring additional focus in the Preliminary Documentation.

The Australian painted snipe (*Rostratula benghalensis australis*) was recorded in 2012 within 1 km of the Referral Area along Bowmans Creek. An Assessment of Significance was completed for this species as part of the Referral process, and this concluded that the Proposed Action is not expected to have a significant impact on this species. This species was not specifically mentioned by DoE in their Guidelines (dated 21 October 2013) as requiring additional focus in the Preliminary Documentation.

The spotted-tailed quoll (*Dasyurus maculatus maculatus*) has not been recorded within the Referral Area, however has been recorded on numerous occasions in a number of areas within the LCO, particularly along Bowmans Creek. As such, considerable focus has been paid to this species as part of the Referral process. The Assessment of Significance concluded that the Proposed Action has the potential to reduce the area of occupancy of this species and had a real chance or possibility to disrupt the breeding cycle of a local population. This species was specifically mentioned by DoE in their Guidelines (dated 21 October 2013) as requiring additional focus in the Preliminary Documentation, as such has been addressed in detail in the remainder of this document.

### 5.3.1 Matters of National Environmental Significance Recorded within the Referral Area

None of the MNES specifically mentioned in the Department's Decision on Referral letter dated 21 October 2013, or attached Guidelines (being the regent honeyeater, swift parrot, spotted-tailed quoll, large-eared pied bat and green and golden bell frog) have been recorded within the Referral Area during surveys for the Proposed Action or for previous projects or ecological monitoring.

The only MNES that has been recorded in the Referral Area is the rainbow bee-eater (*Merops ornatus*).

### 5.3.2 Matters of National Environmental Significance Recorded within LCO

Of the specifically mentioned MNES (being the regent honeyeater, swift parrot, spotted-tailed quoll, large-eared pied bat and green and golden bell frog), the spotted-tailed quoll is the only one that has been recorded within the LCO Development Consent Boundary.

The rainbow bee-eater (*Merops ornatus*) and Australian painted snipe (*Rostratula benghalensis australis*) have also been recorded within the LCO Development Consent Boundary.

### 5.3.3 Matters of National Environmental Significance Recorded within 10 Kilometre Radius of the Referral Area

The following sections document the known records of each of the specifically mentioned MNES within a 10 kilometre radius of the Referral Area, based on records from the OEH Atlas of NSW Wildlife (coordinate-based records as mapped on **Figure 5.1**) and the Department of the Environment Protected Matters Database (which does not provide coordinate-based records). A summary of the records of each species is provided in the sections below.

#### 5.3.3.1 Regent Honeyeater (*Anthochaera phrygia*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, the broader LCO holdings or the nearby Mount Owen Complex, despite annual ecological survey and/or monitoring occurring since 2001.

There are no records of this species within a 10 kilometre radius of the Referral Area (OEH Atlas of NSW Wildlife), however the Protected Matters Search Tool identifies that foraging, feeding or related behaviour is likely to occur within a 10 kilometre radius of the Referral Area.

#### 5.3.3.2 Swift Parrot (*Lathamus discolor*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, or the broader LCO holdings, despite annual ecological survey and/or monitoring occurring since 2001.

The swift parrot has been recorded on two occasions (2005 and 2007) in the vicinity of the Mount Owen Complex within Ravensworth State Forest (See **Figure 5.1**). There have been few records of the species within the central Hunter Valley in the past few years, however recent sightings have been recorded in the winter 2012 season in the Muswellbrook and Bulga areas (Birdline NSW 2012, Umwelt 2012 unpublished).

There are two records of this species within a 10 kilometre radius of the Referral Area (being those discussed above) (OEH Atlas of NSW Wildlife), and the Protected Matters Search Tool identifies that the species or species habitat is likely to occur within a 10 kilometre radius of the Referral Area.

#### 5.3.3.3 Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)

The species has not been recorded in the Referral Area. There are a number of records of this species in the general locality (defined here as the middle Foy Brook area, which comprises the land to the east and north-east of Lake Liddell and to the north of the New England Highway), including records from within the current LCO development consent boundary, the Ravensworth Operations Hillcrest Offset Site and regular records nearby at the Mount Owen Complex.

At least six distinct individuals have been identified from the various captures, photographs and radio-tracking of this species that has occurred within the LCO, Mount Owen Complex and Mountain Block sites. Known individuals include one breeding female with her two joeys (sex undetermined), one male that was radio-tracked at the Mount Owen Complex and at least two other distinct males.

There are 24 records of this species within a 10 km radius of the Referral Area (see **Figure 5.1**) (OEH Atlas of NSW Wildlife), and the Protected Matters Search Tool identifies that the species or species habitat is known to occur within a 10 km radius of the Referral Area.

#### 5.3.3.4 Green and Golden Bell Frog (*Litoria aurea*)

The species has not been recorded in the Referral Area, or within the LCO Development Consent Boundary. It has been recorded in the Mount Owen Complex on four occasions over a 15 year period, with the last confirmed record from 1999 (Forest Fauna Surveys and Newcastle Innovation 2012) (see **Figure 5.1**). The Mount Owen Complex forms part of the Upper Hunter Green and Golden Bell Frog Key Population consisting of one main diffuse population at, or in the vicinity of, the Ravensworth and Liddell area and bordering areas of the Singleton and Muswellbrook local government areas (DECC 2007). The Upper Hunter Key Population is one of two described inland populations of the species and is known from eight verified locations. The population is assumed to have a diffuse distribution across lands encompassed by these locations and has been recorded sporadically, probably caused by climatic circumstances and/or seasonal life cycle changes of the species (DECC 2007).

It is considered highly likely that the precipitous state of the Upper Hunter population is directly due to the impact of disease rather than habitat or other ecological factors (Forest Fauna Surveys and Newcastle Innovation 2011).

An unconfirmed record of the species exists from the north-east shore of Lake Liddell in 2006 (DECC 2007), and the species was recorded during surveys for the Ravensworth North Project in 2009.

There are seven records of this species within a 10 kilometre radius of the Referral Area (OEH Atlas of NSW Wildlife), and the Protected Matters Search Tool identifies that the species or species habitat is likely to occur within a 10 km radius of the Referral Area.

#### 5.3.3.5 Large-eared Pied Bat (*Chalinolobus dwyeri*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, or the broader LCO holdings, despite many years of ecological survey and monitoring.

The large-eared pied bat has been recorded through analysis of echolocation calls on four occasions during monitoring of Mount Owen Complex (Forest Fauna Surveys and Newcastle Innovation 2012). All of these identifications have been deemed as “possible” only; there have been no confirmed records of this species from this monitoring.

There are no records of this species within a 10 kilometre radius of the Referral Area (OEH Atlas of NSW Wildlife), however the Protected Matters Search Tool identifies that this species or species habitat may occur within a 10 kilometre radius of the Referral Area.

## 5.4 Nature, Location and Extent of Threatened Species and Ecological Communities and their Suitable Habitat (including Breeding, Foraging and Roosting Habitat, and Habitat Critical to the Survival of Threatened Species) within the Referral Area and in Surrounding Areas

### 5.4.1 Vegetation Communities Mapped within the Referral Area

#### 5.4.1.1 Vegetation Types and Areas

**Table 5.2** below summarises the vegetation communities mapped within the Referral Area by Umwelt, following consideration of the field data collected by ELA in 2011 and the conduct of verification surveys by Umwelt in 2012. Vegetation communities mapped in the Referral Area are provided in **Figure 6.1**. All of this vegetation will be impacted as part of the Proposed Action.

**Table 5.2 – Vegetation Communities Occurring in the Referral Area**

| Community | Status | Extent in Referral Area (ha) |
|---|---|---|
| Central Hunter Box – Ironbark Woodland | EEC (TSC) | 20 |
| Central Hunter Box – Ironbark Woodland (Rough-barked Apple dominated) | EEC (TSC) | 1 |
| Central Hunter Box – Ironbark Woodland (Regrowth) | EEC (TSC) | 33 |
| Central Hunter Box – Ironbark Derived Native Grassland | - | 59 |
| Central Hunter Swamp Oak Forest | - | 5 |
| Central Hunter Bulloak Forest Regeneration | - | 62 |
| Disturbed Land | - | 5 |
| **Total** | | **185** |

TSC – listed under the NSW *Threatened Species Conservation Act 1995*

Note: All values have been rounded up to the nearest whole number. All values subject to minor mapping/GIS-based variation.

#### 5.4.1.2 Vegetation Community Descriptions including Species Composition

Descriptions of each of the vegetation communities recorded in the Referral Area are provided below. These descriptions draw upon data obtained during field surveys and also from information contained within Peake (2006).

**Central Hunter Box – Ironbark Woodland Variants**

Four variations of this vegetation community were recorded within the Referral Area and are listed below:

- Central Hunter Box – Ironbark Woodland;
- Central Hunter Box – Ironbark Woodland (Rough-barked Apple dominated);
- Central Hunter Box – Ironbark Woodland (Regrowth); and
- Central Hunter Box – Ironbark Derived Native Grassland (DNG).

**Central Hunter Box – Ironbark Woodland**

The Referral Area contains 20 hectares of this vegetation type. This vegetation community is generally consistent with that described by Peake (2006). The pockets of woodland were dominated entirely by narrow-leaved ironbark (*Eucalyptus crebra*) and formed a mid-high canopy (also seen to be actively recruiting) (**Plate 5.1**). No mature grey box (*Eucalyptus moluccana*) or kurrajong (*Brachychiton populneus* subsp. *populneus*) trees were recorded in this community, however there is a potential for these to occur. A mid to dense sub-canopy of bulloak (*Allocasuarina luehmannii*) was generally recorded within the community.

The understorey of this vegetation community was somewhat variable. A sparse to mid-dense small shrub layer was present, with dominant species including leafy templetonia (*Templetonia stenophylla*), gorse bitter pea (*Daviesia ulicifolia*) and Narrawa burr (*Solanum cinereum*). Native grasses, barbed wire grass (*Cymbopogon refractus*), speargrass (*Austrostipa scabra*), *Rytidosperma tenuius* and slender bamboo grass (*Austrostipa verticillata*) were common throughout the ground layer.

The Central Hunter Box – Ironbark Woodland vegetation community conforms to the Central Hunter Grey Box – Ironbark Woodland in the NSW North Coast and Sydney Basin Bioregions EEC listing under the TSC Act. The relevant attributes described within the NSW Scientific Committee – final determination for the EEC that are consistent with the vegetation community within the Referral Area include flora species composition, flora species assemblages and the location of the vegetation.

Central Hunter Box – Ironbark Woodland recorded within the Referral Area included a narrow-leaved ironbark (*Eucalyptus crebra*) dominated canopy layer with rough-barked apple (*Angophora floribunda*) and bulloak (*Allocasuarina luehmannii*) also occurring as sparse canopy trees and/or sub-canopy trees. Many sub-shrub and ground layer forb and grass species identified in a brief list of characteristic flora species within the final determination were also common throughout the Central Hunter Box – Ironbark Woodland community in the Referral Area and are listed in the text above. This community does not conform to any EPBC Act listed TECs.

This community has been specifically separated from the areas of Central Hunter Bulloak Forest, which had a similar group of shrub and grass species (albeit significantly lower in foliage cover) occurring in the understorey, because of the dominance of narrow-leaved ironbark (*Eucalyptus crebra*) in the canopy. Alternatively, the Central Hunter Bulloak Forest vegetation community is essentially absent of narrow-leaved ironbark (*Eucalyptus crebra*) trees or recruiting plants. This community is

described in more detail below. These two communities were separated through analysis of field data recorded during the field survey and aerial photography interpretation.

The young age and small number of mature trees recorded in the canopy the Central Hunter Box – Ironbark Woodland vegetation community suggests that the area has been subject to clearing previously. Despite the vegetation recovering well, the impacts are still noticeable, particularly in the understorey. Species diversity in the sub-shrub and ground layer is typically much higher that what was recorded by ELA during 2011 and Umwelt (2012). For this reason the quality of this vegetation community is considered to be moderate.

**Central Hunter Box – Ironbark Woodland (Rough-barked Apple dominated)**

The Referral Area contains 1 hectare of this vegetation community. Also consistent with the Central Hunter Box – Ironbark Woodland described by Peake (2006), this vegetation community had an open mid-high canopy dominated by rough-barked apple (*Angophora floribunda*) (**Plate 5.2**). It occurred on a south facing slope in the central part of the Referral Area. As an open woodland, the cover of rough-barked apple (*Angophora floribunda*) and bulloak (*Allocasuarina luehmannii*) in the sub-canopy was less than 10 per cent.

A sparse low-shrub layer of cooba (*Acacia salicina*), blue trumpet (*Brunoniella australis*) and *Pimelea* sp. was recorded and appear to be restricted to this community. The introduced shrub species, African olive (*Olea europaea* subsp. *cuspidata*), was also recorded.

The understorey consisted of a mid-dense cover of indigenous grasses in the ground layer, including the dominant species barbed wire grass (*Cymbopogon refractus*), couch (*Cynodon dactylon*), slender bamboo grass (*Austrostipa verticillata*) and purple wiregrass (*Aristida ramosa*). Native forb species were very uncommon in this community, consisting of *Glycine tabacina* and kidney weed (*Dichondra repens*). Additionally, a sparse cover of introduced flora species was also recorded in the ground layer, including flatweed (*Hypochaeris radicata*), fireweed (*Senecio madagascariensis*), *Petrorhagia velutina*, spear thistle (*Cirsium vulgare*) and *Centaurium tenuiflorum*.

This vegetation community has been mapped as a variant of the widely distributed Central Hunter Box – Ironbark Woodland (see **Figure 6.1**). As previously discussed, narrow-leaved ironbark (*Eucalyptus crebra*) is absent from the canopy and is replaced by rough-barked apple (*Angophora floribunda*). The NSW Scientific Committee's Final Determination makes specific mention of this species, as well as grey box (*Eucalyptus moluccana*), occurring and occasionally dominating or co-dominating the canopy. Therefore, this community is also considered to conform to the Central Hunter Grey Box – Ironbark Woodland EEC listed under the TSC Act. This community does not conform with any EPBC Act listed TECs.

The vegetation in this community has been subject to clearing in the past and as a result, primarily consists of younger trees with little mature vegetation present. Vegetation within this community is considered to be resilient, as seen by the diversity and density of groundcover and shrub layers, and of moderate quality.

**Central Hunter Box – Ironbark Woodland (Regrowth)**

The Referral Area contains 33 hectares of this vegetation community. This community comprised an open young tree canopy of narrow-leaved ironbark (*Eucalyptus crebra*) and bulloak (*Allocasuarina luehmannii*), typically less than 8 metres in height (**Plate 5.3**). It occurred as a transitional community between Central Hunter Box – Ironbark Woodland, Central Hunter Box – Ironbark DNG and Central Hunter Bulloak Forest, as shown on **Figure 6.1**.

Mature narrow-leaved ironbark (*Eucalyptus crebra*) and bulloak (*Allocasuarina luehmannii*) trees were effectively absent from this variant in comparison to surrounding stands of woodland and forest. However, the degree of recruitment of the canopy species was noticeably higher in this variant.

The community supports by a mid-dense ground layer of indigenous grasses dominated by barbed wire grass (*Cymbopogon refractus*), purple wiregrass (*Aristida ramosa*) and speargrass (*Austrostipa scabra*). Forb and fern species were less prevalent however common species included kidney weed (*Dichondra repens*), *Cheilanthes sieberi* subsp. *sieberi* and common everlasting (*Chrysocephalum apiculatum*). Introduced flora species were widespread in the ground layer with spear thistle (*Cirsium vulgare*), fireweed (*Senecio madagascariensis*), galenia (*Galenia pubescens*), Paddys lucerne (*Sida rhombifolia*) and barley grass (*Hordeum leporinum*) commonly occurring. Additionally, rocky outcrops were common on the tops of small rises within this community.

Central Hunter Box – Ironbark Woodland (Regrowth) is also considered to conform to the TSC Act listed Central Hunter Grey Box – Ironbark Woodland EEC. This community does not conform with any EPBC Act listed TECs.

The impacts of historical clearing are more evident within the Central Hunter Box – Ironbark Woodland (Regrowth) vegetation community due to the reduced presence of mature trees. The reduced presence of mature narrow-leaved ironbark (*Eucalyptus crebra*) and bulloak (*Allocasuarina luehmannii*) trees reduces the quality of the vegetation to low.

**Central Hunter Box – Ironbark Derived Native Grassland**

The Referral Area contains 59 hectares of this vegetation community. Cleared of all mature trees and shrubs, this community occurs in the form of derived native grassland (DNG) (**Plate 5.4**). Regenerating narrow-leaved ironbark (*Eucalyptus crebra*) and bulloak (*Allocasuarina luehmannii*) occurred but contributed less than 5 per cent foliage cover across the community.

The understorey of the Central Hunter Box – Ironbark DNG community was very similar in composition to that of Central Hunter Box – Ironbark Woodland (Regrowth). The community was characterised by a dense cover of indigenous grasses with barbed wire grass (*Cymbopogon refractus*), purple wiregrass (*Aristida ramosa*) and speargrass (*Austrostipa scabra*) being prominent. Forb and fern species were common but low in cover and dominant species included kidney weed (*Dichondra repens*), *Cheilanthes sieberi* subsp. *sieberi* and common everlasting (*Chrysocephalum apiculatum*).

The proportion of introduced flora species within the community varied from sparse to dense. These variations occurred at a smaller scale than was feasible to map as separate communities. Dominant weeds within the Central Hunter Box – Ironbark DNG community included barley grass (*Hordeum leporinum*), Paddys lucerne (*Sida rhombifolia*), fireweed (*Senecio madagascariensis*), galenia (*Galenia pubescens*) and creeping pear (*Opuntia humifusa*).

Central Hunter Box – Ironbark DNG is closely related to Central Hunter Box – Ironbark Woodland, as it is likely to have been derived from this community. Unlike its parent woodland community Central Hunter Box – Ironbark Woodland, the DNG community is not considered to conform to the TSC Act listed Central Hunter Grey Box – Ironbark Woodland EEC. The species composition in the ground layer is typically consistent with the community description; however the NSW Scientific Committee's final determination for the EEC does not identify grassland variations as part of the EEC. The Final Determination states:

> Central Hunter Grey Box – Ironbark Woodland typically forms a woodland dominated by Eucalyptus crebra (Narrow-leaved Ironbark), Brachychiton populneus subsp. populneus (Kurrajong) and Eucalyptus moluccana (Grey Box).

The NSW Scientific Committee does not specifically identify grassland forms as being included within the EEC final determination and while it is noted that DNGs may have potential to regenerate to be consistent with the Central Hunter Grey Box – Narrow-leaved Ironbark Woodland EEC, grassland areas are not explicitly covered by the EEC listing and are not considered to form part of the EEC. Therefore, it is considered that Central Hunter Box – Ironbark DNG does not conform to any EEC listed under the TSC Act and similarly does not conform to any TECs listed under the EPBC Act.

The quality of the Central Hunter Box – Ironbark DNG vegetation community is considered to be low. It is somewhat degraded as a result of grazing and subsequently is dominated by introduced species. This community has recovered the least from historical clearing out of all woodland vegetation communities in the Referral Area.

**Central Hunter Bulloak Forest**

The Referral Area contains 62 hectares of this vegetation community. Central Hunter Bulloak Forest occurred throughout the Referral Area and occupied similar landscapes to Central Hunter Box – Ironbark Woodland (refer to **Figure 6.1**). Two sub-communities were present, being Central Hunter Bulloak Forest and Central Hunter Bulloak Forest (regrowth). Peake (2006) describes a community consistent with that mapped in the Referral Area of the same name i.e. Central Hunter Bulloak Forest.

Central Hunter Bulloak Forest consists of a dense canopy of both young and mature bulloak (*Allocasuarina luehmannii*) (**Plate 5.5**). Mature bulloak (*Allocasuarina luehmannii*) trees occur within this vegetation community, however they are uncommon. Likewise, young narrow-leaved ironbark (*Eucalyptus crebra*) trees occurred in the canopy but at very low frequency (i.e. not co-dominant).

Central Hunter Bulloak Forest was characterised by a very sparse understorey. With the exception of heavily recruiting bulloak (*Allocasuarina luehmannii*) and the occasional leafy templetonia (*Templetonia stenophylla*) and dolly bush (*Cassinia aculeata*), the shrub layer was virtually absent. The ground layer was highly variable, ranging from completely bare soil and organic bulloak needle material to a variable cover of grasses and forbs. Where present, grasses were dominated by barbed wire grass (*Cymbopogon refractus*), purple wiregrass (*Aristida ramosa*), slender bamboo grass (*Austrostipa verticillata*), *Rytidosperma tenuius*, wallaby grass (*Rytidosperma fulvum*) and red grass (*Bothriochloa decipiens*). The following indigenous forb species also occurred in low numbers: lemon beauty heads (*Calocephalus citreus*), *Glycine tabacina*, *Cheilanthes sieberi* subsp. *sieberi* and yellow burr-daisy (*Calotis lappulacea*).

Additionally, several introduced flora species also occurred in low numbers through this community including creeping pear (*Opuntia humifusa*), tiger pear (*Opuntia aurantiaca*), fireweed (*Senecio madagascariensis*) and onion grass (*Romulea rosea*).

The Central Hunter Bulloak Forest (regrowth) variation consists of the same species assemblages as the Central Hunter Bulloak Forest community. The characteristic differences between the two communities are that the regrowth variant has a younger, lower and more open canopy. In turn, this contributes to an understorey of greater foliage cover.

Central Hunter Bulloak Forest and its regrowth do not conform with any TSC Act or EPBC Act TECs.

The habitat quality in both the Central Hunter Bulloak Forest and its regrowth variant is considered to be low. There were very few mature bulloak (*Allocasuarina luehmannii*) trees observed and the understorey vegetation strata remains modified as a result of historical clearing.

**Central Hunter Swamp Oak Forest**

The Referral Area contains 5 hectares of this vegetation community. The Central Hunter Swamp Oak Forest mapped within the Referral Area occurred along Chain of Ponds Creek, a tributary of Bayswater Creek in the south west of the Referral Area (refer to **Figure 6.1**). The community is consistent with Central Hunter Swamp Oak Forest as described by Peake (2006).

The canopy was dense and dominated by swamp oak (*Casuarina glauca*) to a height of approximately 18 metres (**Plate 5.6**), with an emergent forest red gum (*Eucalyptus tereticornis*) occasionally recorded. Shrubs were generally absent from this community; however introduced species such as African boxthorn (*Lycium ferocissimum*) were recorded.

The ground cover vegetation was generally dense and dominated by grasses, forbs and ferns such as weeping grass (*Microlaena stipoides* var. *stipoides*), whiteroot (*Pratia purpurascens*), slender bamboo grass (*Austrostipa verticillata*), kidney weed (*Dichondra repens*), climbing saltbush (*Einadia nutans*) and *Glycine tabacina*. Introduced species such as galenia (*Galenia pubescens*), *Juncus acutus* and fireweed (*Senecio madagascariensis*) were commonly recorded in the understorey.

As the Central Hunter Swamp Oak Floodplain Forest supports mature swamp oak (*Casuarina glauca*) trees, as well as some mature forest red gum (*Eucalyptus tereticornis*) trees it is considered to be of moderate habitat quality. Despite the relatively disturbed understorey this community is unlikely to have been cleared to the same extent as the remaining vegetation within the Referral Area.

The Central Hunter Swamp Oak Forest present in the Referral Area does not conform to the Swamp Oak Floodplain Forest EEC. Although the particular area of the EEC, and some of the supplementary descriptors, presented in the Final Determination are inclusive of the EEC's presence, the EEC can be ruled out on the following points: a) partly based on the clear intent of the Scientific Committee in limiting the EEC's occurrence to 'rarely above 10 metres elevation'; and b) firmly based on the very restricted number of species listed in the Final Determination that are present at the site (being about 10 per cent).

**Disturbed Land**

Disturbed Land included roads, water management infrastructure and surface infrastructure areas and did not contain any vegetation or habitat. Approximately 5 hectares of the Referral Area comprises Disturbed Land.

#### 5.4.1.3 Habitat Descriptions

**Woodland/Forest Habitat**

A total of 116 hectares of woodland/forest habitat is present in the Referral Area. This habitat typically consisted of dense bulloak (*Allocasuarina luehmannii*) vegetation with some smaller areas dominated by narrow-leaved ironbark (*Eucalyptus crebra*) and occasionally rough-barked apple (*Angophora floribunda*).

Woodland vegetation typically consisted of middle-aged and regrowth trees that were generally too young to have developed hollows. Mature trees were generally scarce, however when present typically provided numerous hollow resources. Stags with small trunk diameters (at breast height) (<20 centimetres) were common throughout this vegetation community and are likely to provide roosting resources for hollow-dwelling micro-bat species. Hollows identified in this formation were rarely large (>30 centimetres) and were most likely to be suitable for small parrots, micro-bats and other smaller arboreal mammals.

Minimal areas of rock on rock habitat, termite mounds or logs were identified, and no rock overhangs, or caves were present. Known cockatoo feed trees bulloak (*Allocasuarina luehmannii*) were abundant throughout this formation.

Little dieback or mistletoe was observed in this woodland habitat formation. Slight grazing pressure from kangaroos and wallabies and a slight level of weed infestation (dominated by tiger pear (*Opuntia aurantiaca*) and creeping pear (*Opuntia humifusa*)) was identified. No evidence of rubbish dumping was recorded. Woodland habitats were typically characterised by gentle (0 to 5 degrees) sloping terrain.

Connectivity between vegetation remnants within the Referral Area and with vegetated areas outside of the Referral Area is considered to be poor.

**Riparian Forest Habitat**

A total of 5 hectares of riparian forest habitat was present in the Referral Area consisting of dense swamp oak (*Casuarina glauca*) with the occasional emergent forest red gum (*Eucalyptus tereticornis*). A moderate extent of mistletoe infestation was identified in this habitat formation.

Tree hollows were present infrequently in middle-aged and mature trees. No large (>30 centimetres) tree hollows were identified and the smaller hollows typically present are likely to primarily provide habitat for hollow-roosting micro-bat species. Hollows occurred in both living and dead trees. Stags (dead standing trees) were scarce in this formation.

The shrub layer ranged between 1 and 2 metres in height and contained low species diversity and a low structural diversity. African boxthorn (*Lycium ferocissimum*) was a commonly recorded shrub species in the community. Log cover (fallen trees and branches) was absent to scarce.

Swamp oak (*Casuarina glauca*) (potential cockatoo feed tree) was abundant throughout this formation. No other specific habitat features were recorded in this habitat formation.

Riparian woodland habitat occurred along ephemeral creeks and drainage lines which when flowing would provide a drinking resource for fauna species.

Riparian habitats in the east of the Referral Area appeared to be generally subject to erosion.

**Grassland Habitat**

A total of 59 hectares of grassland habitat was identified in the Referral Area. Canopy and shrub layers were generally absent from this community, although isolated paddock trees and areas of regenerating eucalypts and shrubs occasionally occurred. Most woody vegetation had been previously cleared for agricultural purposes.

The large areas of open grassland provide a foraging resource for macropods and a hunting resource for owls and micro-bats. Small mammals such as antechinus (*Antechinus* spp.) are provided foraging habitat as well as refuge habitat within the dense grass layers. This habitat type also provides foraging and refuge habitat for a number of reptile species and amphibians.

Few logs were present though hollows were usually present in the sparse large stags and remnant old growth trees.

### 5.4.2 Quantification of the Extent (in Hectares) and Quality of Habitat

The following sections document the extent and quality of habitat (to the fullest extent known) for the specified MNES within the Referral Area, and the surrounding areas. This is based on data collected within the Referral Area, and other parts of LCO, however is estimated as best as possible for the remainder of the 10 kilometre radius (surrounding vegetation) where data is largely absent. In this case, this information has been based in part on the Peake (2006) vegetation mapping for the area, extracting vegetation that has been cleared since the mapping was completed (e.g. for mining purposes) (see **Figure 5.1**). For the purposes of this assessment, this vegetation has been broadly categorised into the following habitat types:

- Riparian Woodland/Forest (including Bulloak Forest);
- Eucalypt-dominated Woodland/Forest;
- Grassland; and
- Rehabilitation/Plantings.

An assessment and justification of the quality of the habitat within the Referral Area for the key MNES is provided in **Table 5.3** below. The justification of habitat quality is based on the habitat descriptions provided above, tailored to the key habitat requirements of the relevant species.

**Table 5.3 – Habitat Quality in the Referral Area for MNES**

| MNES and Key Habitat Attributes Required | Habitat Type/Formation | Area (Hectares) in Referral Area | Habitat Quality | Justification |
|---|---|---|---|---|
| Regent honeyeater (*Anthochaera phrygia*)<br><br>Winter-flowering eucalypts, particularly mature vegetation with mass-flowering. | Woodland/Forest | 116 | Marginal | Typically consists of dense bulloak (*Allocasuarina luehmannii*). Small areas dominated by narrow-leaved ironbark (*Eucalyptus crebra*) (winter-flowering) and occasionally rough-barked apple (*Angophora floribunda*) (spring/summer flowering). Comprises generally middle-aged and regrowth trees, and mature trees more likely to support mass-flowering events are generally scarce. |
| | Riparian Forest | 5 | Poor | A dense community of swamp oak (*Casuarina glauca*) with only occasional forest red gum (*Eucalyptus tereticornis*) (winter-flowering). |
| | Grassland | 59 | Poor | Canopy and shrub layers generally absent, apart from isolated paddock trees or small areas of regenerating eucalypts or shrubs. |
| Swift parrot (*Lathamus discolor*)<br><br>Winter-flowering eucalypts, particularly mature vegetation with mass-flowering. | Woodland/Forest | 116 | Marginal | Typically consists of dense bulloak (*Allocasuarina luehmannii*). Small areas dominated by narrow-leaved ironbark (*Eucalyptus crebra*) (winter-flowering) and occasionally rough-barked apple (*Angophora floribunda*) (spring/summer flowering).<br>Comprises generally middle-aged and regrowth trees, and mature trees more likely to support mass-flowering events are generally scarce. |
| | Riparian Forest | 5 | Poor | A dense community of swamp oak (*Casuarina glauca*) with only occasional forest red gum (*Eucalyptus tereticornis*) (winter-flowering). |
| | Grassland | 59 | Poor | Canopy and shrub layers generally absent, apart from isolated paddock trees or small areas of regenerating eucalypts or shrubs. |
| Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*) | Woodland/Forest | 116 | Moderate | Dense bulloak (*Allocasuarina luehmannii*) with small areas dominated by narrow-leaved ironbark (*Eucalyptus crebra*) and occasionally rough-barked apple |

| | | | | |
|---|---|---|---|---|
| Terrestrial habitat complexity for prey species, denning opportunities in fallen timber, large hollows or rocky areas/overhangs | | | | (*Angophora floribunda*).<br>Generally middle-aged and regrowth trees, most too young for hollows. Mature trees are scarce, however when present often provide multiple hollows. Hollows were rarely large (>30 centimetres). Minimal areas of rock on rock habitat, termite mounds or logs, and no rock overhangs, or caves were present. |
| | Riparian Forest | 5 | Moderate | Generally dense swamp oak (*Casuarina glauca*) with occasional forest red gum (*Eucalyptus tereticornis*). Hollows uncommon. No large (>30 centimetres) hollows. Low species and structural diversity in shrub layer. Fallen timber scarce. No other specific habitat features were recorded in this habitat formation. |
| | Grassland | 59 | Moderate/Poor | Canopy and shrub layers generally absent, except for occasional isolated trees or small areas of regenerating vegetation. The dense grass layers provide some habitat complexity, however very little fallen timber, rock or other terrestrial habitat other than grass cover. |
| Green and golden bell frog (*Litoria aurea*)<br><br>Aquatic habitat with fringing vegetation, connectivity and structural complexity. | Woodland/Forest | 116 | Poor | Four, isolated poor quality farm dams only. |
| | Riparian Forest | 5 | Moderate | Aquatic habitat within riparian zone poor, highly ephemeral with poor water quality. |
| | Grassland | 59 | Poor | Isolated poor quality farm dams only. |
| | Aquatic Habitat | <0.5 | Marginal | Restricted to highly ephemeral drainage lines and four farm dams. Drainage lines had deeply incised banks and very little flow at time of survey. Riparian vegetation dominated by grasses and sedges including exotic weeds. Farm dams are generally small and habitat quality varied from low (no emergent or bank vegetation) to moderate (with emergent and bank vegetation). No dams considered as good amphibian habitat. |
| Large-eared pied bat (*Chalinolobus dwyeri*)<br><br>Caves for roosting/breeding. Vegetation to forage for insects within/over. | Woodland/Forest | 116 | Moderate | Dense bulloak (*Allocasuarina luehmannii*) with small areas dominated by narrow-leaved ironbark (*Eucalyptus crebra*) and occasionally rough-barked apple (*Angophora floribunda*). Generally middle-aged and regrowth trees, most too young to have developed hollows. No rock overhangs, or caves present. |
| | Riparian Forest | 5 | Moderate | Dense swamp oak (*Casuarina glauca*) with occasional forest red gum (*Eucalyptus tereticornis*). |

| | | | | |
|---|---|---|---|---|
| | | | | Hollows uncommon. Low species and structural diversity in shrub layer. |
| | Grassland | 59 | Poor | Canopy and shrub layers generally absent, apart from isolated paddock trees or small areas of regenerating eucalypts or shrubs. |

#### 5.4.2.1 Regent honeyeater (*Anthochaera phrygia*)

**Table 5.4 – Habitat for the Regent Honeyeater**

| Habitat Type (Quality) | Within Referral Area (ha) | Surrounding vegetation (within 10 Kilometre Radius of Referral Area) (ha) |
|---|---|---|
| Eucalypt-dominated Woodland/Forest (Marginal) | 54 | 3,854 |
| **TOTAL** | **54** | **3,854** |

The eucalypt-dominated habitat within the Referral Area and surrounding vegetation is likely to comprise foraging habitat only for this species, as there are no confirmed breeding sites within the broader 10 kilometre radius. This species has been recorded breeding very irregularly within the lower Hunter Valley at Kurri Kurri and Quorrobolong, however these records are not within the core breeding areas for this species (Chiltern, Capertee Valley and Inverell/Barraba) and as such are deemed unusual for this species.

In relation to quality of habitat, the 54 hectares of eucalypt-dominated vegetation within the Referral Area has been assessed as being of marginal quality only for this species, as this vegetation has been previously cleared and is generally young in age with few mature trees present. The only winter-flowering eucalypt in the Referral Area is narrow-leaved ironbark (*Eucalyptus crebra*), which only dominates in the Central Hunter Box Ironbark Woodland community (20 ha) in the Referral Area. The young age and small number of mature trees recorded in this community suggests previous clearing, reducing the likelihood of mass-flowering events or high nectar loads. A large component of this 54 hectares (being 33 hectares) is a Regrowth variant, with an open young canopy of less than 8 metres in height. It is unlikely that such young vegetation would flower in 'mass events' sufficient to attract this species to the site, or produce sufficient resources to make this vegetation important to the species.

The vegetation within a 10 kilometre radius of the Referral Area is likely to contain higher quality foraging habitat for this species, particularly within conservation areas, however is likely to also contain substantial amounts of highly modified or regrowth vegetation, similar to that within the Referral Area.

#### 5.4.2.2 Swift parrot (*Lathamus discolor*)

**Table 5.5 – Habitat for the Swift Parrot**

| Habitat Type (Quality) | Within Referral Area (ha) | Surrounding Vegetation (within 10 Kilometre Radius of Referral Area) (ha) |
|---|---|---|
| Eucalypt-dominated Woodland/Forest (Marginal) | 54 | 3,854 |
| **TOTAL** | **54** | **3,854** |

The eucalypt-dominated habitat within the Referral Area and broader 10 kilometre radius comprises foraging habitat only for this species, as this species does not breed on the Australian mainland.

In relation to quality of habitat, the 54 hectares of eucalypt-dominated vegetation within the Referral Area has been assessed as being of marginal quality only for this species, as this vegetation has been previously cleared and is generally young in age with few mature trees present. The only winter-flowering eucalypt in the Referral Area is narrow-leaved ironbark (*Eucalyptus crebra*), which only dominates in the Central Hunter Box Ironbark Woodland community (20 ha) in the Referral Area. The young age and small number of mature trees recorded in this community suggests previous clearing, reducing the likelihood of mass-flowering events or high nectar loads. A large component of this 54 hectares (being 33 hectares) is a Regrowth variant, with an open young canopy of less than 8 metres in height. It is unlikely that such young vegetation would flower in 'mass events' sufficient to attract this species to the site, or produce sufficient resources to make this vegetation important to the species.

The vegetation within a 10 kilometre radius of the Referral Area is likely to contain higher quality foraging habitat for this species, particularly within conservation areas, however is likely to also contain substantial amounts of highly modified or regrowth vegetation, similar to that within the Referral Area.

#### 5.4.2.3 Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)

**Table 5.6 – Habitat for the Spotted-tailed Quoll**

| Habitat Type (Quality) | Within Referral Area (ha) | Surrounding Vegetation (within 10 Kilometre Radius of Referral Area) (ha) |
|---|---|---|
| Eucalypt-dominated Woodland/Forest (Moderate) | 54 | 3,854 |
| Riparian Woodland/Forest (including Bulloak Forest) (Moderate) | 67 | 356 |
| Grassland (Marginal/Low) | 59 | 18,580 |
| Rehabilitation/Plantings (Moderate) | 0 | 1,414 |
| **TOTAL** | **180** | **24,204** |

This species is known to use a variety of habitat types in the local area, including known local records from forest/woodland (eucalypt-dominated and riparian), grassland and rehabilitation.

For the purposes of impact assessment for the Referral, the vegetated habitats (woodland, rehabilitation and forest) are considered to be moderate quality habitat for this species. The moderate conclusion is based on the young age and disturbed nature of this vegetation providing lower terrestrial habitat complexity (thus fewer prey opportunities) for this species than mature forest/woodland would. The grassland areas have been assessed as being of low quality habitat for this species, primarily due to the lower terrestrial habitat complexity of the grassland providing fewer prey opportunities for this species; however it is known to use this habitat from local records. This species is also known to use Rehabilitation within the local area with den records from Mount Owen Complex rehabilitation.

The known breeding record at LCO was from within a log pile located within existing riparian woodland fringing grassland. There are a number of such log piles throughout the LCO development consent boundary, as well as 'natural' breeding habitat such as existing boulder piles, fallen logs and tree hollows. Targeted searches for such breeding habitat identified low potential for breeding within the Referral Area.

#### 5.4.2.4 Green and golden bell frog (*Litoria aurea*)

**Table 5.7 – Habitat for the Green and Golden Bell Frog**

| Habitat Type (Quality) | Within Referral Area (ha) | Surrounding Vegetation (within 10 Kilometre Radius of Referral Area) (ha) |
|---|---|---|
| Aquatic Habitats (Marginal/low) | <0.5 (not mapped as all below limit of mapping scale) | Unmapped |
| **TOTAL** | **<0.5** | **Unmapped** |

Potential habitat for this species within the Referral Area is deemed to be very limited and restricted to a number of small degraded farm dams. Only a small number of these possessed fringing vegetation and, where present, this vegetation was sparse. Wetland habitat for this species within the broader 10 kilometre radius has not been mapped as part of the Peake (2006) mapping. Known local records of this species have come from dams with substantial amounts of fringing vegetation, and which have been assessed to be high quality for the species. Many dams within this 10 kilometre radius are likely to be in poor condition, with little to no fringing vegetation, poor water quality and high impacts from stock. This species has not been recorded from the two main creek lines within this area, being Bowmans Creek and Bayswater Creek.

#### 5.4.2.5 Large-eared pied bat (*Chalinolobus dwyeri*)

**Table 5.8 – Habitat for the Large-eared Pied Bat**

| Habitat Type (Quality) | Within Referral Area (ha) | Surrounding Vegetation (within 10 Kilometre Radius of Referral Area) (ha) |
|---|---|---|
| Eucalypt-dominated Woodland/Forest (Moderate) | 54 | 3,854 |
| Riparian Woodland/Forest (including Bulloak Forest) (Moderate) | 67 | 356 |
| Rehabilitation/Plantings (Moderate) | 0 | 1,414 |
| **TOTAL** | **121** | **5.624** |

The woodland/forest habitat within the Referral Area and broader 10 kilometre radius is likely to comprise foraging habitat for this species. There are no cave systems known within the Referral Area or LCO that would provide potential roosting and breeding habitat for this species. There is limited potential for such habitat to occur within a 10 kilometre radius of the Referral Area, however none is known.

### 5.4.3 Number of Individuals Present (where relevant)

#### 5.4.3.1 Regent honeyeater (*Anthochaera phrygia*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, or the broader LCO holdings, despite annual ecological survey and/or monitoring occurring since 2001. See **Section 5.3.3** for further information.

#### 5.4.3.2 Swift parrot (*Lathamus discolor*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, or the broader LCO holdings, despite annual ecological survey and/or monitoring occurring since 2001. See **Section 5.3.3.2** for further information.

#### 5.4.3.3 Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)

The species has not been recorded in the Referral Area. There are at least six distinct individuals that have been identified from the various captures, photographs and radio-tracking of this species that has occurred within the LCO, Mount Owen Complex and Mountain Block sites. See **Section 5.3.3.3** for further information.

#### 5.4.3.4 Green and golden bell frog (*Litoria aurea*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, or the broader LCO holdings, despite many years of ecological survey and monitoring. See **Section 5.3.3.4** for further information.

#### 5.4.3.5 Large-eared pied bat (*Chalinolobus dwyeri*)

This species has not been recorded within the Referral Area, the current LCO development consent boundary, or the broader LCO holdings, despite many years of ecological survey and monitoring. See **Section 5.3.3** for further information.

### 5.4.4 Survey Information with Detailed Descriptions of Survey Timing, Location, Effort, Methods and Results

#### 5.4.4.1 Survey Effort, Location and Timing

Eco Logical (Australia) (ELA) has previously undertaken flora, fauna and aquatic field surveys within the Referral Area and other parts of the LCO holdings, with flora surveys undertaken in May and October 2011 and fauna surveys in July, October and December 2011. Aquatic surveys were undertaken by ELA on 20 and 21 July 2012.

In October 2012, Umwelt was engaged to finalise the Ecological Assessment and Biodiversity Offset Strategy for the Proposed Action, as well as to ground-truth and update the existing flora surveys and vegetation mapping. As part of this process, verification of the results of the ELA surveys was undertaken and the methodology utilised as part of this process is described below.

Fauna field surveys were completed by ELA across a number of periods and seasons, and a number of methodologies were employed. In addition to this, Umwelt completed 9 person days of targeted field survey aimed at the spotted-tailed quoll (*Dasyurus maculatus maculatus*) within the Referral Area and along Bowmans Creek, in addition to many days of remote camera trapping for this species. Although Bowmans Creek is not within the Referral Area, it was included within the overall survey effort given that it occurs directly adjacent to the Referral Area to the east, and as such it was considered that the species compositions of both would likely be very similar. The details of the fauna surveys completed as part of this Proposed Action are provided in **Table 5.9** and illustrated in **Figure 5.2**, along with survey completed within the Mountain Block Offset Area and Bowmans Creek Riparian Corridor. Broad weather conditions occurring during the survey period have been included, where available from the Bureau of Meteorology.

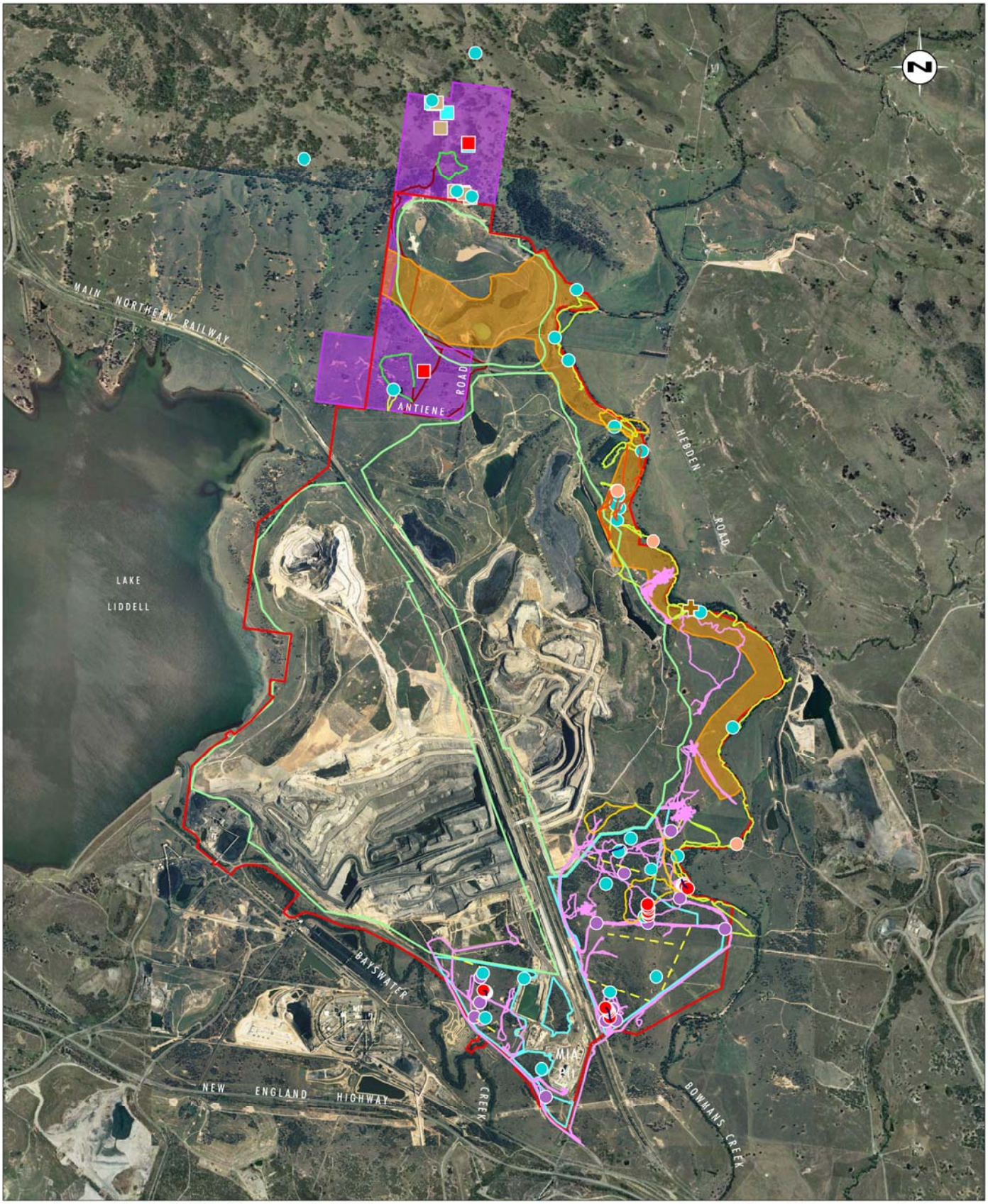



Image Source: Xstrata (2013), Google Earth (2008)
Data Source: Xstrata (2012), ELA (2013)

0 0.5 1.0 2.0km
1:45 000

## Legend

- Liddell Coal Operations Approved DA Boundary
- Approved Mining Footprint
- Referral Area
- Mountain Block Offset Site
- Bowmans Creek Riparian Corridor
- Targeted Prey Transects
- Umwelt Dusk Walking Transects
- Umwelt Spotlighting Transects
- Umwelt Daytime Walking Transects
- Baited Camera Stations
- ELA Remote Camera Site
- Hair Tube Transect (ELA 2013)
- Cage Traps (ELA 2013)
- Fauna Transects (ELA 2013)
- Fauna Survey Sites (ELA 2013)
- Spotted-tailed Quoll Scat Sample Collection
- Habitat Assessment Location
- Spotlighting Transect
- Driving Spotlighting Transect
- Bird Survey
- Scat Collections

FIGURE 5.2

**Fauna Survey Effort within the Referral Area, Bowmans Creek Riparian Corridor and Mountain Block Offset Area**

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20130301 11.10

**Table 5.9 – Referral Area and Bowmans Creek Field Survey Timing and Effort in relation to Key MNES**

| Surveyors | Date of Surveys<br>Broad Weather Conditions During Survey | Survey Method | Survey Effort | Key MNES Targeted |
|---|---|---|---|---|
| ELA<br><br>ELA | 5 to 7 July 2011, 24 to 28 October 2011, 13 to 15 December 2011<br><br>July – Dominated by gusty winds and temperatures between 9°C and 15°C. No rain.<br><br>October –variably windy with temperatures ranging between 9°C to 30°C. 20mm of rain.<br><br>December – temperatures ranged between 15°C to 24°C and winds were mild. Heavy rainfall event prior to survey but none during. | Arboreal hair tubes | Three tubes in 10 habitat trees over four nights per 50 hectare stratification unit | Spotted-tailed quoll |
| | | Terrestrial hair tubes | 10 large and 10 small hair tubes in pairs over 4 days and nights per 50 hectare stratification unit | Spotted-tailed quoll |
| | | Cage trapping | 24 trap nights over 3-4 consecutive nights at 4 sites. | Spotted-tailed quoll |
| | | Remote camera surveys | At each cage trap site | Spotted-tailed quoll |
| | | Spotlighting | 1 km transect over 1 person hr repeated over 2 nights for 4 sites | Spotted-tailed quoll |
| | | Anabat recording | Two Anabats at 4 sites over 2 nights | Large-eared Pied Bat |
| | | Harp trapping | 4 trap nights over 2 consecutive nights at 4 sites | Large-eared Pied Bat |
| | | Diurnal bird census | 20 minutes in spring and 20 minutes in winter at 4 sites | Regent honeyeater<br>Swift parrot |
| | | Nocturnal call playback | At 4 sites over 2 separate nights | Spotted-tailed quoll |
| | | Diurnal herpetofauna surveys | 30 minutes for 2 nights at 4 sites | Green and golden bell frog |
| | | Nocturnal herpetofauna surveys | Walking over 1 km transect for one hour for 2 separate nights | Green and golden bell frog<br>Spotted-tailed quoll |
| | | Opportunistic observations | Made throughout all aspects of survey | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |
| | 30 November 2012 to 18 December 2012 – Targeted spotted-tailed quoll surveys | Remote camera surveys | Six remote sensing cameras over 18 days and nights | Spotted-tailed quoll |
| Umwelt | 17 to 20 December 2012 – Targeted spotted-tailed quoll surveys | Daytime walking searches for signs of presence | 4 days | Spotted-tailed quoll |
| | | Dusk walking surveys | 2 dusk periods, each of approximately 2 person hours duration | Spotted-tailed quoll |

| Surveyors | Date of Surveys<br>Broad Weather Conditions During Survey | Survey Method | Survey Effort | Key MNES Targeted |
|---|---|---|---|---|
| | December – temperatures were mild during the day and cool and windy at night. No rainfall was recorded. | Nocturnal spotlighting | 3 nights of spotlighting, each of approximate duration 5 person hour | Spotted-tailed quoll |
| | | Baited remote camera surveys | 7 stations for 3 nights, 2 stations for two nights and 5 stations for 1 night (30 full survey nights) | Spotted-tailed quoll |
| | | Opportunistic observations | Made throughout all aspects of survey | Green and golden bell frog<br>Large-eared pied bat<br>Spotted-tailed quoll |
| | 6 to 17 June 2013 – Targeted spotted-tailed quoll surveys<br><br>June – light to moderate winds. Temperature ranged between 12°C and 18°C. No rain during survey. | Baited remote camera surveys | 12 stations for 11 nights | Spotted-tailed quoll |
| | | Daytime walking searches for signs of presence | 2 days | Spotted-tailed quoll<br>Regent honeyeater<br>Swift Parrot |
| | | Prey density spotlighting transects | 6 transects surveyed twice over 2 nights | Spotted-tailed quoll<br>Green and golden bell frog |
| | | Opportunistic observations | Made throughout all aspects of survey | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |
| Umwelt | 6 to 8 November 2013<br><br>November – rainfall for the month was 163mm (above average). | Habitat Assessment | 10 Sites | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |
| | | Micro-bat Echolocation Recording | 2 locations for 2 nights each | Large-eared pied bat |
| | | Opportunistic Observations | Undertaken throughout all aspects of survey | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |

Due to the proximity of the Mountain Block Offset Area to the Referral Area, and the similarity of habitats, it is reasonably likely that the majority of species identified as occurring within the Mountain Block Offset Area would also occur within the Referral Area. Although not specifically within the Referral Area, **Table 5.10** contains the details of the fauna survey effort that was undertaken within the Mountain Block Offset Area for this Proposed Action. These are displayed in **Figure 5.2**, along with survey completed within the Referral Area and Bowmans Creek Riparian Corridor.

**Table 5.10 – Mountain Block Offset Area Field Survey Timing and Effort in relation to Key MNES**

| Surveyors | Date of Surveys | Survey Method | Survey Effort | Key MNES Targeted |
|---|---|---|---|---|
| Umwelt | 7 and 12 June 2013 | Diurnal bird census | 3 sites on two separate occasions each survey consisted of 1 person hour | Regent honeyeater<br>Swift parrot |
| | | Habitat assessment | 4 sites | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |
| | | Daytime walking searches for signs of presence | 2 days | Spotted-tailed quoll<br>Regent honeyeater<br>Swift parrot |
| | | Nocturnal spotlighting | 1 night across two sites | Spotted-tailed quoll |
| | | Scat sample collection | Scat collections from potential latrine sites. | Spotted-tailed quoll |
| | | Opportunistic observations | Made throughout all aspects of survey | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |
| | 7 to 17 June 2013 | Baited remote camera surveys | 1 station for 11 nights<br>3 stations for 10 nights | Spotted-tailed quoll |
| | | Opportunistic observations | Made of all non-target species recorded. | Green and golden bell frog<br>Large-eared pied bat<br>Regent honeyeater<br>Swift Parrot<br>Spotted-tailed quoll |

#### 5.4.4.2 Survey Methods

The sections below indicate the methods employed for each of the survey types indicated in **Tables 5.9** and **5.10**.

**Hair Tubes**

Large and small terrestrial hair funnels were baited with a rolled oats, peanut butter and honey mixture. All terrestrial hair funnels were positioned amongst habitat features such as logs, fallen bark, rocks and ground cover. Ten large and ten small hair funnels were distributed in pairs over four days and nights for every 50 ha of vegetation type.

Arboreal hair funnels were baited with the same mixture as the terrestrial funnels. Arboreal hair funnels were positioned within habitat trees approximately 2.0 metres above the ground on tree trucks or branches. The hair funnel and the tree trunk were sprayed with a honey and water emulsion as an attractant. All collected hair samples were identified by Hans Brunner (a recognised expert in the field of hair identification).

**Cage Trapping**

Single ended cage traps (0.6 metres (L) × 0.3 metres (H) × 0.3 metres (W)) were baited with sardines. Half of the length of each trap was covered with a plastic bag and shade cloth to provide shelter for captured animals from the elements (rain, wind and sun). All cage traps were positioned to avoid exposure to early morning sunlight. Traps were positioned on level ground or amongst vegetation where the trap was unable to roll away if a captured animal struggled within the trap.

**Remote Camera Surveys**

Baited remote camera stations were placed in areas that were considered to have a high chance of fauna access. Each station was baited with a chicken carcass and fish oil so that in the event the chicken was taken, fauna would still be attracted by the fish oil.

**Spotlighting**

Spotlighting searches were undertaken both on foot and from a moving vehicle. Walking spotlighting searches were undertaken by two observers for a period of at least 30 minutes (total of one person hour) on each occasion. Vehicle spotlighting searches were undertaken from a slow moving vehicle along vehicle tracks between trapping sites. Walking and vehicle spotlighting searches were undertaken using 30 watt Lightforce spotlights.

Walking spotlighting was always undertaken by two people whereas driving spotlighting was undertaken only by the passenger of the vehicle.

**Anabat Recording**

Echolocation calls were detected using an Anabat II Bat Detector. Echolocation calls were recorded using an Anabat CF storage ZCAIM. The recorders were positioned horizontally on tree trunks or at an approximate 30 degree angle on the ground and tree trunks, with a small roof protecting the detector from rain. This protective cover enabled the recording of calls regardless of weather conditions.

Anabat recorders were positioned within the vicinity of potential micro-bat flyways. The recorders were automated and programmed to start recording one hour before dusk and to stop recording one hour after sunrise the following morning.

Anabat recording undertaken by ELA was analysed by Peter Knock, a trained ELA consultant. Anabat recording undertaken by Umwelt was analysed by Glenn Hoye of Fly by Night Surveys Pty Limited (a recognised expert in the identification of micro-bat calls). The echolocation calls of species analysed by Glen Hoye were identified to one of three levels of confidence:

- confident;
- probable; and
- possible.

For the purposes of this assessment, all three levels of confidence were treated as positive identifications.

**Harp Trapping**

Harp traps were erected in areas of potential bat flight paths inclusive of areas adjacent to open water and trails through areas of woodland. Traps were checked each morning at dawn with captures released that same day at dusk.

**Diurnal Bird Census**

Bird surveys were undertaken in a range of different habitat types at various times of the day, primarily in early to mid morning and mid to late afternoon. Bird searches were undertaken by two observers for a minimum of 30 minutes (for Umwelt surveys) or a minimum of 20 minutes (for ELA Surveys). Bird species were identified from characteristic calls (where confident) and/or by observation using 10 × 42 binoculars.

Focal habitat areas such as large dams and patches of heavily-flowering eucalypts were targeted for opportunistic bird surveys, whenever encountered.

**Nocturnal Call-Playback**

Nocturnal call playback sessions were undertaken by ELA. Calls were broadcast using a 10 watt directional loud hailer. Call playback sessions commenced with a quiet listening period of approximately ten minutes. Each species' call was played for five minutes followed by a listening period of five minutes before the beginning of the next species' call. Ten minutes of combined spotlighting and listening were undertaken at the conclusion of surveys. Call playback sessions included the calls of the:

- Masked owl (*Tyto novaehollandiae*);
- Barking owl (*Ninox connivens*)*;* and
- Powerful owl (*Ninox strenua*).

**Herpetofauna Surveys**

Diurnal searches targeting reptiles and amphibians were undertaken during the warmest parts of the day. Diurnal searches were undertaken by two people for between half a person hour and one person hour on two separate days. Nocturnal searches targeted amphibians and nocturnal reptiles. All reptile and amphibian searches were undertaken by two ecologists for a period of at least 30 minutes.

Nocturnal reptile and amphibian searches were undertaken using Petzl headlamps and/or 30 watt Lightforce spotlights.

Habitat features investigated during reptile and amphibian searches included water bodies, emergent vegetation, wet soak areas, logs, rocks, loose bark on tree trunks, exposed bedrock, leaf litter and open grassland areas. Amphibians not identifiable from their calls were captured for visual identification. All amphibians were handled according to the hygiene protocol for the control of disease in frogs (Wellington and Haering 2001). Non-venomous snake species and small lizards were captured for identification where necessary.

**Daytime Walking Searches for Signs of Presence**

Diurnal walking surveys were undertaken to search for signs of presence of the spotted-tailed quoll (*Dasyurus maculatus maculatus*) such as tracks, latrines and scats. These searches also targeted key habitat features such as latrine sites, log piles, boulder piles and den sites.

**Dusk Walking Surveys**

Dusk walking surveys were undertaken in areas considered to have a high chance of spotted-tailed quoll occurrence. They were undertaken at this particular time of the day due to the general crepuscular nature of this particular species. All species encountered during dusk walking surveys were recorded.

**Prey-density Spotlighting**

Prey-density spotlighting surveys were undertaken to determine available pre-densities for the spotted-tailed quoll. These surveys targeted medium-sized arboreal and terrestrial mammals (0.5 to 5 kilograms body weight) which are known to compose the majority of the species' diet (Belcher and Darrant 2006; Glen and Dickman 2006).

Surveys followed the methodology of Belcher and Darrant (2006) and consisted of conducting spotlight surveys along 500 metre by 20 metre transects within each habitat type present. All potential prey species detected were recorded, and a count was made of individuals occurring within the 500 metre by 20 metre transect area to provide a density estimate.

**Opportunistic Observations and Collections**

Searches for signs of animal presence were conducted opportunistically during all survey activities, particularly during habitat searches and reptile and amphibian searches. Due to the opportunistic nature of signs of presence surveys, the level of survey effort was not recorded. Evidence of presence included scats, feathers, nests, burrows, footprints, bones, tufts of hair and scratch marks on trees.

All hair, scat and bone samples were made as they were encountered for expert identification. Scat collections made for the spotted-tailed quoll targeted aged scats in order to minimise disturbance of latrine sites as territory marking and communication sites between individual quolls. All scats collected were sent to Barbara Triggs for expert analysis, with prey remains identified to a species level where possible.

**Habitat Assessment**

Habitat assessment targeted potential habitat and resources for fauna species, particularly for threatened fauna species. Records of a number of habitat features were made at each habitat assessment site, including:

- evidence of disturbance such as fire, weeds, feral animals, dumping, erosion and logging;
- presence of stumps and stags;
- presence of groundcover features such as rock, litter, grasses, logs, boulder, soil and lichen;
- presence of dieback, insect attack or mistletoe;
- presence of perch sites, fallen and loose bark;
- vegetation strata and composition;
- tree size class (trunk diameter), and age (old growth, mature, regenerating, saplings);
- presence and quantity of SEPP 44 – koala feed tree species;
- presence of other species specific feed resources (such as for cockatoos and honeyeaters); and
- collection of detailed hollow data, including tree species and height, hollow size, orientation, position and height.

Habitat features such as tree hollows and fallen logs were inspected for any evidence of fauna occupation such as scratches on the trunks of trees, chewed entrances to hollows, scratchings or diggings near logs, and scats at the base of trees or near logs.

#### 5.4.4.3 Ecological Monitoring Surveys of LCO from 2005 - 2013

Ecological monitoring surveys have been undertaken annually at Liddell over nine years between 2005 and 2013. In addition to this, detailed field survey was completed as part of the Liddell Colliery Continued Operations Environmental Impact Statement (EIS) (Umwelt 2001). Locations of each of the sites that have been subject to ecological monitoring since 2005 and those surveyed for the 2001 EIS are provided in **Figure 5.3**.

**Table 5.11** identifies each of the previous monitoring or survey sites, including the years they were each surveyed and their position in relation to the broader LCO, Referral Area, Bowmans Creek Riparian Corridor or Mountain Block Offset Area.

Across the LCO, a total of 22 sites have been subject to ecological survey or monitoring of some form between 2001 and 2013:

- seven of these sites are located wither within the Referral Area or close enough to the Referral Area to be relevant;
- four of these sites are directly relevant to the Bowmans Creek Riparian Corridor; and
- one of these sites is directly relevant to the Mountain Block Offset Area.

These sites have been subject to various ecological monitoring methods (which have evolved slightly over the years), including:

- plot-based vegetation surveys in remnant and rehabilitated communities;
- photo monitoring points;
- diurnal bird census;
- herpetological surveys (nocturnal and diurnal);
- spotlighting;
- micro-bat echolocation recording;
- habitat assessment;
- nest box monitoring;
- additional dam surveys for water birds;
- hair funnel sampling (terrestrial and arboreal); and
- landscape function analysis.

The results of these monitoring projects were included within the Ecological Assessment for the Proposed Action, thus already capturing any records of MNES.

**Table 5.12** provides information on the previous monitoring sites that have included targeted amphibian surveys, as they relate to the Referral Area, Bowmans Creek Riparian Corridor and Mountain Block Offset Area. Opportunistic amphibian surveys were undertaken at all ecological monitoring sites identified in **Figure 5.3** however these surveys were not quantified in the table. Also included in the table is information on weather conditions during surveys, as well as the year of survey and total survey effort.

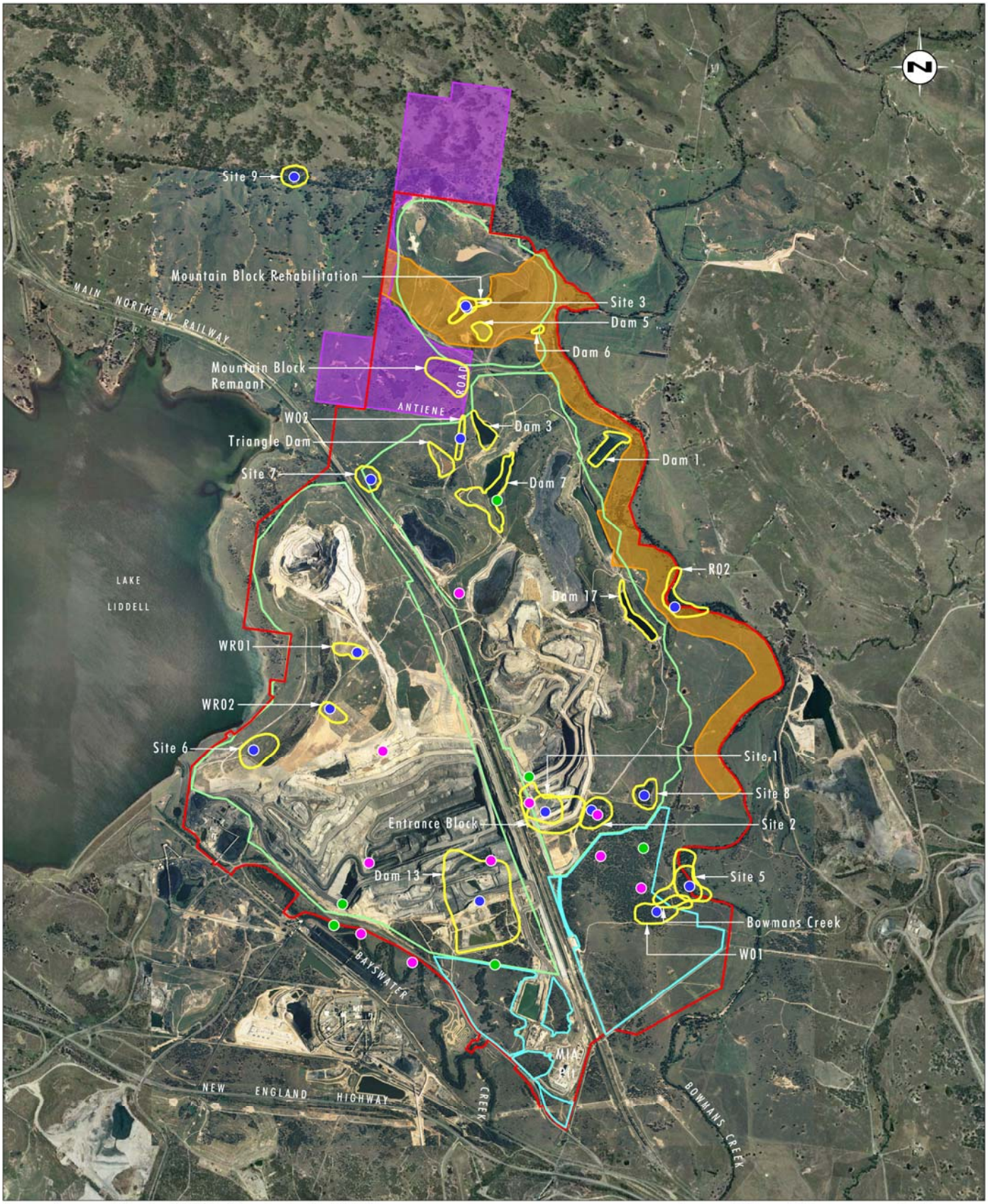



Image Source: Xstrata (2013), Google Earth (2008)
Data Source: Xstrata (2012), ELA (2012)

0 0.5 1.0 2.0km
1:45 000

## Legend

- Liddell Coal Operations Approved DA Boundary
- Approved Mining Footprint
- Referral Area
- Mountain Block Offset Site
- Bowmans Creek Riparian Corridor
- Fauna Monitoring Search Area
- Nocturnal Amphibian Survey Point (Umwelt 2001)
- Herpetological Survey Point (Umwelt 2001)
- Ecological Monitoring Sites

FIGURE 5.3

**Previous Ecological Monitoring or Survey Sites within LCO - from 2001 to 2013**

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**Table 5.11 – Previous Monitoring or Survey Sites within LCO**

| Ecological Monitoring Site | Years Surveyed | | | | | | | | | Area of Relevance | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | Broader LCO | Referral Area | Bowmans Creek Riparian Corridor | Mountain Block Offset Area |
| **Mountain Block Remnant** | X | X | X | X | | | | | | | | | X |
| **Site 1** | X | X | X | X | X | X | | | | | X | | |
| **Site 2** | | | | | X | X | | | | | X | | |
| **Site 3** | X | X | X | X | X | X | X | | | | | X | |
| **Site 5** | X | X | X | X | X | X | X | X | X | | X | | |
| **Site 6** | | | | | X | X | | | | X | | | |
| **Site 7** | | | | | X | X | X | | | X | | | |
| **Site 8** | | | | | X | X | | | | | X | | |
| **Site 9** | | | | | X | X | | | | X | | | |
| **Dam 1** | | | X | X | X | X | X | | | | | X | |
| **Dam3** | | | X | X | X | X | X | | | X | | | |
| **Dam 5** | | | X | X | | | | | | | | X | |
| **Dam 6** | | | X | X | | | | X | X | | | X | |
| **Dam 7** | | | X | | | | | | | X | | | |
| **Dam 13*** | X | X | X | X | X | X | X | | | | X | | |
| **Dam 17** | | | X | X | X | X | | | | | | X | |
| **Triangle Dam** | | | | | | | X | X | X | X | | | |
| **W01** | | | | | | | | X | X | | X | | |
| **W02** | | | | | | | | X | X | X | | | |
| **R02** | | | | | | | | X | X | | | X | |
| **WR01** | | | | | | | | X | X | | X | | |
| **WR02** | | | | | | | | X | X | X | | | |

*This dam no longer exists in the Referral Area as it has now been mined through as part of currently approved activities at LCO in accordance with DA 305-11-01.

**Table 5.12 – Targeted Amphibian Surveys Undertaken as Part of Previous Studies and Ecological Monitoring**

| Survey Type | Year | Season | Weather Conditions During Surveys | Monthly Rainfall (mm) | Diurnal or Nocturnal Surveys | Amphibian Survey Effort | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Referral Area | Bowmans Creek Riparian Corridor | Mountain Block Offset Area |
| | | | | | | Relevant Sites* | Relevant Sites | Relevant Sites |
| EIS (Umwelt 2001) | 2000-2001 | Summer | Humid conditions. No rain | December : 80.5 | Both | 5.25 person hrs | - | - |
| | | | | March : 110.8 | | 6 diurnal amphibian sites<br>3 nocturnal amphibian sites | - | - |
| Monitoring | 2005 | Spring | NA | September : 57.1 | Both | 12 person hrs | 4 person hrs | 4 person hrs |
| | | | | October: 80.8 | | Site 1, Site 5, Dam 13** | Site 3 | Mountain Block Remnant |
| | | | | November : 117.2 | | | | |
| Monitoring | 2006 | Winter | Cool to cold. Light rains. Temperatures -5 °C to 15°C | July: 43.9 | Both | 12 person hrs | 4 person hrs | 4 person hrs |
| | | | | | | Site 1, Site 5, Dam 13 | Site 3 | Mountain Block Remnant |
| Monitoring | 2007 | Autumn | Warm. No rain. Temperatures 10 °C to 25°C | May: 30.8 | Both | 12 person hrs | 4 person hrs | 4 person hrs |
| | | | | | | Site 1, Site 5, Dam 13 | Site 3 | Mountain Block Remnant |
| Monitoring | 2008 | Autumn | Warm. No rain. Temperatures 1 °C to 27°C | March: 44.6 | Both | 12 person hrs | 4 person hrs | 4 person hrs |
| | | | | | | Site 1, Site 5, Dam 13 | Site 3 | Mountain Block Remnant |
| Monitoring | 2009 | Winter | Moderate winds. No rain. Temperatures 17 °C to 25°C | August : 3.5 | Diurnal | 8 person hrs | 2 person hrs | - |
| | | | | September: 36.3 | | Site 1, Site 2, Site 5, Site 8 | Site 3 | |
| Monitoring | 2010 | Spring | Moderate winds. No rain. Temperatures 17 °C to 28°C | November: 137.9 | Diurnal | 8 person hrs | 2 person hrs | - |
| | | | | December: 108.0 | | Site 1, Site 2, Site 5, Site 8 | Site 3 | |
| Monitoring | 2011 | Summer | Cool temperatures and heavy rains. Temperatures 11 °C to 31°C | October: 63.5 | Diurnal | 2 person hrs | 2 person hrs | - |
| | | | | December: 33.0 | | Site 5 | Site 3 | |

* All relevant survey sites listed in the table are either within or are proximate to the Referral Area, Bowmans Creek Riparian Corridor or Mountain Block Offset Area.
** This dam no longer exists in the Referral Area as it has now been mined through as part of currently approved activities at LCO in accordance with DA 305-11-01.

Targeted amphibian surveys were undertaken as part of the monitoring program between 2005 and 2011, however this was removed from the monitoring program during 2012. Opportunistic records were made of amphibians during all aspects of fauna survey from 2005 to 2013.

Diurnal herpetofauna surveys typically consisted of habitat searches between 11:00 am and 3:00 pm. Nocturnal herpetofauna surveys typically consisted of spotlighting habitat searches of dams, drainage lines and groundcover between dusk and midnight. Amphibian species were identified via visual identification and calls.

At the seven sites relevant to the Referral Area, a total of 66 person hours of targeted amphibian surveys have been undertaken (24 nocturnal and 42 diurnal survey).

At the six sites relevant to Bowmans Creek a total of 22 person hours of targeted amphibian surveys were undertaken (eight nocturnal and 14 diurnal survey).

At the one site relevant to Mountain Block a total of 16 person hours of targeted amphibian surveys were undertaken (eight nocturnal and eight of diurnal survey).

#### 5.4.4.4 Adequacy of Survey Effort

**Table 5.13** below provides a summary of the survey effort undertaken and a comparison of this survey effort against the Department of the Environment guidelines including:

- Survey Guidelines for Australia's Threatened Bats (DEWHA 2010a);
- Survey Guidelines for Australia's Threatened Birds (DEWHA 2010b);
- Survey Guidelines for Australia's Threatened Frogs (DEWHA 2010c); and
- Survey Guidelines for Australia's Threatened Mammals (DSEWPC 2011).

**Table 5.13 – Comparison of Survey Effort Undertaken and the Department of the Environment Guidelines**

| Species | Suggested Survey Type and Effort[1] | Field Surveys Undertaken within the Referral Area and Reasoning[2] | Adequacy of Survey Effort Against Guidelines | Results |
|---|---|---|---|---|
| Regent honeyeater | 20 hours of surveys across five days targeting areas of heavy flowering trees and flocks of other blossom feeding birds. | A total of 5.3 hours (320 minutes) of targeted winter bird surveys across three days were undertaken within the Referral Area which contains approximately 54 hectares of potential foraging habitat for this species.<br>An additional 2 days of opportunistic records.<br>A total of 6 hours over five days of targeted winter bird surveys across Mountain Block which is considered likely to have the same species composition as the Referral Area. | Adequate with consideration of opportunistic records.<br>Dense areas of eucalyptus species were limited due to sparse vegetation. Most trees within the Referral Area are not considered to be mature. | No regent honeyeaters were recorded within the Referral Area. Other blossom feeding species that are often recorded with the regent honeyeater including the noisy friarbird (*Philemon corniculatus*) and white-plumed honeyeater (*Lichenostomus penicillatus*) were recorded in the Referral Area, albeit in low abundance. |
| Swift parrot | 20 hours of survey across eight days targeting areas of heavy flowering trees. | A total of 5.3 hours (320 minutes) of targeted winter bird surveys across three days were undertaken within the Referral Area which contains approximately 54 hectares of potential foraging habitat for this species.<br>An additional 2 days of opportunistic records.<br>A total of 6 hours over five days of targeted winter bird surveys across Mountain Block which is considered likely to have the same species composition as the Referral Area. | Adequate with consideration of opportunistic records.<br>Dense areas of eucalyptus species were limited due to sparse vegetation. Most trees within the Referral Area are not considered to be mature. | No swift parrots were recorded within the Referral Area. Other blossom feeding species that are often recorded with the swift parrot including the noisy friarbird (*Philemon corniculatus*) and white-plumed honeyeater (*Lichenostomus penicillatus*) were recorded in the Referral Area, albeit in low abundance. |

| Species | Suggested Survey Type and Effort[1] | Field Surveys Undertaken within the Referral Area and Reasoning[2] | Adequacy of Survey Effort Against Guidelines | Results |
|---|---|---|---|---|
| Spotted-tailed quoll | Daytime searches for habitat resources. | 6 days of targeted surveys for habitat resources and signs of presence were undertaken within the Referral Area and Bowmans Creek.<br>Surveys additionally comprised 10 habitat assessments and 12 prey-density spotlighting transects | Adequate.<br>There is little diversity of habitat throughout the Referral Area, this extent of survey is adequate for the variety of habitat available | The spotted-tailed quoll has not been recorded in the Referral Area. This species has been recorded at numerous locations along Bowmans Creek and further to the north of the Referral Area, within the LCO DA Boundary. |
| | Daytime searches for signs of presence. | 6 days of targeted surveys for habitat resources and signs of presence were undertaken within the Referral Area and Bowmans Creek. | Adequate | |
| | Hair sampling surveys including 40 widely spaced hair sampling devices over 100 hectares. | A total of 80 terrestrial hair funnels over 49 nights and 30 arboreal hair funnels over 49 nights of survey effort was undertaken within the Referral Area. | Adequate | |
| | Remote cameras, sampling for a minimum of three weeks. | 366 day/nights of remote camera survey have been undertaken within the Referral Area across 4 survey events. | Adequate | |

| Species | Suggested Survey Type and Effort[1] | Field Surveys Undertaken within the Referral Area and Reasoning[2] | Adequacy of Survey Effort Against Guidelines | Results |
|---|---|---|---|---|
| Green and golden bell frog | Call detection, call playback and spotlighting surveys. Surveys to be undertaken between September and March and one hour duration at each area (<50 hectares). | 1 hour of diurnal herpetofauna surveys were undertaken at each of four different sites within the Referral Area.<br>2 hours of nocturnal transect surveys were undertake within the Referral Area.<br>Additionally, 11 days of opportunistic surveys were undertaken by ELA within the Referral Area and a further 9 days of opportunistic observations were undertaken by Umwelt within the Referral Area and Bowmans Creek.<br>Six days of opportunistic surveys were also undertaken within the Mountain Block site.<br>Minimal amphibian habitat is available within the Referral Area due to a lack of dams with appropriate fringing vegetation such as Typha and Phragmites. Opportunistic observations were made during all aspects of surveys of all fauna identified at dam locations.<br>In addition to the above, a total of 66 person hours (24 hours nocturnal and 42 hours diurnal) of targeted amphibian searches have been undertaken within or near the Referral Area as part of monitoring surveys undertaken between 2005 and 2013. 22 of these survey hours were during spring/summer.<br>5.25 person hours (2.25 nocturnal and 3 hours diurnal) of targeted amphibian searches were undertaken as part of surveys for the 2001 Ecological Assessment. All of these surveys were completed during spring/summer. | Adequate given the lack of appropriate habitat for this species | The green and golden bell frog has not been recorded within the Referral Area, along Bowmans Creek or within the broader LCO despite regular surveys having been undertaken as part of an ongoing monitoring program since 2005 in which three dams were subject to diurnal surveys. Note however that these three dams are outside of the Referral Area. |
| Large-eared pied bat | 16 stationary Anabat detector recording nights across a minimum of four nights. | 14 stationary Anabat detector nights over two nights were undertaken within the Referral Area by ELA; and 4 stationary Anabat detector nights over two nights were undertaken within Bowmans Creek by Umwelt. | Not adequate; however close to guidelines. | The large-eared pied bat was not recorded within the Referral Area. The large-eared pied bat has not been recorded within the LCO holdings during any surveys and has not been recorded on the OEH NSW Wildlife |

| Species | Suggested Survey Type and Effort[1] | Field Surveys Undertaken within the Referral Area and Reasoning[2] | Adequacy of Survey Effort Against Guidelines | Results |
|---|---|---|---|---|
| | Six hours of active Anabat recording (non-stationary) over three nights. | No active Anabat recording was undertaken within the Referral Area. | Not adequate | Atlas within 10 km of the Referral Area. |
| | 16 harp trap or mist net nights over four nights. | 16 harp trap nights over two nights were undertaken within the Referral Area. | Not adequate; however close to guidelines. | |

[1] Suggested survey effort is based on the information given in the various guidelines published by the Department of the Environment (DEWHA 2010a, 2010b, 2010c and DSEWPC 2011). Where applicable, the suggested survey effort was based on an area greater than 50 hectares.

[2] Field surveys include only those undertaken for the Proposed Action including those undertaken by EcoLogical Australia (ELA 2013) and Umwelt (Umwelt 2013b).

In terms of adequacy of survey effort undertaken within the Referral Area, the regent honeyeater, swift parrot and spotted-tailed quoll met the requisite survey guidelines. Surveys undertaken for the green and golden bell frog and the large-eared pied bat were not strictly compliant with the recommendations of the guidelines; however are considered to be sufficient given:

- neither the large-eared pied bat or the green and golden bell frog have been recorded within the LCO holdings during any of the surveys undertaken in the LCO during previous monitoring events (undertaken annually since 2001);
- there is no requisite escarpment/cave habitat for the large-eared pied bat within the Referral Area;
- the dams occurring within the Referral Area do not contain requisite fringing vegetation needed by the green and golden bell frog;
- there are no records of the large-eared pied bat occurring within 10 km of the Referral Area based upon OEH NSW Wildlife Atlas; and
- when water bodies were encountered during surveys, they were subject to opportunistic faunal observation, during which if green and golden bell frogs were present they would have been readily identifiable.

## 5.5 Known Populations (and Records), or Habitat for the Relevant Protected Matter(s), within a Ten Kilometre Radius of the Development Site

### 5.5.1 Known Populations

This subject has been addressed in detail in **Section 5.3** for each of the specified MNES, both within the Referral Area and within a 10 kilometre radius of the Referral Area.

### 5.5.2 Known Habitat

This subject has been addressed in detail in **Section 5.4.2** for each of the specified MNES, both within the Referral Area and within a 10 kilometre radius of the Referral Area.

## 5.6 Condition, Diversity and Connectivity Values of Bayswater and Bowmans Creek to the Site

This section includes information on the connectivity to potential habitat area/s in the vicinity of the proposed action, and the condition and habitat values of those area/s.

The Referral Area is bounded to the east by Bowmans Creek and to the south-west by Bayswater Creek. The Referral Area is approximately 150 metres away from Bowmans Creek at its closest point, and approximately 125 metres from Bayswater Creek at its closest point.

Both of these creeks consist of a narrow width of riparian vegetation (no more than 100 metres wide, and regularly less than 50 metres wide), which is often very narrow or discontinuous. In relation to the surrounding landscape, these two creeks are relatively well-connected along their length (despite gaps in the riparian vegetation), however are poorly connected laterally outside of the riparian zone to other areas of proximate habitat. Although these creek lines have poor lateral connectivity, they form locally important linkages across the central Hunter Valley landscape which is typically devoid of other continuous treed vegetation. These creeks are therefore important riparian linkages within a highly modified landscape.

The vegetation occurring along Bayswater Creek is dominated by swamp oak (*Casuarina glauca*) (ELA 2013 and Umwelt 2013b). This vegetation is moderately weed infested and deemed to be in a generally poor condition, with the aquatic macro-invertebrate taxa present dominated by pollution-tolerant species (ELA 2013). The lowest oxygen levels recorded were just 47% saturation at one point along this creek, which is substantially below the ANZECC guidelines. Electrical conductivity recorded along Bayswater Creek has been greater than 4,100 µS/cm, which is in excess of ANZECC guidelines. Heavy sediment loads, bank erosion and a fine-black dust layer on the surface of the water were also typical of this creek line.

The riparian vegetation of Bowmans Creek is dominated by river oak (*Casuarina cunninghamiana*) and is considered to be in a moderate condition compared to Bayswater Creek (ELA 2013). As this riparian vegetation supports mature river oak (*Casuarina cunninghamiana*) trees, as well as some mature forest red gum (*Eucalyptus tereticornis*) trees, it is considered to be of moderate habitat quality. Despite the relatively disturbed understorey, this community is unlikely to have been cleared to the same extent as the remaining vegetation within the Referral Area. The aquatic survey results from this creek line identified a broader range of sensitive and tolerant aquatic macro-invertebrate taxa. Electrical conductivity was recorded at 997 µS/cm at its highest and had oxygen saturation levels of between 97.6 and 114.4% (ELA 2013).

A female platypus (*Ornithorhynchus anatinus*) has been captured during surveys undertaken of Bowmans Creek. No threatened aquatic species or ecological communities are known to occur along these creeklines.

The Riparian Channel and Environmental (RCE) scores for all sites completed along Bowmans Creek were 34, while the sites at Bayswater Creek returned scores varying between 30 and 37. These scores are deemed to be moderate given that the total possible RCE score is 52, however are typical of similar scores for nearby creeks.

# 6.0 RELEVANT IMPACTS

Information relating to the potential impacts on MNES (threatened species and communities, and migratory species) that are identified as being present, or potentially present, within and adjacent to the Referral Area is provided in the sections below. The information presented is in accordance with the requirements set out in Section 5 of the "Guidelines for Additional Information – Assessment by Preliminary Documentation" (DoE) with the relevant requirement in **bold** and the information presented below.

**The preliminary documentation must address how the elements of the action (during construction, operational and decommissioning phases) may impact on matters of national environmental significance that are identified as being present, or potentially present, within and adjacent to the proposal area. For each of the protected matters listed at 3(c), please provide:**

## 6.1 Quantification of the Extent (in hectares) and Quality of Habitat Likely to be Impacted

This subject has been addressed in detail in **Section 5.4.1** for each of the specified MNES, both within the Referral Area and within a 10 kilometre radius of the Referral Area. In terms of impact, all of the vegetation/habitat within the Referral Area will be removed as part of this Proposed Action. The current vegetation of the Referral Area is provided in **Figure 6.1**.

## 6.2 Number of Individuals Likely to be Impacted (where relevant)

This subject has been addressed in detail in **Section 5.3.3** for each of the specified MNES, both within the Referral Area and within a 10 kilometre radius of the Referral Area. In terms of impact, all of the vegetation/habitat within the Referral Area will be removed as part of this Proposed Action. As there have been no individuals of any of the specified MNES recorded within the Referral Area (see **Section 5.3.3**) it is unlikely that any individuals will be directly impacted. The local records of the spotted-tailed quoll have the potential to be indirectly impacted, and this is discussed further in **Section 6.4.3**.

## 6.3 Distance of Proposed Works (including Off-site, e.g. Road Upgrades) to any Habitat for (or individuals of) Listed Threatened Species and Communities within 1km of the Disturbance Footprint

**This section is also to include information about the likely long term viability of those matters if the proposal was to proceed. The information should consider and describe in detail all possible indirect impacts associated with the action, and should quantify the areas of habitat in hectares (and/or as number of individuals) that may be indirectly impacted as a result of the proposal.**

### 6.3.1 Indirect and Offsite Impacts

The Proposed Action involves an extension of existing open cut mining operations in a south-easterly direction from current mining activities in both the Entrance Pit and South Pit (see **Figure 1.2**). There are currently no changes proposed to currently approved production levels, mining methods, mining equipment or operating hours. There would therefore be no increase in mining related activities in the general area associated with the Proposed Action.

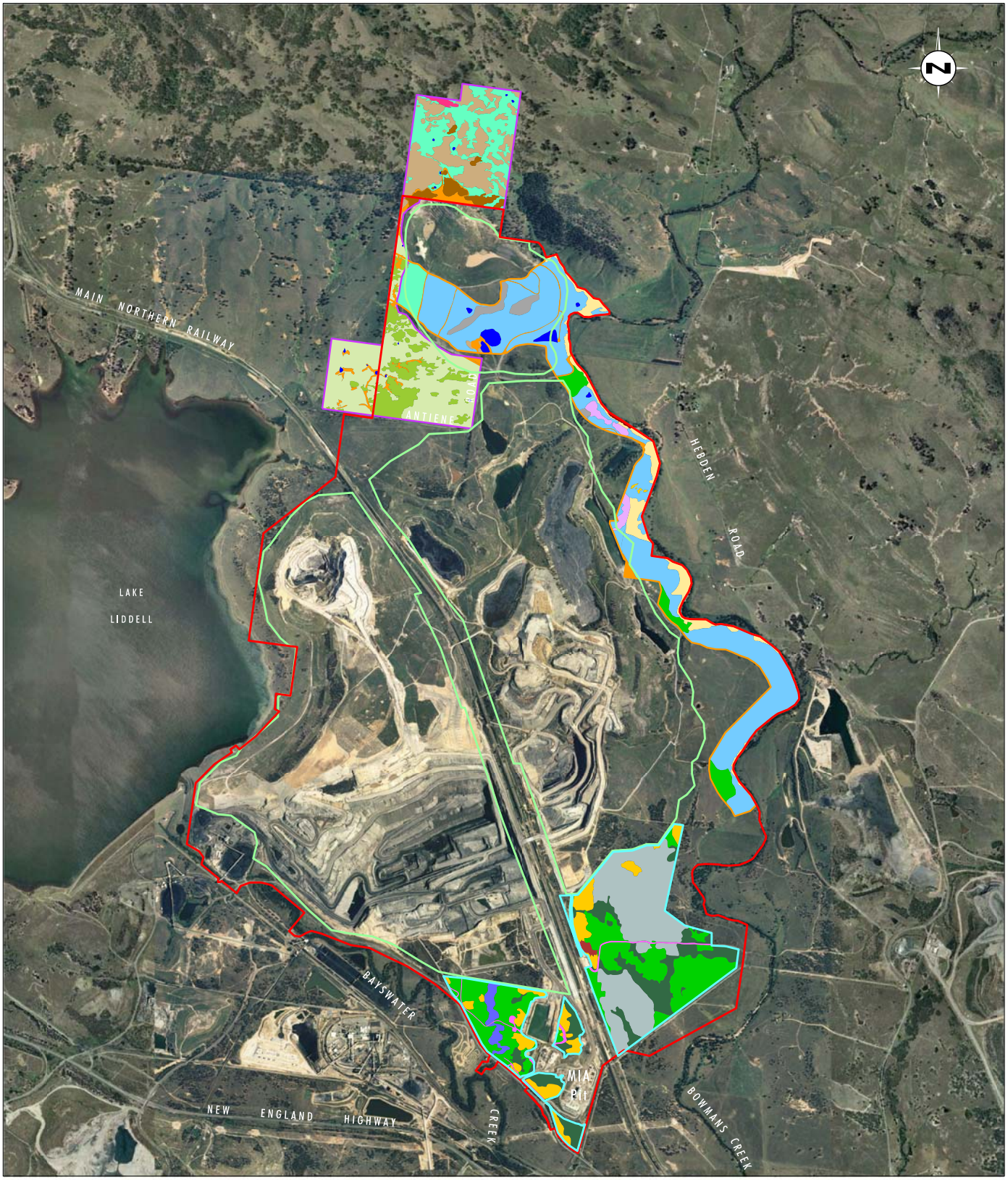



Image Source: Xstrata (2013), Google Earth (2008)
Data Source: Xstrata (2012), ELA (2013)

0 0.5 1.0 2.0km
1:50 000

## Legend

- Liddell Coal Operations Approved DA Boundary
- Approved Mining Footprint
- Referral Area
- Mountain Block Offset Site
- Bowmans Creek Riparian Corridor
- Dam
- Disturbed Land
- Grey Myrtle - Kangaroo Vine Dry Rainforest
- Narrow-leaved Ironbark - Bulloak Open Forest
- Narrow Leaved Ironbark - Bulloak Open Forest DNG
- Narrow leaved Ironbark - Spotted Gum Woodland
- Narrow leaved Ironbark - Spotted Gum Woodland DNG
- Rusty Fig Dry Rainforest
- Central Hunter Box - Ironbark DNG
- Central Hunter Box - Ironbark Woodland
- Central Hunter Box - Ironbark Woodland (regrowth)
- Central Hunter Box - Ironbark Woodland (Rough-barked Apple Dominated)
- Central Hunter Bulloak Forest Regeneration
- Central Hunter Swamp Oak Forest
- Cleared
- Hunter Valley River Oak Forest
- Introduced Grassland
- Introduced Woodland
- Rehabilitation
- Water Body

FIGURE 6.1

**Current Vegetation of the Referral Area, Bowmans Creek Riparian Corridor and Mountain Block Offset Area**

File Name (A4): R06/3122_079.dgn
20131205 15.15

The main sources of potential indirect impact relating to the Proposed Action include dust, noise and groundwater impacts. The existing vegetation in the Referral Area is currently fragmented with only poor connectivity outside of LCO. The Proposed Action will remove this isolated patch of remnant vegetation; however this is unlikely to disrupt local corridor function, as the narrow riparian corridor along Bowmans Creek will not be impacted. Further discussion on potential indirect impacts is provided below.

#### 6.3.1.1 Proximity of Disturbance to Bowmans Creek

The proposed extension of open cut mining associated with the Proposed Action is in the direction Bowmans Creek. However, whilst the Entrance Pit will be extending closer to a portion of Bowmans Creek, existing mining operations at LCO have been undertaken for many years in parallel with the creek, and the proposed extension is a continuation of this as is evident on **Figure 1.2**. The proposed extent of the Entrance Pit at its closest point will be approximately 160 metres from Bowmans Creek, consistent with existing approved operations, which at various locations have come within 110 metres of the creek within the approved mining footprint.

Therefore, given that there are no changes proposed to production levels, mining equipment or mining methods, and that the proposed Entrance Pit extension will be no closer to the creek than previously approved open cut mining activities, the indirect impacts as a result of the Proposed Action are not anticipated to be different to that currently approved.

In relation to potential indirect impacts to the key MNES addressed in this report, only the spotted-tailed quoll has been recorded in the vicinity of, but not within, the Referral Area. This species is known to use the habitats of the Bowmans Creek Riparian Corridor, thus proximity of mining to the creek is relevant to this species. As part of the Proposed Action, the Entrance Pit will extend closer to the Bowmans Creek Riparian Corridor than it currently is. However, the closest point will be approximately 160 metres from the creek, thus will be at least 50 metres further from the creek than previous works within the approved mining footprint. The recorded ongoing use of the corridor by this species (since at least 2008) suggests a degree of resilience to this issue.

The Bowmans Creek Riparian Corridor is assessed as providing poor to moderate habitat for the remaining MNES addressed in this report. This is primarily a result of lack of records (despite considerable survey) and presence of poor (regent honeyeater and swift parrot) to moderate (large-eared pied bat and green and golden bell frog) quality habitat for these species. It is not likely that the increased proximity of the Entrance Pit to the creek will create additional impact to potential habitat for these species.

#### 6.3.1.2 Noise Impacts

With regards to specific indirect impacts as a result of the Proposed Action, particularly in relation to noise, the Noise Assessment conducted by Global Acoustics (2013) concluded that since the Proposed Action will see LCO continuing to dump in similar locations to the operations of the last two years, and that LCO will be required to continue to meet the existing noise criteria for the life of the mine, similar noise levels could therefore be reasonably expected as a result of the Proposed Action.

The spotted-tailed quoll has been recorded in the vicinity of, but not within the Referral Area. Given that noise impacts are currently operating within the habitats of the Referral Area and surrounding areas, and that these noise impacts are not expected to increase as a result of the Proposed Action, there is not likely to be an increase in the impact of noise on this species. This species has utilised and bred in areas affected by comparable noise levels since at least 2008.

Given the lack of records of the remaining MNES within, or near to the Referral Area (despite considerable survey), it is not likely that continuation of the current noise levels as part of the Proposed Action will create additional impact to potential habitat for these species.

#### 6.3.1.3 Lighting Impacts

An increase in lighting related indirect impacts on ecological communities and species is not anticipated given that the Proposed Action will involve a continuation of mining in parallel with Bowmans Creek at the same production levels and operating hours as are currently approved.

The spotted-tailed quoll has been recorded in the vicinity of, but not within the Referral Area. Given that lighting impacts are currently operating within the habitats of the Referral Area and surrounding areas, and that these impacts are not expected to increase as a result of the Proposed Action, there is not likely to be an increase in the impact of lighting on this species. This species has utilised areas affected by comparable lighting levels since at least 2008.

Given the lack of records of the remaining MNES within, or near to the Referral Area (despite considerable survey), it is not likely that continuation of the current lighting impacts as part of the Proposed Action will create additional impact to potential habitat for these species.

#### 6.3.1.4 Dust Impacts

Similarly, an increase in dust related indirect impacts on ecological communities and species is not anticipated given that the Proposed Action will involve a continuation of mining in parallel with Bowmans Creek at the same production levels and operating hours as are currently approved.

The spotted-tailed quoll has been recorded in the vicinity of, but not within the Referral Area. Given that current dust levels/impacts are not expected to increase as a result of the Proposed Action, there is not likely to be an increase in the impact of dust on this species. This species has utilised areas affected by comparable dust levels since at least 2008.

Given the lack of records of the remaining MNES within, or near to the Referral Area (despite considerable survey), it is not likely that continuation of the current dust levels as part of the Proposed Action will create additional impact to potential habitat for these species.

#### 6.3.1.5 Erosion and Sedimentation

Ongoing implementation of effective and appropriate erosion and sediment control measures will continue in the Referral Area, and therefore no indirect impacts to aquatic species in Bowmans and Bayswater Creeks are anticipated to occur. Erosion and sediment control measures are implemented at LCO in accordance with the Landscape Management Plan (LCO, 2013), attached as **Appendix H**.

These measures include:

- Construction of appropriately designed final landform drainage structures;
- Diverting clean water from disturbed areas, and redirecting sediment-loaded water into sedimentation basins;
- Utilisation of cover crops to provide quick re-establishment of ground cover over reshaped emplacement areas for protection against wind and water erosion;
- Construction of sediment control structures where required (e.g. silt fences, hay bales etc.);
- Rehabilitating overburden emplacement areas as close as practical behind active mining areas; and
- Repairs are undertaken to older rehabilitation areas where erosion is evident.

#### 6.3.1.6 Aquifer Drawdown

Expected drawdown along the alluvial aquifer of Bowmans Creek throughout the life of the Proposed Action has been modelled by SKM (2014), and is predicted to peak during the last year of mining in the Entrance Pit, at approximately 1.4 m below the steady state water level pre-1990. Of this 1.4 m, less than 1 m is attributed to the Proposed Action (i.e. the incremental drawdown) with the remaining drawdown as a result of other approved activities in the area.

The peak predicted drawdown is not expected to result in any significant impacts on the aquifer, aquatic ecological features or groundwater dependent ecosystems (GDEs). Whilst ELA (2013) identified stygofauna as a GDE in the Bowmans Creek alluvial aquifer, the predicted impact to Bowmans Creek Alluvium as a result of the Proposed Action is predicted to be minimal. The predicted drawdown in the alluvium will be less than 2 m in two localised areas (refer to **Figure 10.3**) where the depth of alluvium is in excess of 10 m and where water levels are more than 5 m above the base of the formation. Hence, the potential impact will not dry the system and is comparable to seasonal variability. The potential impact would also be very short-lived (during the last year of operations) and recovery is expected to be immediate in these highly transmissive systems. No significant impact is therefore anticipated on stygofauna as a result of the Proposed Action.

It is acknowledged that riparian vegetation along Bowmans Creek also has the potential to be a GDE. In relation to the potential impact of aquifer drawdown on riparian vegetation, the key species of relevance include:

- river oak (*Casuarina cunninghamiana*);
- swamp oak (*Casuarina glauca*);
- forest red gum (*Eucalyptus tereticornis*); and
- rough-barked apple (*Angophora costata*).

From Hubble, Docker and Rutherford (2006), river oak has been stated as having a maximum root depths at 6 to 8 m with minimum depths recorded at 4 m. The stated average maximum root depth for young swamp oak was 44% of its tree height, and 44% for rough-barked apple. In relation to eucalypts, *E. amplifolia* (a species closely related to *E. tereticornis* and growing in similar situations), can have root depths of up to 69% of tree height.

The swamp oak and river oak of the site were recorded at heights of up to 18 m (thus having a root depth in the order of 8 m), with the rough-barked apple being an occasional emergent in that community (thus having a root depth of greater than eight metres). The forest red gum was estimated to be of an average height similar to the rough-barked apple, thus an estimated root depth of greater than ten metres.

As a result, it is unlikely that the dominant riparian canopy species of the riparian communities will be impacted by the predicted aquifer drawdown of approximately 1.4 m below the steady state water level pre-1990. As discussed above this drawdown peak is not expected to be experienced until the last year of mining in the Entrance Pit. There will be at least 7 m of saturated sediments remaining over the majority of the aquifer that will not be impacted, and therefore all of the above species will retain access to groundwater resources within their estimated root depths.

#### 6.3.1.7 Discussion on Adopted Approach to Assessing Indirect Impacts

Indirect impacts should be, and have been as part of the Ecological Assessment, considered on a case by case basis, because the potential for indirect impacts on each species, community or population is different. It is not possible to accurately produce a map showing the expected indirect impacts caused by the Proposed Action. The area over which indirect impacts such as noise and dust pollution could affect ecological communities, endangered populations and species is unique to each indirect impact

type and to the ecological community or species potentially affected. For example indirect impacts from dust will vary according to wind strength and direction and will also vary over time (from hourly to across seasons). Additionally indirect impacts may extend beyond the Proposed Action disturbance footprint to varying distances depending on the ecological community or species affected. While impacts on some species may be relatively localised, impacts on other species may extend a considerable distance from the impact area.

The most pertinent example of this case by case approach is the precautionary assessment approach adopted for the spotted-tailed quoll (*Dasyurus maculatus maculatus*). While the Proposed Action will not directly impact the known breeding den within the LCO holdings, the loss of 121 hectares of moderate quality and 59 hectares of lower quality foraging habitat for this breeding female from the Referral Area could have the potential to threaten future breeding success of this species in the immediate area. Based on the application of the precautionary principle it was concluded that as a result of this indirect impact, the Proposed Action has the potential to result in a significant impact on this species. This conclusion has been reached without confirmation of direct use of the habitats of the Referral Area by this species, despite detailed surveys.

### 6.3.2 Distance of proposed works to habitat of MNES within 1km radius

#### 6.3.2.1 Regent honeyeater (*Anthochaera phrygia*)

There are no records of this species within 1 kilometre of the Referral Area. All of the eucalypt-dominated vegetation within 1 kilometre of the Referral Area would comprise potential habitat for this species, and this is estimated to be approximately 24 hectares. Given the lack of records and relatively small amount of habitat likely to be impacted, it is not likely that the Proposed Action will threaten the likely long-term viability of this species if it were to proceed.

#### 6.3.2.2 Swift parrot (*Lathamus discolor*)

There are no records of this species within 1 kilometre of the Referral Area. All of the eucalypt-dominated vegetation within 1 kilometre of the Referral Area would comprise potential habitat for this species, and this is estimated to be approximately 24 hectares. Given the lack of records and relatively small amount of habitat likely to be impacted, it is not likely that the Proposed Action will threaten the likely long-term viability of this species if it were to proceed.

#### 6.3.2.3 Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)

There are two records of the spotted-tailed quoll within 1 kilometre of the Referral Area, one of these being along Bowmans Creek in the eastern portion of the Referral Area, and the other occurring along Bayswater Creek, in the western portion of the Referral Area. Both of these records lie within 100 metres of the boundary of the Referral Area.

The majority of the habitat within 1 kilometre of the Referral Area comprises likely habitat for the spotted-tailed quoll, being riparian vegetation, woodland, grassland and rehabilitation/planted areas. The only exception would be the highly modified operational areas such as the open cut pit and associated infrastructure. Given the number of records of this species within the LCO Development Consent Boundary and broader area, it must be recognised that these individuals are living (and breeding) within a currently highly modified landscape. Usage of Bowmans Creek by this species has been demonstrated to be high, even with the existing mining operations being within a similar distance to where it will be if the Proposed Action were to proceed. The Proposed Action represents a continuation of comparable levels of those existing disturbances/impacts, however with a commitment to substantial impact mitigation and offsetting outcomes to compensate for the identified loss of habitat. With these commitments in place, it is not likely that the Proposed Action will threaten the long-term viability of this species in the local area.

#### 6.3.2.4 Green and golden bell frog (*Litoria aurea*)

There are no records of this species within 1 km of the Referral Area. Given the lack of records and very small amount of habitat likely to be impacted, it is not likely that the Proposed Action will threaten the likely long-term viability of this species if it were to proceed.

#### 6.3.2.5 Large-eared pied bat (*Chalinolobus dwyeri*)

There are no records of this species within 1 km of the Referral Area. All of the wooded vegetation (including forest/woodland, riparian and rehabilitation/planted habitats) within 1 km of the Referral Area would comprise potential habitat for this species, and this is estimated to be less than 1 ha. Given the lack of records and relatively small amount of habitat likely to be impacted, it is not likely that the Proposed Action will threaten the likely long-term viability of this species if it were to proceed.

## 6.4 Local and Regional Scale Analysis of the Likely Impacts to Protected Matters with Particular Consideration of the Potential for the Proposal to Contribute to Cumulative Impacts

### 6.4.1 Regent honeyeater (*Anthochaera phrygia*)

The regent honeyeater has not been previously recorded within the Referral Area or within a 10 kilometre radius of the Referral Area. Potential habitat for the species comprises eucalypt-dominated woodlands/forests within the Referral Area and due to the significant decrease in habitat for this species (throughout its range, including within the Hunter Valley) and the importance of potential habitat conservation, the removal of approximately 54 hectares of box-gum ironbark woodland within the Referral Area may reduce potential foraging habitat for the species in the local area.

This species is known to undertake a complex series of movements, which are thought to be governed mainly by the flowering of a select number of eucalyptus species. The species is highly mobile, and capable of travelling large distances. The key trend in the movement patterns that relate to the Hunter catchment is:

> Movement into parts of northern NSW and south-east Queensland…in autumn, followed by the concentration of birds into core breeding areas on the inland slopes of the Great Dividing Range in north-western, central-western and south-western NSW…in late winter. (Garnett & Crowley 2000)

It is thought that these regular movements between regions may also be combined with movements on a local scale.

In the Capertee Valley, regent honeyeaters tend to disperse once breeding is complete. Dispersal begins with short distance movements (up to 30 km) into forests on adjacent talus slopes during November and December. More extensive movements begin to occur in February, but the distances and destinations of these movements have yet to be documented.

Recent records from coastal regions of NSW exhibit no seasonal patterns, and it is thought that at least some coastal areas are used when food is scarce in the core breeding areas, none of which occur in the Hunter catchment, occurring in the Bundarra-Barraba area NSW, the Capertee Valley in NSW, and north-eastern Victoria.

The estimated potential habitat for the regent honeyeater within the Hunter region is up to 10,000 $km^2$ (1,000,000 hectares) of eucalypt-dominated woodland and forest. Based on the lack of local records of this species and the loss of a small area of moderate quality habitat, it is not likely that the potential impacts of the Proposed Action will threaten the persistence of this species in the local area or region.

### 6.4.2 Swift Parrot (*Lathamus discolor*)

The swift parrot has been recorded on two occasions in the vicinity of the Mount Owen Complex within Ravensworth State Forest. There have been few records of the species within the central Hunter Valley in the past few years, however recent sightings have been recorded in the winter 2012 season in the Muswellbrook and Bulga (Birdline NSW 2012, Umwelt 2013b) areas. This species may make use of the eucalypt-dominated woodland and forest habitats of the Referral Area, however there have been no records of this species within the LCO Development Consent Boundary. Any use of the habitats of the Referral Area would be intermittent use of prolific flowering eucalypts and this migratory species is likely to move throughout the area in response to mass flowering events. This species does not breed on mainland Australia, and as such the Referral Area only represents foraging habitat for this species. The Proposed Action will result in the removal of approximately 54 hectares of known and potential habitat for the species.

This species breeds in Tasmania and moves to mainland Australia for the non-breeding season (usually arriving between February and March). Most of the population winters in Victoria and New South Wales. Until recently it was believed that in New South Wales, swift parrots forage mostly in the western slopes region along the inland slopes of the Great Dividing Range but are patchily distributed along the north and south coast including the Sydney region. However, evidence is growing that the forests on the coastal plains from southern to northern NSW are also important. They return to Tasmania in spring (September-October). The movements of this species on the mainland are poorly understood, but it is considered to be nomadic and irruptive, moving in response to food supply.

Upon reaching their core non-breeding range there is no known geographical pattern of movement. During the non-breeding season, the home-range varies tremendously between individuals and between years.

The estimated potential habitat for the swift parrot within the Hunter region is up to 10,000 $km^2$ (1,000,000 hectares) of eucalypt-dominated woodland and forest. Based on the lack of local records of this species and the loss of a small area of moderate quality habitat, it is not likely that the potential impacts of the Proposed Action will threaten the persistence of this species in the local area or region.

### 6.4.3 Spotted-tailed quoll (SE mainland population) (*Dasyurus maculatus maculatus*)

There are a number of records of this species in the general locality (defined here as the middle Foy Brook area, which comprises the land to the east and north-east of Lake Liddell and to the north of the New England Highway). At least six distinct individuals have been identified from the various captures, photographs and radio-tracking of this species that has occurred within the LCO, Mount Owen Complex and Mountain Block sites.

These records are deemed to represent a local population of spotted-tailed quolls making regular use of the various habitat types within the Foy Brook area, including within LCO, Mount Owen Complex, Ravensworth State Forest, Mount Owen Offset Areas, Ravensworth Operations Hillcrest Offset Area, Bowmans Creek and Mountain Block Offset Area. Records in the locality are generally concentrated on Bowmans Creek and Ravensworth State Forest, however also extend into the more disturbed areas (from operational mining, power stations or cleared agricultural areas) surrounding these.

A known female breeding den site occurs to the west of Bowmans Creek within LCO and about 1.75 km to the north of the Referral Area. A number of known male den sites are located nearby at Mount Owen and within the Mountain Block Offset Area.

All of the natural and derived native vegetation communities in the local area provide potential foraging habitat for the spotted-tailed quoll. These include derived native grassland, woodland, forest, riparian, rainforest and rehabilitated vegetation. Thus the various habitats of the Referral Area are likely to form part of the home range of the breeding female identified at LCO, and also possibly an overlapping

(although generally larger) male home range. The Referral Area itself does not contain known den or breeding sites for the spotted-tailed quoll, however a den where breeding is known to have occurred is located approximately 1.75 km to the north of the Referral Area.

The presence of this local population is of importance as there are few areas within the central Hunter Valley lowlands (the main Hunter Valley) that are of sufficient size to support the home ranges of this species and that contain such a concentration of known records, including a confirmed breeding den.

The Proposed Action will remove 180 hectares of potential foraging habitat for this local population. However, most of the habitat is likely to be of moderate habitat quality at best. Furthermore, the habitat loss is staged so that the resulting impact to potential habitat for this species will occur over a number of years.

The Proposed Action will not directly impact on the known breeding den site. There is the potential for indirect impacts, through the removal of potential foraging habitat, to affect the ongoing use of the den site by the breeding female.

Although the loss of 180 ha of potential foraging habitat is important in the local context, at the scale of the regional population defined for this assessment it constitutes only 0.11 per cent of habitat which is potentially available for the spotted-tailed quoll.

There are few woodland areas within the central Hunter Valley lowlands (the main Hunter Valley) that are of sufficient size to support the home range of this species. It is recognised that for a habitat generalist such as the quoll it is difficult to define a regional population. It is likely that the fragmented habitats of the Hunter Valley floor (as well as major road, rail and other infrastructure networks crossing it) would limit genetic exchange from the Barrington Tops area in a southerly direction, thus providing a likely genetic barrier to individuals of this species in the Wollemi/Yengo National Parks areas. The Barrington Tops and Mount Royal Range areas provide reasonable geographic features with which to bound the population to the north, although there is likely to be no firm discontinuity in species records between the Referral Area and habitats to the north of Barrington Tops. For the purpose of this assessment, it is taken that a regional population of this species is focused on the foot slopes to the south and west of the Barrington Tops and that this is likely to be genetically distinct and fragmented from those on the southern side of the Hunter Valley. This area comprises some 1800 $km^2$ of land, of which approximately 48 per cent is wooded, with about 52 per cent comprising agricultural lands. This regional population includes the middle Foy Brook local population identified earlier.

While the Proposed Action will not directly impact the known breeding den within the LCO holdings, the loss of 121 hectares of moderate quality and 59 hectares of lower quality foraging habitat for this breeding female from the Referral Area could have the potential to threaten future breeding success of this species in the immediate area. Based on the application of the precautionary principle it was concluded that as a result of this indirect impact, the Proposed Action has the potential to result in a significant impact on this species. This conclusion has been reached without confirmation of direct use of the habitats of the Referral Area by this species, despite detailed surveys.

### 6.4.4 Green and golden bell frog (*Litoria aurea*)

There are no records of the green and golden bell frog in the Referral Area or within LCO. An unconfirmed record of the species exists from the north-east shore of Lake Liddell in 2006 (DECC 2007), and the species was recorded during surveys for the Ravensworth North Project in 2009. This species has been recorded at the Mount Owen Complex, with the last confirmed record being in 1999 (Forest Fauna Surveys and Newcastle Innovation 2012) (refer to **Figure 5.1**).

These records form part of the Upper Hunter Green and Golden Bell Frog Key Population consisting of one main diffuse population at, or in the vicinity of, the Ravensworth and Liddell area and bordering areas of the Singleton and Muswellbrook local government areas (DECC 2007). The Upper Hunter Key

Population is one of two inland populations of the species and is known from eight verified locations. The population is assumed to have a diffuse distribution across lands encompassed by these locations and has been recorded only sporadically, probably as a result of climatic circumstances and/or seasonal life cycle changes of the species (DECC 2007).

Researchers from the University of Newcastle indicate that it is highly likely that the precipitous state of the Upper Hunter population is directly due to the impact of disease rather than habitat or other ecological factors (Forest Fauna Surveys and Newcastle Innovation 2012).

The Proposed Action will impact on <0.5 hectares of potential habitat for this species within the Referral Area. This habitat is of particularly poor quality, comprising four small farm dams (smaller than the minimum mapping unit for the project) with little to no fringing vegetation and often poor water quality. Based on the loss of such a small area of poor quality habitat with no records of the species for many years, and in considering the conclusions of the University of Newcastle relating to the key threats to the Upper Hunter Green and Golden Bell Frog Key Population, it is not likely that the potential impacts of the Proposed Action will threaten the persistence of this species in the local area or region.

### 6.4.5 Large-eared pied bat (*Chalinolobus dwyeri*)

This species has not been recorded within the Referral Area or within the broader LCO holdings, despite many years of ecological survey and monitoring.

The large-eared pied bat has been recorded through analysis of echolocation calls on four occasions during monitoring of the Mount Owen Complex (Forest Fauna Surveys and Newcastle Innovation 2012). All of these identifications have been deemed as “possible” only; there have been no confirmed records of this species from this monitoring.

There are no records of this species within a 10 kilometre radius of the Referral Area (OEH Atlas of NSW Wildlife), however the Protected Matters Search Tool identifies that this species or species habitat may occur within a 10 kilometre radius of the Referral Area.

All woodland vegetation within the Referral Area is expected to provide potential foraging habitat for this species, however no roosting habitat for this cave roosting species has been identified. The Referral Area is considered to comprise an area of foraging habitat for this species however is unlikely to contain significant breeding and roosting habitat.

The estimated potential habitat for the large-eared pied bat within the Hunter region is up to 10,000 $km^2$ (1,000,000 hectares) of eucalypt-dominated woodland and forest. Based on the lack of local records of this species and the loss of a small area of moderate quality habitat, it is not likely that the potential impacts of the Proposed Action will threaten the persistence of this species in the local area or region.

## 6.5 Whether any Impacts are Likely to be Unknown, Unpredictable or Irreversible

The impact assessment has considered all anticipated impacts from the Proposed Action on MNES, including both direct impacts (from vegetation clearing/habitat loss) and indirect impacts (see **Section 6.3.1**) such as dust, noise and impacts on groundwater resources. In adopting a precautionary approach to impact assessment, including which species may be impacted upon, this Preliminary Documentation has presented a robust impact assessment that has considered all known, predicted and potential impacts on MNES.

Part of this impact assessment process has been a strong commitment to avoid, minimise, mitigate and then finally offset residual impacts. Part of this process it to build in a strong commitment to rehabilitation of disturbed areas, with focus on returning ecological communities comparable to those which were

impacted. Successful reestablishment and ongoing management of vegetation communities and fauna habitat (to the standards committed to within the Proposed Action) will ensure that, in the medium to long term, the impacts of vegetation loss as a result of the Proposed Action will not be irreversible.

## 6.6 Additional Studies or Surveys not Included in the Referral

**Tables 5.9 and 5.10** identify those field surveys which have been considered as part of this Proposed Action. Those surveys that have been completed since the submission of the Referral include the following:

- Umwelt – Referral Area and Bowmans Creek Riparian Corridor - 6 to 17 June 2013 – targeted spotted-tailed quoll surveys including remote camera surveys, targeted quoll habitat searches, opportunistic surveys, habitat assessments, and spotlighting;

- Umwelt - Bowmans Creek Riparian Corridor - 6 to 8 November 2013 – including habitat assessment, Anabat echolocation surveys and opportunistic observations; and

- Umwelt – Mountain Block Offset Area - 7 and 12 June 2013 – including remote camera surveys, targeted quoll habitat searches, opportunistic surveys, bird census, habitat assessments and spotlighting.

In addition to this, **Section 5.4.4.3** identifies those previous ecological monitoring projects or surveys for ecological monitoring projects and surveys for earlier approvals between 2001 and 2013. The results of these surveys have been incorporated into this document, where appropriate, particularly in relation to records of the spotted-tailed quoll and survey and habitat issues relating to the regent honeyeater, swift parrot, green and golden bell frog, large-eared pied bat and any other MNES relevant to this Proposed Action.

# 7.0 PROPOSED AVOIDANCE, MANAGEMENT AND MITIGATION MEASURES

**The preliminary documentation must provide information about measures proposed to be undertaken to avoid, mitigate, and manage potential impacts to matters of national environmental significance, including:**

## 7.1 A Description of, and Discussion About, the Suitability and Likely Effectiveness of any Proposed Measures to Avoid and Mitigate Impacts, with Reference to any Relevant Literature and the Provision of Examples, where appropriate

### 7.1.1 Proposed Action Changes to Avoid and Minimise Impacts

The potential impacts of the Proposed Action on the ecological values of the Referral Area were recognised early in the project planning. LCO has undertaken detailed concept and pre-feasibility studies into the Proposed Action and as part of this process numerous alternative mine and infrastructure plans were considered. Minimising environmental and community impacts and maximising economic resource recovery have been major considerations in the evaluation of alternative options.

The original proposed limit of open cut mining associated with the Entrance Pit was reduced in the vicinity of Bowmans Creek, primarily to minimise disturbance of a Sensitive Archaeological Landscape (SAL) identified in the Cultural Heritage Assessment as much as possible. The Entrance Pit Extension was also designed to ensure that the limit of open cut mining is a minimum 150 metres from the mapped alluvial boundary associated with Bowmans Creek. This avoidance of the creek line has also avoided sensitive riparian vegetation and threatened species habitat.

A variation to the final landform was also investigated as part of the iterative mine design process. An additional out-of-pit dump emplacement was considered immediately adjacent to the south eastern boundary of the Entrance Pit open cut extension area, adjacent to Bowmans Creek. Locating an overburden emplacement in this area was most advantageous due to the short haul distance from the active mining area. Despite being the most economic efficient location, this out-of-pit dump was removed from the Project for two reasons; firstly it involved disturbance of the Bowmans Creek SAL, and secondly, the location of the dump was found to be Class 2 (alluvial) land during completion of the Soil and Land Resource Assessment for the Project (GSSE, 2013a). Approval for this dump is therefore no longer sought, reducing the impacts on land resources, riparian vegetation and archaeological values associated with the Project.

In addition, the original proposal included the construction of a tailings dam to the north of Reservoir block (north of the current Referral Area), with material from the excavation to be dumped around the western edge of the dam. This tailing dam is not included in the current Proposed Action. The proposed location of this dam was directly west of the recently identified latrine site of the spotted-tailed quoll, and its removal both reduces the additional surface disturbance associated with the Proposed Action, and extends the distance between the latrine site, den site and the Referral Area. This dam would also have required disturbance to an established rehabilitation area. The South Pit void will now be used to accommodate tailings disposal.

Furthermore, the Proposed Action will not extend outside of the confines of the existing approved development consent boundary.

### 7.1.2 Impact Mitigation and Management Strategies

One of the key goals of the impact mitigation strategy is to maintain or improve ecological features within the area, in order to manage and minimise unavoidable impacts on the ecological features of the Referral Area. To achieve this, current management actions that are being employed at LCO are described, as well as additional actions that will be adopted as part of this Proposed Action.

LCO currently implements a number of general ecological management actions across LCO as identified in the Liddell Landscape Management Plan (Umwelt 2012). Specific control measures that are considered integral to the protection and preservation of the ecological features of the LCO holdings are detailed in **Section 7.3**.

The LCO Landscape Management Plan (Umwelt 2012) (refer **Appendix H**) will be updated in order to capture the specific ecological impact mitigation and management strategies that have been determined as part of the Proposed Action (as presented below in detail in **Section 7.1.3** for each MNES). This plan will detail how the commitments from the Proposed Action will be implemented across the proposed offset areas as described below in **Section 7.1.3**, and will be submitted to the relevant agencies for review and approval. The document will include a concise and auditable strategy for the implementation of the offset strategy.

Further details of the avoidance and mitigation measures as they relate to the specifically-mentioned MNES are provided in the sections below.

### 7.1.3 Avoidance and Mitigation Measures – Regent Honeyeater and Swift Parrot

#### 7.1.3.1 Species Occurrence and Nature of Impact

There are no records of either the regent honeyeater or swift parrot within the Referral Area or within the broader LCO holdings despite many years of ecological survey and monitoring. Local records and records within a 10 kilometre radius of the Referral Area are discussed in **Section 5.3.3**, above.

The Proposed Action will result in a variety of impacts on the ecological features of the Referral Area, the majority of these being direct impacts from the extension of existing open cut mining operations and associated infrastructure. In relation to the impacts on the regent honeyeater and swift parrot, the most pertinent impact is the loss of 54 hectares of moderate quality potential habitat as a result of vegetation clearance across the Referral Area.

In developing the avoidance and mitigation measures, the scale of the impact of the Action on the regent honeyeater and swift parrot was assessed using the Department of the Environment Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DEWHA 2009) in the form of an assessment of significance. It was considered in that assessment that the lack of records, the proposed loss of 54 hectares of only moderate quality potential habitat and the proposed measures to avoid or reduce impacts on the regent honeyeater and swift parrot were enough to reduce the level of impact below the considered 'significant impact' threshold.

#### 7.1.3.2 Avoidance Measures

The potential impacts of the Proposed Action on the ecological values of the Referral Area were recognised early in the Project. LCO undertook detailed concept and pre-feasibility studies into the proposed mining operation and as part of this process numerous alternative mine and infrastructure plans were considered. Minimising environmental and community impacts while maximising economic resource recovery have been major considerations in the evaluation of alternative options.

Throughout the project planning process, LCO has undertaken revisions of the Referral Area including a reduction to the original proposed limit of the Entrance Pit to avoid riparian areas and relocation of a

proposed tailings dam into the South Pit void to avoid disturbance to a rehabilitation area near to known records of MNES (spotted-tailed quoll). These measures have all served to reduce the clearing of vegetation required for the Proposed Action, thus will avoid loss of potential habitat for these species.

#### 7.1.3.3 Proposed Mitigation Measures

The key biodiversity mitigation strategies relevant to the regent honeyeater and swift parrot proposed for the Proposed Action are:

- rehabilitation and/or regeneration of grassland areas to woodland form;
- fencing/access control;
- weed control;
- feral animal control;
- bushfire management;
- adaptive management, using the findings of the monitoring and inspection programs to refine mitigation strategies or develop new strategies as required;
- implementation of a tree felling procedure; and
- habitat enhancement of existing areas (via nest boxes, hollow salvage and replacement of other specific habitat features).

Each of these proposed mitigation strategies will result in a reduction in the extent or intensity of the impacts of the Proposed Action on the regent honeyeater and swift parrot. Rehabilitation/regeneration will directly increase the amount of eucalypt-dominated habitat for these species within the proposed offset areas. Fencing/access control, weed control, feral animal control and appropriate bushfire management will all contribute to improved habitat quality for these species by reducing the incidence of these known threats on the quality of habitat within the proposed offset areas. The remaining measures will have a reduced benefit to these species as they are not dependent on the hollows of the area and habitat enhancement measures are not likely to increase specific habitat features for these species. The implementation of the above measures, particularly the rehabilitation of previously disturbed areas and grassland to woodland/forest habitats will counterbalance the potential impacts of the Proposed Action on potential habitat for these species.

General noise, dust, fugitive light and water mitigation measures will also act to indirectly minimise potential impacts on areas of potential habitat occurring adjacent to the Referral Area. Comprehensive and effective mitigation measures for each of these potential impacts are already in place at LCO, and will continue as mining activities progress into the Referral Area as part of the Proposed Action. These measures are outlines below in **Section 7.3.8**.

The progressive rehabilitation of post-mining areas throughout the life of the Proposed Action will result in the creation of approximately 731 hectares of potential foraging habitat for the regent honeyeater and swift parrot in the medium term. Rehabilitation will focus on the establishment of a mixture of grassland for future agricultural uses and eucalypt dominated corridors that will provide fauna habitat as well as promote local connectivity. Target communities will be representative of the communities that were present within the Referral Area and LCO prior to mining and will include:

- 731 hectares of Native Woodland (consistent with Central Hunter Box – Ironbark Woodland); and
- 1247 hectares of Open Grassland with Pockets of Native Vegetation.

It is noted that of this total planned post-mining rehabilitation, 615 hectares of mined land has already been rehabilitated at LCO, as reported in the 2012 Annual Environmental Management Report.

Planted rehabilitation areas are anticipated to provide foraging habitat for the swift parrot and regent honeyeater from around 10 years of age, however, it could be much earlier and will depend on what age the establishing eucalypts flower (flowering has been seen as early as 2-3 years with many sites around 5 years).

In addition to proposed avoidance and mitigation measures that will be undertaken, there is a large amount of potential and known habitat for the regent honeyeater and swift parrot within a 10 kilometre radius of the Referral Area, as identified in **Section 5.4.1**.

The outcomes of ecological monitoring will be reviewed and used to improve site ecological management where results of monitoring indicated this is required. The management of the ecological components of the Proposed Action will be responsive to any new ecological data that may arise through the ecological monitoring of the Referral Area, or any other studies completed as part of the Proposed Action. This will enable a flexible approach to the mitigation requirements of the Proposed Action, allowing ongoing feedback and refinement of the mitigation strategy.

### 7.1.4 Avoidance and Mitigation Measures – Spotted-tailed Quoll

#### 7.1.4.1 Species Occurrence and Nature of Impact

There are no records of the spotted-tailed quoll within the Referral Area, however at least six individuals have been recorded from the broader local area, including the Bowmans Creek Corridor, Mountain Block, LCO, Mount Owen Complex and Ravensworth Operations Hillcrest Offset Area. Local records and records within a 10 kilometre radius of the Referral Area are discussed in **Section 5.3.3**, above.

The Proposed Action will result in a variety of impacts on the ecological features of the Referral Area, the majority of these being direct impacts from the extension of existing open cut mining operations and associated infrastructure. In relation to the impacts on spotted-tailed quoll, the most pertinent impact is the loss of 180 hectares of potential habitat (121 hectares of moderate quality potential habitat and 59 hectares of low quality potential habitat) as a result of vegetation clearance across the Referral Area.

In developing the avoidance and mitigation measures, the scale of the impact of the Action on the spotted-tailed quoll was assessed using the Department of the Environment Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DEWHA 2009) in the form of an assessment of significance. It was considered in that assessment that the lack of records, the proposed loss of 180 hectares of only moderate and low quality potential habitat and the proposed measures to avoid or reduce impacts on the spotted-tailed quoll were not enough to reduce the level of impact below the considered ‘significant impact’ threshold.

#### 7.1.4.2 Avoidance Measures

The potential impacts of the Proposed Action on the ecological values of the Referral Area were recognised early in the Project. LCO undertook detailed concept and pre-feasibility studies of the proposed mining operation and as part of this process numerous alternative mine and infrastructure plans were considered. Minimising environmental and community impacts while maximising economic resource recovery have been major considerations in the evaluation of alternative options.

Throughout the project planning process, LCO has undertaken revisions of the Referral Area including a reduction to the original proposed limit of the Entrance Pit to avoid riparian areas and relocation of a proposed tailings dam into the South Pit void to avoid disturbance to a rehabilitation area near to known records of MNES (spotted-tailed quoll). These measures have all served to reduce the clearing of vegetation required for the Proposed Action, thus will avoid loss of potential habitat for the spotted-tailed quoll.

#### 7.1.4.3 Proposed Mitigation Measures

The key biodiversity mitigation strategies relevant to the spotted-tailed quoll proposed for the Proposed Action are:

- rehabilitation and/or regeneration of grassland areas to woodland form;
- fencing/access control;
- weed control;
- feral animal control;
- bushfire management;
- adaptive management, using the findings of the monitoring and inspection programs to refine mitigation strategies or develop new strategies as required;
- implementation of a tree felling procedure; and
- habitat enhancement of existing areas (via nest boxes, hollow salvage and replacement of other specific habitat features).

Each of these proposed mitigation strategies will result in a reduction in the extent or intensity of the impacts of the Proposed Action on the spotted-tailed quoll. Rehabilitation/regeneration will directly increase the amount of vegetated habitat for this species within the proposed offset areas. Fencing/access control, weed control, feral animal control and appropriate bushfire management will all contribute to improved habitat quality for this species by reducing the incidence of these known threats in the proposed offset areas. Feral animal control will be of particular benefit to this species by reducing direct predation and competition from dogs and foxes, as well as reduce predation pressure on quoll prey species by dogs, cats and foxes.

A detailed tree felling procedure will ensure as little potential for injury to this species during the clearing/construction phase as possible. Habitat enhancement works will be targeted to this species where denning opportunities (such as timber/boulder piles and tree hollows) can be augmented within existing vegetation (where deemed lacking) and within rehabilitated/regenerated areas. Other habitat augmentation activities are likely to increase habitat for prey species such as possums and terrestrial species such as reptiles and small mammals.

The implementation of the above measures, particularly the rehabilitation of previously disturbed areas and grassland to woodland/forest habitats will counterbalance the potential impacts of the Proposed Action on potential habitat for the spotted-tailed quoll.

General noise, dust, fugitive light and water mitigation measures will also act to indirectly minimise potential impacts on areas of potential habitat occurring adjacent to the Referral Area. Comprehensive and effective mitigation measures for each of these potential impacts are already in place at LCO, and will continue as mining activities progress into the Referral Area as part of the Proposed Action. These measures are outlines below in **Section 7.3.8**.

The progressive rehabilitation of post-mining areas throughout the life of the Proposed Action will result in the creation of approximately 1978 hectares of potential foraging habitat for the spotted-tailed quoll in the medium term within the LCO DA boundary. Of this total planned post-mining rehabilitation, 615 hectares of mined land has already been rehabilitated at LCO, as reported in the 2012 Annual Environmental Management Report.

Rehabilitation will focus on the establishment of a mixture of grassland for future agricultural uses and eucalypt dominated corridors that will provide fauna habitat as well as promote local connectivity. Both habitat types will form habitat for the spotted-tailed quoll. Target communities will be representative of the communities that were present within the Referral Area and LCO prior to mining and will include:

- 731 hectares of Native Woodland (consistent with Central Hunter Box – Ironbark Woodland); and
- 1247 hectares of Open Grassland with Pockets of Native Vegetation.

Planted rehabilitation areas are anticipated to provide foraging habitat for the spotted-tailed quoll from an early age, estimated to be in the order of 5 years, depending on the level of habitat augmentation employed in these areas.

In addition to proposed avoidance and mitigation measures that will be undertaken, there is a large amount of potential and known habitat for the spotted-tailed quoll within a 10 kilometre radius of the Referral Area, as identified in **Section 5.4.1**.

The outcomes of ecological monitoring will be reviewed and used to improve site ecological management. The management of the ecological components of the Proposed Action will be responsive to any new ecological data that may arise through the ecological monitoring of the Referral Area, or any other studies completed as part of the Proposed Action. This will enable a flexible approach to the mitigation requirements of the Proposed Action, allowing ongoing feedback and refinement of the mitigation strategy.

### 7.1.5 Avoidance and Mitigation Measures – Green and Golden Bell Frog

There are no records of the green and golden bell frog within the Referral Area or within the broader LCO holdings despite many years of ecological survey and monitoring. Local records and records within a 10 kilometre radius of the Referral Area are presented on **Figure 5.1**.

Due to a lack of appropriate habitat for this species within the Referral Area, and a paucity of recent records within a 10 kilometre radius of the Referral Area (the most recent confirmed record was made at Mount Owen in 1999 (Forest Fauna Surveys and Newcastle Innovation 2012)) it is not considered likely that this species would occur within the Referral Area or be impacted by the Proposed Action. In the event that this species were to occur within the Referral Area, there would be less than 0.5 hectares of low quality habitat available to it. The habitat within the Referral area is not considered significant to this species.

#### 7.1.5.1 Avoidance Measures

The potential impacts of the Proposed Action on the ecological values of the Referral Area were recognised early in the Project. LCO undertook detailed concept and pre-feasibility studies into the proposed mining operation and as part of this process numerous alternative mine and infrastructure plans were considered. Minimising environmental and community impacts while maximising economic resource recovery have been major considerations in the evaluation of alternative options.

Throughout the project planning process, LCO has undertaken revisions of the Referral Area including a reduction to the original proposed limit of the Entrance Pit to avoid riparian areas and relocation of a proposed tailings dam into the South Pit void to avoid disturbance to a rehabilitation area near to known records of MNES (spotted-tailed quoll). These measures have all served to reduce the clearing of vegetation required for the Proposed Action, thus will avoid loss of potential riparian habitat for this species.

#### 7.1.5.2 Proposed Mitigation Measures

The key biodiversity mitigation strategies relevant to the green and golden bell frog proposed for the Proposed Action are:

- fencing/access control;
- weed control;

- feral animal control;
- bushfire management;
- adaptive management, using the findings of the monitoring and inspection programs to refine mitigation strategies or develop new strategies as required; and
- implementation of a pre-clearing procedure.

Each of these proposed mitigation strategies will result in a reduction in the extent or intensity of the impacts of the Proposed Action on the green and golden bell frog. Rehabilitation/regeneration works proposed within the Bowmans Creek Riparian Corridor will improve riparian habitat for this species, as well as assist in bank stabilisation and reduce erosion. Access control to the riparian areas will assist in reducing unintentional damage to creek banks and weed infestations. Feral animal control will reduce predation potential to dispersing individuals. In particular, the pre-clearance procedure will be used to identify potentially occurring green and golden bell frog records in dams prior to undertaking any clearance works.

General noise, dust, fugitive light and water mitigation measures will also act to indirectly minimise potential impacts on areas of potential habitat occurring adjacent to the Referral Area. Comprehensive and effective mitigation measures for each of these potential impacts are already in place at LCO, and will continue as mining activities progress into the Referral Area as part of the Proposed Action. These measures are outlines below in **Section 7.3.8**.

In addition to proposed avoidance and mitigation measures that will be undertaken, there is a large amount of potential habitat for the green and golden bell frog within a 10 kilometre radius of the Referral Area.

The outcomes of ecological monitoring will be reviewed and used to improve site ecological management. The management of the ecological components of the Proposed Action will be responsive to any new ecological data that may arise through the ecological monitoring of the Referral Area, or any other studies completed as part of the Proposed Action. This will enable a flexible approach to the mitigation requirements of the Proposed Action, allowing ongoing feedback and refinement of the mitigation strategy.

### 7.1.6 Avoidance and Mitigation Measures – Large-eared Pied Bat

There are no records of the large-eared pied bat within the Referral Area or within the broader LCO holdings despite many years of ecological survey and monitoring. Local records and records within a 10 kilometre radius of the Referral Area are discussed in **Section 5.3.3**, above.

The Proposed Action will result in a variety of impacts on the ecological features of the Referral Area, the majority of these being direct impacts from the extension of existing open cut mining operations and associated infrastructure. In relation to the impacts on the large-eared pied bat, the most pertinent impact is the loss of 121 hectares of moderate quality potential habitat as a result of vegetation clearance across the Referral Area.

In developing the avoidance and mitigation measures, the scale of the impact of the Action on the large-eared pied bat was assessed using the Department of the Environment Significant Impact Guidelines 1.1 – Matters of National Environmental Significance (DEWHA 2009) in the form of an assessment of significance. It was considered in that assessment that the lack of records, the proposed loss of 121 hectares of only moderate quality potential habitat and the proposed measures to avoid or reduce impacts on the large-eared pied bat were enough to reduce the level of impact below the considered ‘significant impact’ threshold.

#### 7.1.6.1 Avoidance Measures

The potential impacts of the Proposed Action on the ecological values of the Referral Area were recognised early in the Project. LCO undertook detailed concept and pre-feasibility studies into the proposed mining operation and as part of this process numerous alternative mine and infrastructure plans were considered. Minimising environmental and community impacts while maximising economic resource recovery have been major considerations in the evaluation of alternative options.

Throughout the project planning process, LCO has undertaken revisions of the Referral Area including a reduction to the original proposed limit of the Entrance Pit to avoid riparian areas and relocation of a proposed tailings dam into the South Pit void to avoid disturbance to a rehabilitation area near to known records of MNES (spotted-tailed quoll). These measures have all served to reduce the clearing of vegetation required for the Proposed Action, thus will avoid loss of potential habitat for these species.

#### 7.1.6.2 Proposed Mitigation Measures

The key biodiversity mitigation strategies relevant to the large-eared pied bat proposed for the Proposed Action are:

- rehabilitation and/or regeneration of grassland areas to woodland form;
- fencing/access control;
- weed control;
- feral animal control;
- bushfire management;
- adaptive management, using the findings of the monitoring and inspection programs to refine mitigation strategies or develop new strategies as required;
- implementation of a tree felling procedure; and
- habitat enhancement of existing areas (via nest boxes, hollow salvage and replacement of other specific habitat features).

Each of these proposed mitigation strategies will result in a reduction in the extent or intensity of the impacts of the Proposed Action on the large-eared pied bat. Rehabilitation/regeneration will directly increase the amount of vegetated habitat for this species within the proposed offset areas. Fencing/access control, weed control, feral animal control and appropriate bushfire management will all contribute to improved habitat quality for this species by reducing the incidence of these known threats on the quality of habitat within the proposed offset areas. The remaining measures will have a reduced benefit to these species as they are not dependent on the hollows of the area and habitat enhancement measures are not likely to increase specific habitat features for these species.

The implementation of the above measures, particularly the rehabilitation of previously disturbed areas and grassland to woodland/forest habitats will counterbalance the potential impacts of the Proposed Action on potential habitat for the large-eared pied bat.

General noise, dust, fugitive light and water mitigation measures will also act to indirectly minimise potential impacts on areas of potential habitat occurring adjacent to the Referral Area. Comprehensive and effective mitigation measures for each of these potential impacts are already in place at LCO, and will continue as mining activities progress into the Referral Area as part of the Proposed Action. These measures are outlines below in **Section 7.3.8**.

The progressive rehabilitation of post-mining areas throughout the life of the Proposed Action will result in the creation of approximately 731 hectares of potential foraging habitat for the large-eared pied bat in the medium term. Rehabilitation will focus on the establishment of a mixture of grassland for future agricultural uses and eucalypt dominated corridors that will provide fauna habitat as well as promote

local connectivity. Target communities will be representative of the communities that were present within the Referral Area and LCO prior to mining and will include:

- 731 hectares of Native Woodland (consistent with Central Hunter Box – Ironbark Woodland); and
- 1247 hectares of Open Grassland with Pockets of Native Vegetation.

It is noted that of this total planned post-mining rehabilitation, 615 hectares of mined land has already been rehabilitated at LCO, as reported in the 2012 Annual Environmental Management Report.

Planted rehabilitation areas are anticipated to provide foraging habitat for the large-eared pied bat from around 10 years of age, however, it could be much earlier and will depend on what age the establishing eucalypts flower (flowering has been seen as early as 2-3 years with many sites around 5 years).

In addition to proposed avoidance and mitigation measures that will be undertaken, there is a large amount of potential habitat for the large-eared pied bat within a 10 kilometre radius of the Referral Area, as identified in **Section 5.4.1**.

The outcomes of ecological monitoring will be reviewed and used to improve site ecological management. The management of the ecological components of the Proposed Action will be responsive to any new ecological data that may arise through the ecological monitoring of the Referral Area, or any other studies completed as part of the Proposed Action. This will enable a flexible approach to the mitigation requirements of the Proposed Action, allowing ongoing feedback and refinement of the mitigation strategy.

## 7.2 Map(s) Illustrating the Location(s) of any Proposed Construction Exclusion Zones and Buffer Zones, and Details about how those areas will be Avoided or Protected

There are no proposed construction exclusion zones or buffer zones included within the Referral Area. For the purposes of the Proposed Action, it has been assumed that all vegetation within the Referral Area will be removed. The impact assessment and design of avoidance, minimisation, mitigation and offsetting strategies has been based on this approach.

## 7.3 Description of any Mitigation Measures Proposed to Address Indirect Impacts to Matters of National Environmental Significance that occur both On and Off-site

**This is to include (for example) erosion, sediment, weed and hygiene control measures. Any proposal to rehabilitate temporarily disturbed areas must also be described in detail. For all mitigation measures, please include environmental objectives, performance criteria, methodology, timing, duration, monitoring, reporting (by whom, to whom, how often), corrective actions and responsibility for implementation. This must be addressed for all phases of the proposed action.**

LCO has sought to avoid and minimise potential impacts on the ecological values of the Referral Area throughout the planning phases of the Proposed Action. This has included avoidance and minimisation of key vegetation communities and associated fauna habitats. LCO has committed to the design and implementation of a comprehensive mitigation strategy to mitigate the unavoidable impacts of the Proposed Action – both direct and indirect. Further to this, a comprehensive biodiversity offset strategy has been developed, which includes the protection and enhancement of native vegetation and threatened species habitat, to develop a positive long-term outcome for the threatened species and key ecological features affected by the Proposed Action.

### 7.3.1 Actions to Maintain Ecological Value in the LCO Holdings

LCO currently implements a number of general ecological management actions across the LCO holdings as identified in the LCO Landscape Management Plan (Umwelt 2012). As part of the requirements of this Plan, the following specific control measures are considered to be integral to the protection and preservation of the ecological features of the LCO holdings:

- rehabilitation of post-mined and other disturbed areas to vegetation communities consistent with extant vegetation communities;
- use of native species of suitable local provenance (wherever possible) in rehabilitation works, and planning for the linkage and integration of rehabilitation areas with existing vegetated areas to improve ecological function and provide appropriate fauna habitat;
- ongoing monitoring and maintenance of all revegetation works and habitat enhancement activities;
- a comprehensive tree-felling procedure to minimise impacts of clearing on native fauna and flora;
- fencing and access control;
- weed control and feral animal control in accordance with existing practices across the LCO holdings;
- ensuring appropriate erosion and sediment controls are implemented to ensure minimal impact on remnant vegetation and aquatic habitats;
- inclusion of an adaptive management approach if a previously unrecorded or assessed threatened species is identified in the Referral Area during operations; and
- ecological monitoring programs.

Each of the above is described in further detail in the below sections.

### 7.3.2 Fencing and Access Control

Fencing and access control will be used to protect retained vegetation within the Bowmans Creek Riparian Corridor, Mountain Block Offset Area, rehabilitation area and any other remnant vegetation within the broader LCO from human-induced impacts such as damage to vegetation from vehicles or trampling, increased rubbish dumping and alteration to normal fauna behaviour patterns due to human presence. In areas where fencing is deemed as being unsuitable, appropriate signage will be used in its place. Signage will exclude access (where appropriate), instruct vehicles to remain on formed tracks only, or highlight sensitive ecological areas to be avoided.

Any new fencing used within the Bowmans Creek Riparian Corridor, Mountain Block Offset Area, rehabilitation area and any other remnant vegetation within the broader LCO will use no barbed wire on the upper strands, and as little barbed wire generally as possible. This will ensure as minimal impact on native species as possible. The minimal usage of barbed wire from fencing will minimise potential injury or death of fauna species, particularly macropods and gliding or flying mammals and threatened micro-bats. Fencing design will also consider the use of as few wire strands as practical to reduce potential for fauna entanglement.

### 7.3.3 Weed Control

A Weed Management Strategy (WMS) was implemented during 2013 at LCO for the control of targeted weed species in both rehabilitation and grazing areas. This site wide approach to weed management was developed in conjunction with Eco Logical Australia (ELA) to ensure consistent and strategic weed management at LCO. The WMS involves the following:

- Incorporation of both long term objectives (~20 years), and short-term weed control goals, and will be reviewed every 3 to 5 years;
- Weed management issues / processes on rehabilitation areas (both native and pasture), remnant areas, and areas marked for future clearance;
- Identification of priority areas for weed control;
- Discussion / research in regard to best practice weed control and trials or experimental methods;
- Vehicle and equipment hygiene and control;
- Assessment of whether the project is complying with the relevant standards, performance measures and statutory requirements; and
- Review the adequacy of any existing strategies / plans or recommendations to improve the environmental outcomes.

Weed management in the Referral Area, proposed offset areas or rehabilitation areas will prioritise:

- weed species and their target areas;
- treatment of entire infestations where possible;
- re-treatment of recurring infestations at regular intervals;
- annual monitoring of key weed infestations;
- annual monitoring for new infestations;
- mapping of key weed infestations following monitoring to track progress and focus control activities where necessary; and
- prompt rehabilitation of land post disturbance.

Where annual monitoring identifies existing infestations or new infestations requiring management, an appropriate methodology will be developed to address the infestation, depending on the species of weed involved, its location (e.g. near a waterway), and the intensity of infestation. Management actions will be planned using the most recent (and appropriate) current best practice for the relevant weed species.

### 7.3.4 Feral Animal Control

Vertebrate pest control is undertaken at LCO in consultation with the NSW Local Land Services, the Hebden Wild Dog Association and neighbouring landholders. Programs to control vertebrate pests include the determination of appropriate control practices, consultation with the appropriate authority, obtaining appropriate approvals, implementing control practice and undertaking follow-up monitoring and control as required. If monitoring shows a substantial increase in the density of any known vertebrate pest species or the occurrence of a previously unrecorded species is discovered, LCO will seek expert advice on the management and control options for that species and endeavour to minimise its impact on native flora and fauna.

A Vertebrate Pest Control Program is carried out on a seasonal basis (Winter, Autumn and Spring) by Enright Land Management Pty Limited. Each season, the results from the previous program (along with any focused control required) are considered to plan the following control program. The vertebrate pest control program is based on a comprehensive baiting program to target wild dogs and foxes using meat baits injected with sodium monoflouroacetate (commonly known as 1080), traps are utilised for both feral pigs and cats in the area. Open range shooting is also used to control pest species including kangaroos, foxes, wild dogs, pigs, cats, rabbits and hares.

Foxes, feral cats and wild dogs represent a substantial threat to the ongoing persistence of the spotted-tailed quoll (*Dasyurus maculatus maculatus*) in the LCO holdings, as well as the broader Foy Brook area. Targeted and intensive control of such predators will be a key factor in mitigating current impacts on this species in the local area. Current management practices for feral animals within the LCO holdings will be reconsidered with a specific focus on the protection of the spotted-tailed quoll (*Dasyurus maculatus maculatus*) population in this area. Particular focus will be paid to adopting feral animal control measures (particularly foxes and wild dogs) that have minimal direct or indirect negative impact on the spotted-tailed quoll.

Regular monitoring of revegetation and regeneration areas will be undertaken to determine the impact of feral animals, particularly on vegetation establishment. Feral animal control works will continue to be undertaken periodically as described above to ensure the suppression of feral animals, and will consider ecological impacts.

Where annual monitoring identifies feral animal populations requiring management, an appropriate methodology will be developed to address the population, depending on the species involved. Management actions will be planned using the most recent (and appropriate) current best practice for the relevant species.

### 7.3.5 Bushfire Management

The vegetation of the Referral Area, proposed offset areas and the wider LCO site will require appropriate bushfire management to protect life and property, while providing necessary protection to the significant ecological features identified. The existing LCO Bushfire Management Plan (Umwelt 2011) will be updated to incorporate the Proposed Action, and will allow for the application of fire research knowledge to generate ecological outcomes through the appropriate use of fire as an ecological management tool.

The updated Bushfire Management Plan will consider:

- exclusion of planned bushfire from revegetation and regeneration areas to allow replanted and regenerating communities to mature to a stage where they are able to withstand bushfire and regenerate naturally following such an event (nominally at least 15 years, but dependent on the success of plant establishment and the vegetation community present);
- consideration of the sensitivities of threatened species and TECs to bushfire and appropriate bushfire planning and management in relation to known occurrences of these. This will include specific focus on appropriate bushfire planning for protecting habitat for the spotted-tailed quoll (*Dasyurus maculatus maculatus*), which is known to be particularly sensitive to inappropriate fire regimes (Long and Nelson 2004);
- the use of ecologically appropriate fire regimes (be they related to burn frequency, duration or intensity), as these have the potential to impact negatively on significant ecological features;
- asset protection; and
- appropriate incorporation of all relevant ecological requirements into an updated Bushfire Management Plan.

### 7.3.6 Habitat Enhancement Measures

Habitat enhancement will be undertaken in rehabilitation areas, Mountain Block Offset Area and Bowmans Creek Riparian Corridor, and will focus on the protection and provision of specific habitat features for MNES (particularly the spotted-tailed quoll, regent honeyeater and swift parrot). This will aim to increase specific habitat features for these species, thereby improving the quality of the habitat so it is able to support greater numbers of those species. Specific habitat features are those that can be a

limiting factor to population thresholds, and can include for example habitat features such as tree hollows, complex ground strata and specific foraging resources.

Measures will include:

- **Nest Boxes** – the Proposed Action will provide staged mitigation of hollow loss from the Referral Area by placing nest boxes in surrounding secure vegetation, and by placement of nest boxes within the post-mining rehabilitation areas and corridors (once vegetation reaches suitable maturity). A range of nest box designs will be provided. Each tree hollow suitable for use by fauna species identified during pre-clearing surveys will be replaced with a nest box in rehabilitation areas. Nest boxes will be regularly monitored and maintained within rehabilitation areas for the life of the mine to ensure that hollow-dependent species are able to inhabit rehabilitated areas.

- **Habitat Feature Salvage** - features such as boulders, hollow logs and hollow-bearing trees will be identified during pre-clearing surveys, and selectively salvaged as part of the clearing process. These will be stockpiled for use in rehabilitated areas and the Bowmans Creek Riparian Corridor to increase the value and complexity of rehabilitation areas, thus making them more suitable for native fauna colonisation (particularly that of threatened species).

- **Planting of Specific Foraging Resources** - a variety of plant foraging resource species, particularly flowering resources that will attract nectarivorous species, as well as insects that will attract insectivorous species will be planted. Species planted will target those that were removed from the Referral Area.

- **Dam Reconstruction** – any constructed dams will be designed to increase habitat complexity and provide a range of micro-habitats to increase faunal usage.

- **Spotted-tailed Quoll Habitat Enhancement** - measures will be undertaken to benefit the spotted-tailed quoll, including salvage of hollow-bearing trees felled during construction and placement as log piles within rehabilitation and Bowmans Creek Riparian Corridor (particularly along drainage lines) and salvage and placement of large rocks and boulders into piles as further potential denning habitat.

### 7.3.7 Tree Felling Procedure

A robust tree felling procedure will be implemented to minimise the potential for impacts on native fauna species (including threatened species) as a result of the clearing of hollow-bearing trees. The procedure will include:

- detailed pre-clearing surveys by a suitably experienced persons to mark hollow-bearing trees and notable habitat features for salvage and reuse;

- removal of non hollow-bearing trees/vegetation as close to the hollow-bearing tree felling date as possible (in order to discourage fauna usage of the area);

- detailed hollow-bearing tree felling procedures, including (but not limited to):
    - shaking of hollow-bearing tree (with heavy machinery) prior to felling to encourage fauna to abandon the tree;
    - supervision of all hollow-bearing tree felling by a suitably experienced persons. If an ecological issue is encountered, further advice is to be sought on the most appropriate measures to ensure minimal impact on fauna species, particularly threatened species;

- visual canopy inspection on the day of the felling of hollow-bearing trees for species and nests that may have become active since pre-clearing surveys;
- shaking of hollow-bearing tree (with heavy machinery) for at least 10 seconds to encourage resident fauna to abandon tree, prior to felling;
- lowering of hollow-bearing trees as gently as possible with heavy machinery;
- inspection of all hollows in felled trees by a suitably experienced and licensed persons;
- capture of any displaced/injured fauna by a suitably experienced persons or wildlife carer;
- release of unharmed fauna into nearby secure habitats by a suitably experienced persons;
- injured fauna to be assessed and taken to wildlife carer, if necessary, by a suitably experienced persons;
- felled trees to be rolled so that the number of hollows blocked against the ground are minimised;
- all felled trees are to remain in place overnight to allow any unidentified fauna to escape; and
- salvage of suitable hollows for use as compensatory habitat, where practicable.

All personnel who will capture/handle/house and/or transport native fauna species (injured or uninjured) must be appropriately licensed under the requirements of the NSW Animal Ethics Committee.

### 7.3.8 Indirect Impact Mitigation Measures – Dust, Noise and Lighting

As mentioned above, general noise, dust, fugitive light and water mitigation measures will also act to indirectly minimise potential impacts on areas of potential habitat occurring adjacent to the Referral Area. Comprehensive and effective mitigation measures for each of these potential impacts are already in place at LCO, and will continue as mining activities progress into the Referral Area as part of the Proposed Action. These mitigation measures are outlined below.

**Noise**

- Real time noise monitoring is undertaken in proximity to the nearest receptors at LCO, providing alerts if mining noise levels are close to the Project Specific Noise Criteria (PSNC). These alerts will prompt adaptive management techniques to allow mining operations to be altered as necessary for noise levels to remain within PSNC.
- Where the potential for an exceedance is identified, possible techniques to address potential exceedances include;
  - The review of digging and dumping activities likely to have resulted in a noise exceedance, taking into consideration wind direction and height / proximity to the continuous noise monitor;
  - The relocation of equipment closest to receivers to lower risk areas;
  - The temporary reduction in height of operations; and
  - The shutting down of mining equipment, as deemed necessary to meet criteria.
- A continued program of regular sound power screening testing that will assist in managing sound power levels, and identify plant items requiring maintenance to noise attenuation packages, including identification of new attenuation technologies as methods develop with time; and
- A continued program of attended monitoring will assist in demonstrating compliance with approved noise criteria.

**Dust**

Dust emissions are managed through the following techniques:

- Undertaking regular dust inspections. Mining activities may be ceased or modified if excessive dust is observed;
- Disturbance of the minimal area necessary for mining operations to occur, and rehabilitation of disturbed areas as soon as possible;
- Effective dust suppression of the active haul road network and hardstand areas;
- Prompt, progressive rehabilitation of disturbed areas following completion of mining, including temporary rehabilitation of long term overburden dumps and mine infrastructure areas where practical;
- The use of dust suppression sprays on the ROM hopper and transfer conveyor points;
- Regular maintenance of equipment to ensure efficient operation, reducing emissions; and
- Real time dust monitoring is undertaken to assist with the proactive management of dust on-site.

**Lighting**

Potential offsite lighting related impacts are minimised through the following measures:

- Design of overburden emplacement areas to effectively shield operations from views to the north and northeast, reducing the impact of light on surrounding residences, road users and general surrounding area;
- Revegetation of the overburden emplacement areas to further screen and filter lighting impacts;
- Lighting treatments for specific plant and equipment to reduce light spill to non-operational areas, especially with regard to mobile lighting plants; and
- Mine infrastructure treatments to reduce the impact of lighting from fixed light sources.

**Erosion and Sediment Control**

As described above in **Section 6.3.1.5**, measures to ensure the risk of offsite erosion and sedimentation impacts are minimised include:

- Construction of appropriately designed final landform drainage structures;
- Diverting clean water from disturbed areas, and redirecting sediment-loaded water into sedimentation basins;
- Utilisation of cover crops to provide quick re-establishment of ground cover over reshaped emplacement areas for protection against wind and water erosion;
- Construction of sediment control structures where required (e.g. silt fences, hay bales etc.);
- Rehabilitating overburden emplacement areas as close as practical behind active mining areas; and
- Repairs are undertaken to older rehabilitation areas where erosion is evident.

### 7.3.9 Adaptive Management

A strong positive feedback loop between monitoring and adaptive management will continue to be implemented through the existing LCO Landscape Management Plan (Umwelt 2012). The management of the ecological components of the Proposed Action will be responsive to any new ecological data that may arise through the ecological monitoring of the Referral Area, or any other studies completed as part of the Proposed Action. This will enable a flexible approach to the management requirements of the Proposed Action, allowing ongoing feedback and refinement of the management strategy.

Additional general management strategies that will be employed across the Referral Area will include:

- staff education – all LCO personnel and contractors will be informed of ecological values of the Referral Area; particularly in relation to TECs and threatened fauna as well as what to do in the event of encountering injured wildlife; and

- topsoil management – topsoil stripped during clearing will be appropriately stockpiled for use in the rehabilitation process.

The LCO Landscape Management Plan (Umwelt 2012) will be updated in order to capture the specific ecological impact mitigation and management strategies that have been determined as part of the Proposed Action. This will document the requirements of the impact mitigation measures to be employed, as well as performance criteria and monitoring to ensure the objectives of the mitigation strategy are being met.

# 8.0 OFFSET STRATEGY

**The preliminary documentation must provide information on any offset measures that are available and achievable, in the event they are deemed to be required by the department. This section should consider offsets for all EPBC listed species and communities for which there may be significant residual impacts.**

**The offset proposal must include a number of issues, as defined in the following sections.**

## 8.1 Background

As part of the Proposed Action, LCO has proposed a comprehensive biodiversity offset strategy that has been designed to offset the residual impacts of the Proposed Action on ecological values, including on MNES.

The planning and design of biodiversity offset packages includes a fundamental commitment to manage biodiversity offsets to maintain or improve the ecological value of offset areas over time. This includes passive or active rehabilitation of native vegetation communities, remediation of degraded areas, assisted natural regeneration, removal or control of weeds and pests, and habitat enhancement works to increase fauna diversity.

Biodiversity offsets are provided as a land-based approach (dedication and management of target land areas for biodiversity gain) or non-land based approaches, such as provision of funding for community groups or scientific research aimed at environmental gain and an increase in knowledge for significant ecological matters.

The precise combination of measures that make up an offset strategy should be determined following thorough consideration of planning, policy and legislative factors and other site based or regional drivers and social/community factors.

Glencore seeks to locate offsets to make positive contributions to vegetated connectivity (corridors) at a local and regional scale. Preference is given to offset sites that can enhance regional connectivity, sure up existing conservation reserves and avoid areas subject to future mining, other development pressures or risks, or areas that otherwise support important agricultural activities.

When targeting properties for strategic biodiversity offsets, Glencore prioritises the following geographic criteria:

- **Location within the same bioregion or nearby in adjoining bioregions** – to ensure impacts are offset within the same Bioregion where possible, or nearby when required.
- **Vegetation type requirements** – considers the vegetation type being impacted as a priority within the selection of Glencore biodiversity offset properties.
- **Species habitat requirements** – considers the habitat types being impacted as a priority within the selection of Glencore biodiversity offset properties.
- **Landscape positioning with other Glencore offset areas** – prioritising clustering of Glencore biodiversity offset properties (where possible) allows consolidation of benefits through concurrent management and development of corridors.
- **Proximity to existing conservation reserves** – targeting Glencore biodiversity offset properties to adjoin existing conservation areas to build on the value of management of these areas for conservation outcomes.

- **Keeping offsets out of mining districts** – wherever possible, ensuring that offsets are not located within mining districts, except for irreplaceable features that cannot be appropriately offset elsewhere or where information on potential coal resources is available and no economically recoverable coal reserves exist.
- **Location within Great Eastern Ranges Initiative target areas** – where possible, to allow Glencore biodiversity offset properties to contribute to broader conservation initiatives, thus creating benefit on larger scale.
- **Location within the Upper Hunter Strategic Assessment priority offset landscapes for projects in the Hunter Valley, NSW** – to ensure Glencore biodiversity offset properties can contribute to regional biodiversity outcomes.

As a Glencore business, LCO has followed these principles in designing the proposed biodiversity offset strategy for the Proposed Action, with the proposed offset sites meeting the above criteria, as best as possible. Two offset sites are proposed as part of the biodiversity offset strategy for the Proposed Action and comprise the 183 hectare Bowmans Creek Riparian Corridor and the 166 hectare Mountain Block Offset Area (see **Figure 6.1**).

The biodiversity offset strategy provides two local offset sites (Mountain Block Offset Area and Bowmans Creek Riparian Corridor) that complement other local offset areas for Ravensworth Operations and the Mount Owen Complex. The Mountain Block Offset Area is strategically positioned to the north of Bowmans Creek and adjoining the Ravensworth Operations Hillcrest Offset Area, thus providing a strategically important contribution to regional biodiversity conservation.

The following sections detail the value of each of the proposed offset sites for the regent honeyeater, swift parrot, spotted-tailed quoll, large-eared pied bat and green and golden bell frog, as required by the Department of the Environment.

The precautionary principle has been considered in the impact assessment process due to uncertainty and a lack of published information for some threatened species and vegetation communities with the potential to be significantly impacted by the Proposed Action. The precautionary principle assumes the maximum reasonable potential impact is applied to these species in the impact assessment and therefore helps to ensure that offsets are robust and adequate for the species they target. The biodiversity offset strategy has been designed to address impacts on relevant ecological matters of national environmental significance as well as State listed threatened species and communities, in addition to providing an offset for the other ecological impacts of the Proposed Action.

The key objectives for the Biodiversity Offset Strategy are to:

- maintain or improve the biodiversity values of the surrounding region in the medium to long term;
- maintain or improve the viability of threatened species that could be affected by the Proposed Action through the securing and/or restoration of habitat in the Hunter Valley or elsewhere within their range; and
- ensure that there are no residual significant impacts on key threatened species and ecological communities in the long term as a result of the construction and operation of the Proposed Action.

The Biodiversity Offset Strategy consists of a number of components designed to address the identified impacts on TECs and threatened species. These measures include:

- immediate establishment and long-term protection of the 166 hectares of land in the form of the Mountain Block land–based Offset Area to allow for the conservation of comparable areas of existing vegetation and the protection of threatened woodland birds, likely spotted-tailed quoll habitat, micro-bats and TECs;

- ongoing management and monitoring of the Mountain Block Offset Area to increase existing biodiversity values, including actions such as weed and feral animal management, fencing, and natural regeneration;
- the development of an appropriate ecological monitoring program to assess the success of the Biodiversity Offset Strategy in counterbalancing the impacts of the Proposed Action on ecological values; and
- establishment of an effective targeted rehabilitation strategy to be undertaken on a progressive basis and commenced immediately after cessation of works to reduce impacts of the Proposed Action at any one time and reduce offsetting requirements.

The following sections provide descriptions of each of the two proposed offset sites and their offsetting value for the regent honeyeater, swift parrot, spotted-tailed quoll and large-eared pied bat. In summary, the proposed biodiversity offset strategy provides the following outcomes for these species:

- 301 hectares of appropriate habitat for the regent honeyeater, offsetting the 54 hectares of potential habitat impacted by the Proposed Action;
- 301 hectares of appropriate habitat for the swift parrot, offsetting the 54 hectares of potential habitat impacted by the Proposed Action;
- 343 hectares of habitat for the spotted-tailed quoll, offsetting the 180 hectares of potential habitat impacted by the Proposed Action; and
- 343 hectares of appropriate habitat for the large-eared pied bat, offsetting the 121 hectares of potential habitat impacted by the Proposed Action.

The green and golden bell frog has not been considered in specific detail in the following sections as it does not have potential to be significantly impacted by the Project; however the offset strategy will provide 6 hectares of appropriate habitat for the green and golden bell frog, offsetting the <0.5 hectares of potential low quality habitat impacted by the Proposed Action.

### 8.1.1 Great Eastern Ranges Initiative

The Great Eastern Ranges Initiative (GERI) aims to maintain and improve the ‘corridor’ connectivity of mountain ecosystems running the length of eastern Australia. The focal area of the Initiative includes the Great Dividing Range and the Great Escarpment of Eastern Australia which extend along the majority of Australia’s east coast. The corridor includes un-fragmented natural ecosystems along extensive sections of these two major geomorphic structures. The current area of focus for this initiative is the 1200 kilometre section of the Great Eastern Ranges that falls within NSW.

The Initiative aims to strengthen the resilience of natural ecosystems, of native plant and animal species, to help protect water supplies for over 93 per cent of eastern Australia’s population and to support the regions significant nature-based tourism assets. The Initiative focuses on bringing together the various stakeholders including the government, non-government groups, industry and the community to achieve its purposes.

The Hunter Valley has been identified as one of the five priority areas along the ranges and is considered to be the most diverse and complex in regards to its biodiversity and connectivity and its social and economic factors. The Hunter Valley represents a significant east-west linkage of natural vegetation in the Great Eastern Ranges, with the potential for north-south 'stepping stones' of vegetation to allow species movement.

While the Mountain Block Offset Area and Bowmans Creek Riparian Corridor are not located in an identified priority area for this Initiative, they do fall on the southern footslopes of the Mount Royal/Barrington Tops National Parks which are a recognised connectivity gap in the central Hunter region. These offset areas lie with a cluster of other Glencore offset areas established for the Ravensworth and Mount Owen Operations (**Figure 8.1**).

This cluster of offset areas currently serves to protect existing vegetation in the highly cleared Lake Liddell area, and will assist in securing existing 'stepping-stone' habitat in this area that leads from the valley floor north into secure conservation areas. In addition to protecting existing vegetation, the management commitments for these areas will promote active and natural regeneration of native vegetation communities to further enhance this habitat connectivity.

## 8.2 Detailed Description of the Offsets - Mountain Block Offset Area

The Mountain Block Offset Area (**Figure 6.1**) is a 166 hectare property located to the immediate north-west of LCO. The majority of the property occurs within the Sydney Basin Bioregion, however the northern part occurs within the NSW North Coast Bioregion. It lies within the Hunter-Central Rivers Catchment. It is located approximately 30 km north-west of Singleton. The Mountain Block Offset Area, including land ownership information and cadastral boundaries, is presented in **Figure 8.2**.

Approximately 61 per cent of the Mountain Block Offset Area has been historically cleared and used for agricultural purposes. The remainder of the property is well vegetated and contains an array of rocky areas. The property also contains a number of gullies ranging from gradual to steep slopes. These gullies contain drainage lines which generally remain dry, and support dry rainforest communities. There are also a small number of farm dams scattered on the lower slopes and upper plateau of the property, generally in areas cleared for livestock grazing.

The alluvial flats and lower slopes of the property trend from open grassland, to grassland with scattered trees to woodland areas, representing several different vegetation community types.

### 8.2.1 Ecological Surveys Completed

**Table 5.10** above summarises the survey methods and survey effort undertaken across the Mountain Block Offset Area for the purposes of the Proposed Action.

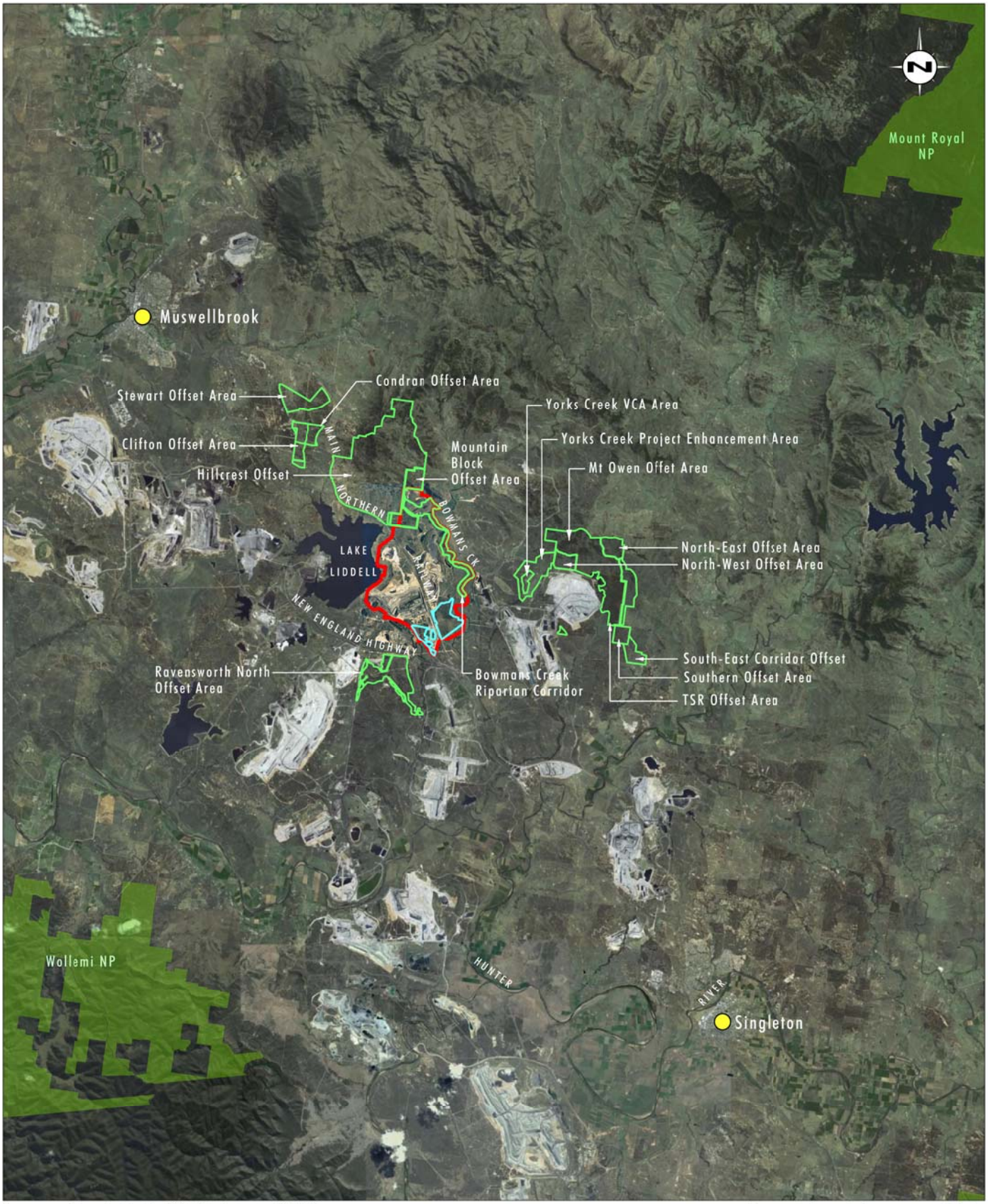
**Figure 5.2** shows the location of the flora and fauna survey techniques undertaken across the Mountain Block Offset Area.

#### 8.2.1.1 Flora Survey Results

This section briefly describes the flora survey results from the surveys undertaken across the Mountain Block Offset Area by Umwelt during 2013.

**Vegetation Communities**

Six vegetation communities were recorded in the Mountain Block Offset Area that were not considered to conform to TECs listed on the EPBC Act (although two did conform to vegetation communities listed under the TSC Act). A number of farm dams were also mapped as a separate unit, as was Disturbed Land. **Table 8.1** lists the six vegetation communities and the area of each recorded within the Mountain Block Offset Area. **Figure 6.1** shows the location of each of these vegetation communities within the Mountain Block Offset Area.




**Source:** Google Earth (2010), Xstrata (2013)

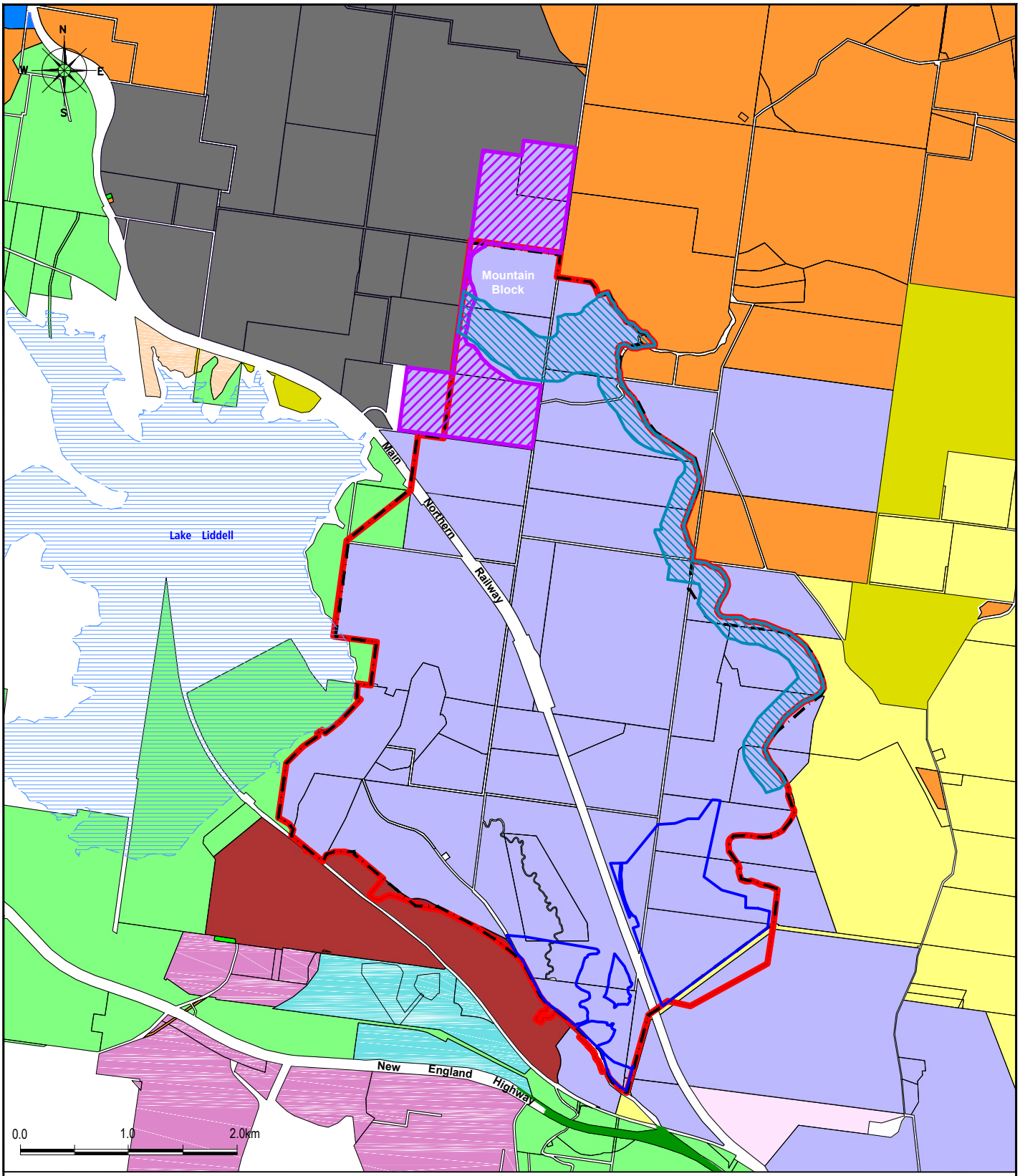
0 2.5 5.0 10 km
1:250 000

**Legend**

- Liddell Coal Operations Approved DA Boundary
- Referral Area
- Approved Glencore Offsets
- National Park

FIGURE 8.1

**Conservation Areas Surrounding Liddell Coal Operations**




LEGEND

- DA boundary / Project Site
- Referral Areas
- ML 1597
- Lake Liddell
- Liddell Coal Operations (Glencore)
- Macquarie Generation
- Ravensworth Surface Operations (Glencore)
- Glencore Coal Pty Limited
- Ravensworth Operations Pty Limited (Glencore)
- Ravensworth Underground Mine (Glencore)
- Mt Owen (Glencore)
- Glendell (Glencore)
- Coal & Allied
- Department of Lands (crown) / Freehold
- RMS
- Privately owned land
- Minister for Lands
- Land ownership boundary
- Mountain Block Offset Area
- Bowmans Creek Riparian Corridor

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*To be printed A4*

Land Ownership

**FIGURE 8.2**

**Table 8.1 –Vegetation Communities recorded in the Mountain Block Offset Area**

| Vegetation Community Name | HRVP[1] | GHVPC[2] | Legal Status | | Area (ha)[3] |
|---|---|---|---|---|---|
| | | | TSC Act | EPBC Act | |
| Narrow-leaved Ironbark – Spotted Gum Woodland | MU 27 | MU086 | EEC - Central Hunter Ironbark – Spotted Gum – Grey Box Forest | - | 35 |
| Narrow-leaved Ironbark – Bulloak Open Forest | MU 10 | MU173 | EEC - Central Hunter Grey Box – Ironbark Woodland | - | 22 |
| Narrow-leaved Ironbark – Spotted Gum Woodland DNG | MU 27 | MU086 | - | - | 33 |
| Grey Myrtle – Kangaroo Vine Dry Rainforest | MU 3 | MU025 | - | - | 1.1 |
| Rusty Fig Dry Rainforest | MU 3 | MU025 | - | - | 6.9 |
| Narrow-leaved Ironbark – Bulloak Open Forest DNG | MU 10 | MU173 | - | - | 60 |
| Disturbed Land | - | - | - | - | 7.7 |
| Dam | - | - | - | - | 0.58 |
| **TOTAL** | | | | | **166** |

Notes
[1] = Vegetation map unit described in Hunter Remnant Vegetation Project (Peake 2006).
[2] = Vegetation map unit described in Greater Hunter Vegetation Mapping Classification Unit (Sivertsen, 2012).
[3] = Rounding of totals applied (numbers less than 1 – 2 decimal places, numbers between 1 and 10 – 1 decimal place, and greater than 10 no decimal places).

**Threatened Flora Species and Endangered Populations**

No threatened flora species or endangered flora populations listed on the EPBC Act were recorded within the Mountain Block Offset Area.

**Non-threatened Flora Species**

A total of 84 plant species were identified in the Mountain Block Offset Area during surveys. Plants were recorded from two major vascular plant classes and from 43 plant families. A total of 22 introduced flora species were recorded (26 per cent) across the Mountain Block Offset Area.

### 8.2.1.2 Fauna Survey Results

Following is a summary of the results of the fauna surveys undertaken across the Mountain Block Offset Area.

### Threatened Fauna Species

One threatened fauna species listed on the EPBC Act was identified in the Mountain Block Offset Area during field surveys (refer to **Figure 5.1**). **Table 8.2** identifies this species and the likely frequency of its occurrence.

**Table 8.2 – Threatened Fauna Species Recorded in the Mountain Block Offset Area**

| Common Name | Scientific Name | TSC Act | EPBC Act | Likely Frequency of Occurrence |
|---|---|---|---|---|
| **Mammals** | | | | |
| Spotted-tailed quoll | *Dasyurus maculatus maculatus* | V | E | Recorded. Known male den site recorded. Numerous individuals identified from remote camera surveys. Numerous active latrine sites indicate area of high social activity for this species. Likely to be resident onsite. |

E Endangered
V Vulnerable

### Endangered Fauna Populations and Migratory Species

No endangered fauna populations were recorded or are considered likely to occur within the Mountain Block Offset Area. Four migratory species listed on the EPBC Act were recorded in the Mountain Block Offset Area (**Table 8.3**).

**Table 8.3 – Migratory Species recorded in the Mountain Block Offset Area**

| Common Name | Scientific Name | TSC Act | EPBC Act |
|---|---|---|---|
| brown goshawk | *Accipiter fasciatus* | - | Mig |
| silvereye | *Zosterops lateralis* | - | Mig |
| welcome swallow | *Hirundo neoxena* | - | Mig |
| tree martin | *Hirundo nigricans* | - | Mig |

Mig Migratory Species

### Non-threatened Fauna Species

A total of 49 vertebrate fauna species have been recorded in the Mountain Block Offset Area, comprising two amphibians, no reptiles, 36 birds and three mammals.

## 8.2.2 Key Ecological Values and Condition of the Mountain Block Offset Area

The Mountain Block Offset Area consists of eucalypt dominated woodland, rainforest and grassland areas. The woodland areas are largely unmodified, containing abundant mature and regenerating trees, with reasonable shrub and groundcover in good condition. There is some evidence of edge effects on the woodland communities from agriculture and mining activities in the area. The rainforest areas are largely unmodified and provide high quality habitat in the form of rock/boulder habitat, and abundant fruiting trees and shrubs. The site is well connected to other areas of eucalypt dominated woodland to the north, with regional connectivity to the south limited due to the presence of existing mining activities, however this will continue to improve as a result of rehabilitation works at LCO. The grassland areas within Mountain Block are highly modified and disturbed, and are virtually devoid of mature trees, although are considered to have a high capacity for regeneration.

The Mountain Block Offset Area has many ecological values that make it beneficial as a Biodiversity Offset Site for the Referral Area; these include known values, likely predicted values and its location relative to the central Hunter Valley. The values provided by the Mountain Block Offset Area are provided below.

From the ecological assessments and surveys completed within the Mountain Block Offset Area to date, a number of key ecological features have been identified. Of these, those with legislative status have been summarised below:

- 35 hectares of Central Hunter Ironbark-Spotted Gum-Grey Box Forest in the New South Wales North Coast and Sydney Basin Bioregions EEC (listed under the TSC Act);
- 22 hectares of Central Hunter Grey Box – Ironbark Woodland in the Sydney Basin Bioregion EEC (listed under the TSC Act);
- one individual of the endangered flora population *Cymbidium canaliculatum* in the Hunter Catchment (listed under the TSC Act);
- speckled warbler (*Chthonicola sagittata*) (V TSC Act);
- spotted harrier (*Circus assimilis*) (V TSC Act);
- spotted-tailed quoll (*Dasyurus maculatus maculatus*) (V TSC Act and E EPBC Act); and
- three migratory species listed under the EPBC Act.

Based on the identified ecological features of the broader area, the Mountain Block Offset Area has potential to contain habitat for:

- threatened flora species lobed bluegrass (*Bothriochloa biloba*), painted diuris (*Diuris tricolor*) and austral toadflax (*Thesium australe*);
- habitat areas for the non-threatened vegetation communities listed in **Table 8.1** above. Non-threatened vegetation communities provide habitat for a wide range of flora and fauna species; and
- threatened fauna species that have not been recorded but which may occur. Threatened species may not have been recorded due to the amount and type of surveys completed, temporal and spatial variation of species distribution across the Mountain Block Offset Area or due to the cryptic nature of some species. A total of 35 threatened fauna species (including seven MNES as provided in **Table 8.4**) have been identified as potentially occurring within the Mountain Block Offset Area due to the presence of suitable habitat areas.

**Table 8.4 - Matters of National Environmental Significance with Potential to Occur in the Mountain Block Offset Area**

| Scientific Name | Common Name | EPBC Act Status | Notes |
|---|---|---|---|
| *Lathamus discolor* | swift parrot | E | Winter flowering eucalypt habitat |
| *Anthochaera phrygia* | regent honeyeater | E, MIG | Winter flowering eucalypt habitat |
| *Phascolarctos cinereus* | koala | V | Appropriate foraging habitat |
| *Petrogale penicillata* | brush-tailed rock wallaby | V | Appropriate foraging habitat |
| *Pteropus poliocephalus* | grey-headed flying fox | V | Appropriate foraging habitat |
| *Nyctophilus corbeni* | Corbens long-eared bat | V | Appropriate foraging habitat |
| *Chalinolobus dwyeri* | large-eared pied bat | V | Appropriate foraging habitat |

E Endangered
EPBC *Environment Protection Biodiversity Conservation Act 1999*
MIG Migratory
V Vulnerable

## 8.3 Detailed Description of the Offsets - Bowmans Creek Riparian Corridor

A key component of the Biodiversity Offset Strategy is the completion of habitat enhancement works along the Bowmans Creek riparian corridor within the LCO DA boundary, with the specific purpose of enhancing existing habitat, and providing additional habitat for the spotted-tailed quoll (*Dasyurus maculatus maculatus*). This corridor will cover both mined and non-mined land; with the proportion of non-mined areas versus previously-mined areas being 91 hectares to 92 hectares, respectively. A description of the corridor is provided in the sections below.

### 8.3.1 Ecological Surveys Completed

Flora surveys aimed to verify and update existing vegetation mapping as well as identify threatened flora species, endangered populations, TECs and species of local or regional significance occurring or considered to potentially occur within the Bowmans Creek Riparian Corridor. Surveys were undertaken on 6 to 8 November 2013.

A total of 15 systematic plot-based surveys, 14 rapid assessments and approximately 20 km of meandering transects were undertaken within the Bowmans Creek Riparian Corridor. **Figure 5.2** shows the location of the flora and fauna survey techniques undertaken across the Bowmans Creek Riparian Corridor.

**Table 8.5** summarises the survey methods and survey effort undertaken across the Bowmans Creek Riparian Corridor.

**Table 8.5 – Bowmans Creek Riparian Corridor Survey Methodology and Survey Effort**

| Date of Surveys | Method | Effort<br>Umwelt (2013) |
|---|---|---|
| **Flora** | | |
| 6 to 8 November 2013 | Systematic plot based survey | 15 Plots |
| | Rapid vegetation assessments | 14 Locations |
| | Field reconnaissance | Approximately 20 km |
| | Opportunistic observations | Undertaken throughout all aspects of survey |
| **Fauna** | | |
| 17 to 20 December 2012 – Targeted spotted-tailed quoll surveys | Daytime walking searches and signs for presence | 4 days |
| | Dusk walking surveys | 2 dusk periods, each of approximately 2 person hours duration |
| | Nocturnal spotlighting | 3 nights of spotlighting, each of approximate duration 5 person hours |
| | Baited remote camera survey | 6 stations for 3 nights, 2 stations for two nights (22 full survey nights) |
| | Opportunistic observations | Undertaken throughout all aspects of survey |
| 6 to 8 November 2013 | Habitat Assessment | 10 Sites |
| | Micro-bat Echolocation Recording | 2 locations for 2 nights each |
| | Opportunistic Observations | Undertaken throughout all aspects of survey |

Fauna surveys of the Bowmans Creek Riparian Corridor were undertaken primarily to map habitat and survey for the spotted-tailed quoll (*Dasyurus maculatus maculatus*). As such no general fauna surveys were undertaken within the corridor. Micro-bat echolocation detectors were also employed over two nights to gather information on threatened micro-bat activity within the Bowmans Creek Riparian Corridor. **Table 8.5** above summarises the fauna survey methods and survey effort undertaken across the Bowmans Creek Riparian Corridor.

Opportunistic observations of flora and fauna were undertaken throughout all aspects of survey.

#### 8.3.1.1 Flora Survey Results

This section describes the flora survey results from the surveys undertaken across the Bowmans Creek Riparian Corridor by Umwelt during 2013.

**Flora Species**

A total of 75 plant species were identified in the Bowmans Creek Riparian Corridor during surveys. Plants were recorded from two major vascular plant classes and from 31 plant families. A total of 43 introduced flora species were recorded (57 per cent) across the Bowmans Creek Riparian Corridor.

No threatened flora species or endangered flora populations were identified during these surveys; however, a total of four regionally significant flora species (Peake *et al*. 2003) were identified across the Bowmans Creek Riparian Corridor. The presence of these regionally significant flora species adds to the ecological value of the vegetation of the Bowmans Creek Riparian Corridor.

**Vegetation Communities**

Eight vegetation communities were identified within the Bowmans Creek Riparian Corridor, none of which were considered to conform to TECs listed on the EPBC Act (although two did conform to TECs listed on the TSC Act). A number of farm dams were also mapped as a separate unit, as was Disturbed Land, and the water of the creek itself (mapped as "Waterbody"). **Table 8.6** lists the vegetation communities and the area of each recorded within the Bowmans Creek Riparian Corridor.

**Table 8.6 – Vegetation Communities recorded in the Bowmans Creek Riparian Corridor**

| Vegetation Community Name | HRVP[1] | GHVPC[2] | Legal Status | | Area (ha)[3] |
|---|---|---|---|---|---|
| | | | TSC Act | EPBC Act | |
| Central Hunter Ironbark-Spotted Gum- Grey Box Forest | MU 27 | MU086 | EEC - Central Hunter Ironbark – Spotted Gum – Grey Box Forest | - | 1.9 |
| Central Hunter Grey Box – Ironbark Woodland | MU 10 | MU173 | EEC - Central Hunter Grey Box – Ironbark Woodland | - | 0.27 |
| **TOTAL TEC VEGETATION** | | | | | **2.1** |
| Central Hunter Box – Ironbark DNG | MU 10 | HU 817 | - | - | 10 |
| Narrow-leaved Ironbark – Spotted Gum Woodland DNG | MU 27 | HU 818 | - | - | 8.6 |
| Hunter Valley River Oak Forest | MU 30 | HU 711 | - | - | 20 |
| Rehabilitation | MU 27 | HU 818 | - | - | 6.5 |
| Introduced Grassland | Nil | Nil | - | - | 121 |
| Introduced Woodland | Nil | Nil | - | - | 4.1 |
| **TOTAL NON-TEC VEGETATION** | | | | | **170** |
| Disturbed Land | Nil | Nil | - | - | 4.9 |
| Water Body | Nil | Nil | - | - | 0.50 |
| Dam | Nil | Nil | - | - | 3.9 |
| **TOTAL NON-VEGETATED AREAS** | | | | | **9.3** |
| **COMBINED TOTAL** | | | | | **182** |

Notes
[1] = Vegetation map unit described in Hunter Remnant Vegetation Project (Peake 2006).
[2] = Vegetation map unit described in Greater Hunter Vegetation Mapping Classification Unit (Sivertsen, 2012).
[3] = Rounding of totals applied (numbers less than 1 – 2 decimal places, numbers between 1 and 10 – 1 decimal place, and greater than 10 no decimal places).
TSC Act = *Threatened Species Conservation Act 1995*
EPBC Act = *Environment Protection and Biodiversity Conservation Act 1999*

**Figure 6.1** shows the location of each of these non-threatened ecological communities within the Bowmans Creek Riparian Corridor.

#### 8.3.1.2 Fauna Survey Results

A total of 69 fauna species were opportunistically recorded within the proposed quoll corridor, being species common to the area and comprising 51 bird species, 9 mammal species, four reptile species, three amphibians and two fish species.

Observations included eight introduced species, being the common myna (*Sturnis tristis*), European starling (*Sturnis vulgaris*), fox (*Vulpes vulpes*), dog (*Canis lupus familiaris*), hare (*Lepus capensis*), European rabbit (*Oryctolagus cuniculus*), pig (*Sus scrofa*) and European carp (*Cyprinus carpio*).

Two threatened fauna species listed on the EPBC Act (including one species that is additionally listed as migratory under the EPBC Act) and one species that is only listed as migratory under the EPBC Act have been identified in the Bowmans Creek Riparian Corridor during field surveys. **Table 8.7** lists the species and the likely frequency of occurrence of each species.

**Table 8.7 – Threatened Fauna Species Recorded in the Bowmans Creek Riparian Corridor**

| Common Name | Scientific Name | TSC Act | EPBC Act | Likely Frequency of Occurrence |
|---|---|---|---|---|
| **Birds** | | | | |
| Painted snipe | *Rostratula australis* | E | E, Mig | Recorded. Likely to be using site as foraging habitat as part of larger range. Unlikely to be breeding. |
| Rainbow bee-eater | *Merops ornatus* | - | Mig | Recorded. Likely utilising the site for forage and potentially for breeding |
| **Mammals** | | | | |
| Spotted-tailed quoll | *Dasyurus maculatus maculatus* | V | E | Recorded. Known den site recorded. Numerous individuals identified from remote camera surveys. Numerous active latrine sites indicate area of high social activity for this species. Resident population |

E Endangered
V Vulnerable
Mig Migratory Species

It is considered likely that the Bowmans Creek Riparian Corridor also has potential to provide habitat for all the threatened species identified as occurring within the Referral Area, as well as the majority of the threatened species identified as having potential to occur within the Referral Area.

### 8.3.2 Key Ecological Values and Condition of the Bowmans Creek Riparian Corridor

The Bowmans Creek Riparian Corridor consists of woodland and grassland areas, with vegetation of the corridor typically dominated by dense river oak (*Casuarina cunninghamiana*). The wooded areas are moderately disturbed and have a largely absent shrub layer. When a shrub layer is present it is largely modified and dominated by African olive (*Olea europaea subsp. cuspidata*). Edge effects acting on the corridor, particularly from agriculture and mining, are high due to its narrow nature. Disturbance and modification of grassland areas are also high and have little resemblance to their original state. The corridor has moderate connectivity to the north and south, which will be enhanced by the rehabilitation works proposed (refer **Section 8.4.4**).

The Bowmans Creek Riparian Corridor has many ecological values that make it beneficial as a Biodiversity Offset Site for the Referral Area; these include known values, likely predicted values and its location within the central Hunter Valley as well as near and connecting existing Glencore Coal offset sites. The values provided by the Bowmans Creek Riparian Corridor are discussed below.

From the ecological assessments and surveys completed within the Bowmans Creek Riparian Corridor to date, a number of key ecological features have been identified. These are:

- Known breeding site for the spotted-tailed quoll listed as an endangered species under the EPBC Act and as a vulnerable species under the TSC Act;
- Known habitat for the painted snipe, listed as an endangered species under the TSC Act and EPBC Act and additionally as a migratory species under the EPBC Act;
- Known habitat for the grey-crowned babbler, listed as a vulnerable species under the TSC Act;
- Known habitat for the rainbow bee-eater, listed as a vulnerable species under the EPBC Act;
- 1.9 hectares of Central Hunter Ironbark – Spotted Gum – Grey Box Forest listed as an EEC under the TSC Act;
- 0.27 hectares of Central Hunter Grey Box – Ironbark Woodland listed as an EEC under the TSC Act;
- a vegetated connective corridor in an area of the central Hunter Valley that is largely devoid of remnant native vegetation; and
- potential habitat for four additional MNES, as provided in **Table 8.8**.

**Table 8.8 - Matters of National Environmental Significance with Potential to Occur in the Bowmans Creek Riparian Corridor**

| Scientific Name | Common Name | EPBC Act Status | Notes |
|---|---|---|---|
| *Lathamus discolor* | swift parrot | E | Small amount of winter flowering eucalypt habitat |
| *Anthochaera phrygia* | regent honeyeater | E, MIG | Small amount of Winter flowering eucalypt habitat |
| *Nyctophilus corbeni* | Corbens long-eared bat | V | Appropriate foraging habitat, potential roosting habitat |
| *Pteropus poliocephalus* | grey-headed flying fox | V | Appropriate foraging habitat |

E Endangered
EPBC *Environment Protection Biodiversity Conservation Act 1999*
MIG Migratory
V Vulnerable

## 8.4 Offset Management and Improvements for Mountain Block Offset Area and Bowmans Creek Riparian Corridor

This section describes the improvements and management actions to be undertaken across the Mountain Block Offset Area and the Bowmans Creek Riparian Corridor. A Biodiversity Offset Management Plan will be prepared to detail the planned improvements for both areas and ongoing management for ecological value. This Plan may form part of a broader Management Plan for the Mountain Block Offset Area and Bowmans Creek Riparian Corridor.

The Mountain Block Offset Area and Bowmans Creek Riparian Corridor will be managed to conserve ecological values, with a focus on weed and pest control, fencing and regeneration of derived native grassland (DNG) areas. A strong focus on rehabilitation of disturbed area to woodland and riparian communities will be needed for the Bowmans Creek Riparian Corridor. A monitoring program will be established to assess the progress and determine the success of ongoing management actions.

Preliminary on-ground works will likely involve:

- weed and pest control programs (aimed at having the greatest benefit to the spotted-tailed quoll);
- fencing of both Biodiversity Offset Areas to manage stock access;
- undertaking ecological monitoring across the Mountain Block Offset Area to monitor the success of the recovery of grassland areas to their original woodland communities;
- undertaking detailed rehabilitation works along the Bowmans Creek Riparian Corridor; and
- undertaking habitat augmentation works in areas providing minimal spotted-tailed quoll habitat.

Following the completion of the Biodiversity Offset Management Plan it will be submitted to DPE for approval. The Biodiversity Offset Management Plan will include a concise and auditable strategy for the implementation of the offsets.

### 8.4.1 Access Management and Strategic Management of Stock

Domestic stock will be strategically managed across both Biodiversity Offset Areas, to help achieve desired ecological outcomes and manage key risks such as weeds and bushfire. Areas of retained vegetation and rehabilitated vegetation will be fenced to help manage livestock, unauthorised access and disturbance. All fences will be suitably signposted to identify the value of these areas.

Any new fencing used within, or on the boundary of, the Biodiversity Offset Areas will use no barbed wire on the upper strands, and as little barbed wire generally as possible, to ensure minimal impact on native fauna species. The minimal usage of barbed wire from fencing will minimise potential injury or death of fauna species, particularly macropods and gliding or flying mammals and threatened micro-bats. Fencing design will also consider the use of as few wire strands as practical to reduce potential for fauna entanglement. As part of the ongoing monitoring program, if a restricted level of barbed wire on fencing is shown to fail to exclude stock, additional measures that pose minimal impact to native fauna will be investigated and implemented.

Appropriate signage will be used throughout the Biodiversity Offset Areas to identify areas of high ecological significance, such as areas of regeneration and fenced areas containing threatened species, endangered populations or TECs.

### 8.4.2 Weed Management

Both of the proposed offset areas contain a range of introduced species which are considered environmental weeds, including cobble's pegs (*Bidens pilosa*), galenia (*Galenia pubescens*), narrow-leaved cotton bush (*Gomphocarpus fruticosus*), African boxthorn (*Lycium ferocissimum*), African olive (*Olea europaea* subsp. *cuspidata*), creeping pear (*Opuntia humifusa*), common prickly pear (*Opuntia stricta* var. *stricta*), blackberry complex (*Rubus fruticosus*), pepper tree (*Schinus areira*) and tiger pear (*Opuntia aurantiaca*). Five species recorded are declared noxious in the Upper Hunter County Council control area and these are listed in **Table 8.9**.

**Table 8.9 - Noxious Weeds Recorded at Mountain Block and Bowmans Creek Riparian Corridor**

| Family | Botanical name | Common name | Noxious weed control objective |
|---|---|---|---|
| Cactaceae | *Opuntia aurantiaca* | tiger pear | 4 |
| Cactaceae | * *Opuntia humifusa* | creeping pear | 4 |
| Cactaceae | * *Opuntia stricta* var. *stricta* | common prickly pear | 4 |
| Rosaceae | * *Rubus fruticosus* | blackberry complex | 4 |
| Solanaceae | **Lycium ferocissimum* | African boxthorn | 4 |

Notes: Control objectives:
4 Minimise the negative impact of those plants on the economy, community or environment of NSW.
* Denotes introduced – not native to Australia.

There are no legal requirements to control these species, however the success of the Biodiversity Offset Strategy will depend in part on their appropriate management if present in areas of ecological significance. The success of the Bowmans Creek Riparian Corridor will be at least partially dependent on the ongoing suppression of these species. A weed control program will be implemented to limit the spread and colonisation of noxious and environmental weeds within the Mountain Block Offset Area and Bowmans Creek Riparian Corridor, and this will include:

- an annual weed control program across both areas targeting noxious weeds;
- the implementation of weed management measures including hand removal, mechanical removal and application of approved herbicides in authorised areas when favourable conditions prevail;
- control of noxious weeds in accordance with the relevant legislation;
- monitoring and inspections of areas to assess the effectiveness of the weed control program and to ascertain the requirement for further work; and
- ongoing consultation with the relevant authorities regarding weed listings, weed occurrence and management technologies.

### 8.4.3 Pest Management

A Biodiversity Offset Management Plan will be prepared for the Mountain Block Offset Area and Bowmans Creek Riparian Corridor which will provide for the control and management of feral fauna species. Confirmed feral fauna species within these two offset areas include the pig (*Sus scrofa*), fox (*Vulpes vulpes*) and wild dog (*Canis lupus familiaris*) and it is highly likely that other pest species will occur in these areas. These species may impact on the native fauna species through predation and competition for resources such as food, shelter, and breeding sites. Feral animals can also have a detrimental effect on regenerating areas as well as soil stability.

Monitoring will include surveys for the presence of significant populations of feral fauna species. Records of significant populations of such species may trigger appropriate control strategies to reduce and control numbers.

### 8.4.4 Rehabilitation and Habitat Enhancement of Bowmans Creek Riparian Corridor

Rehabilitation of the Bowmans Creek Riparian Corridor will be completed to improve the current poor levels of vegetative connectivity within the LCO holdings and to adjoining remnant vegetation in the local area. These works will also serve to increase existing fauna habitat in the area, with particular focus on the spotted-tailed quoll, however also providing increased habitat for the regent honeyeater, swift parrot and large-eared pied bat as a result of increasing the amount of eucalypt-dominated woodlands in the corridor. Rehabilitation works in this corridor will be commenced as soon as practicable to minimise the time taken for habitat for these species to develop. These works will also assist in preventing bank erosion along Bowmans Creek.

Rehabilitation works are proposed across 143 hectares of either current grassland or disturbed land occurring within the Bowmans Creek Riparian Corridor. Proposed rehabilitated target communities are provided in **Table 8.10** below and the post-rehabilitation vegetation communities are presented in **Figure 8.3**.

**Table 8.10 –Target Rehabilitated Communities within Bowmans Creek Riparian Corridor**

| Target Rehabilitation Community | Status | | Area (ha) |
|---|---|---|---|
| | TSC Act | EPBC Act | |
| Central Hunter Box – Ironbark Woodland | EEC | - | 130.7 |
| Narrow-leaved Ironbark Spotted Gum Woodland | EEC | - | 10.5 |
| Hunter Valley River Oak Forest | - | - | 1.5 |

Rehabilitation works will include a mixture of earthworks, weed control and tree plantings adjacent to the creekline. It is the intention that these works will link this area with native vegetation corridors established on rehabilitated mined land to facilitate the movement of the spotted-tailed quoll and other fauna species to other remnant vegetation areas in the region such as the Mountain Block Offset Area and the Hillcrest Offset Area (managed by Glencore Coal's Ravensworth Operations).

As well as active rehabilitation of the corridor, habitat enhancement measures to be completed will include the introduction of spotted-tailed quoll specific habitat structures such as log-piles (similar to that containing the known female spotted-tailed quoll den site), as well as works aimed at increasing prey-densities for the spotted-tailed quoll through installation of nest boxes and the planting of specific foraging resources.

Salvage of hollow-bearing trees (and non-hollow bearing trees if sufficient resources are lacking) felled during construction and placement of log piles within areas of rehabilitation (particularly along drainage lines); as well as salvage and placement of large rocks and boulders will be used to increase the extent of potential foraging and denning habitat.

Details of specific habitat enhancement works will be provided within a Biodiversity Offset Management Plan prepared for the Bowmans Creek Riparian Corridor.

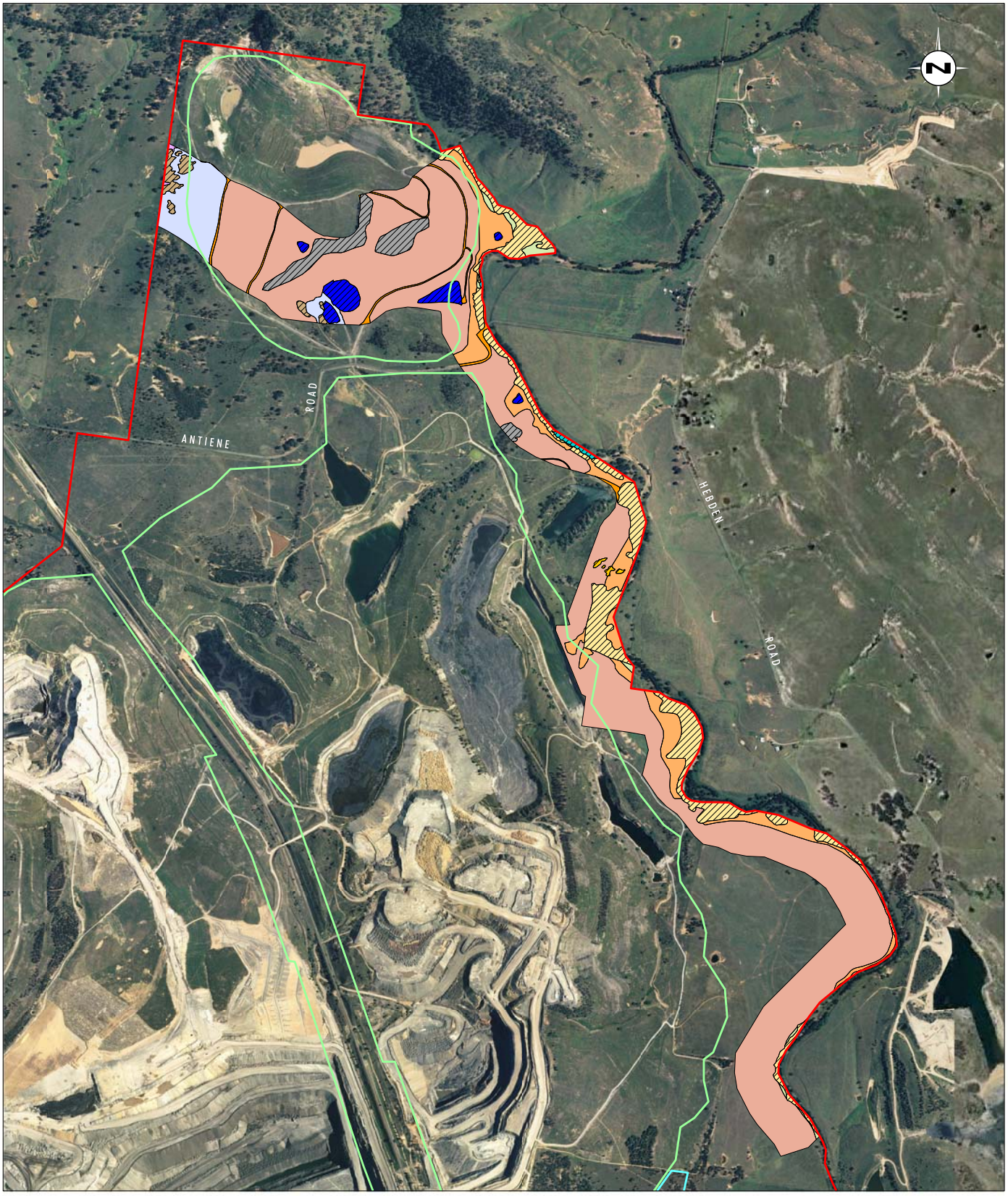



Image Source: Xstrata (2013), Google Earth (2008)
Data Source: Xstrata (2012)

0 0.5 1.0 1.25km
1:25 000

## Legend

- Liddell Coal Operations Approved DA Boundary
- Approved Mining Footprint
- Referral Area
- Central Hunter Box - Ironbark - Angophora Dominated - Rehabilitation
- Central Hunter Box - Ironbark -Ironbark Dominated - Rehabilitation
- Central Hunter Box - Ironbark Woodland
- Dam
- Disturbed Land
- Hunter Valley River Oak Forest
- Hunter Valley River Oak Forest - Revegetation
- Narrow-leaved Ironbark - Spotted Gum Woodland
- Narrow-leaved Ironbark - Spotted Gum Woodland - Rehabilitation
- Narrow-leaved Ironbark - Spotted Gum Woodland DNG
- Rehabilitation
- Water Body
- Unchanged Vegetation

FIGURE 8.3

**Post Rehabilitation of Bowmans Creek Riparian Corridor**

### 8.4.5 Regeneration Works within Mountain Block Offset Area

As part of Proposed Action, previously-disturbed vegetation within the Mountain Block Offset Area will be regenerated back to their benchmark community. This will result in increased areas of key TECs, as well as increase and improve the quality of fauna habitat, particularly for MNES such as the spotted-tailed quoll, regent honeyeater and swift parrot.

Regeneration works will also serve to improve connectivity throughout the area and build upon the connectivity of the existing vegetation patches in the Offset Area and to adjoining remnant vegetation in the local area.

Approximately 101 hectares of either current grassland or disturbed land occurring within the Mountain Block Offset Area are proposed to be regenerated. Proposed regenerated target communities are provided in **Table 8.11** below, and the post-regeneration vegetation communities are presented in **Figure 8.4**.

**Table 8.11 –Target Regeneration Communities within Mountain Block Offset Area**

| Target Rehabilitation Community | Status | | Current Area (ha) | Target Post-Regeneration Area (ha) |
|---|---|---|---|---|
| | TSC Act | EPBC Act | | |
| Narrow-leaved Ironbark Spotted Gum Woodland | EEC | - | 35 | 73 |
| Narrow-leaved Ironbark – Bulloak Open Forest | EEC | - | 22 | 84.7 |
| Narrow-leaved Ironbark Spotted Gum Woodland DNG | - | - | 33 | - |
| Grey Myrtle – Kangaroo Vine Dry Rainforest | - | - | 1.1 | 1.1 |
| Rusty Fig Dry Rainforest | - | - | 6.9 | 6.9 |
| Narrow-leaved Ironbark – Bulloak Open Forest DNG | - | - | 60 | - |
| Disturbed Land | - | - | 7.7 | - |
| Dam | - | - | 0.6 | 0.6 |
| **TOTAL** | | | **166.3** | **166.3** |

Regeneration works will primarily focus on passive methods, however will include plantings or active regeneration works where necessary. Habitat augmentation will also occur within this Offset Area, where monitoring identifies that particular resources for key MNES are lacking. It is the intention that these works will strengthen the current link to the Bowmans Creek Riparian Corridor, as well as to the existing Hillcrest Offset Area (for the neighbouring Ravensworth Operations). This will assist in facilitating the movement of the spotted-tailed quoll and other fauna species throughout the local area by way of vegetated habitat and corridors.

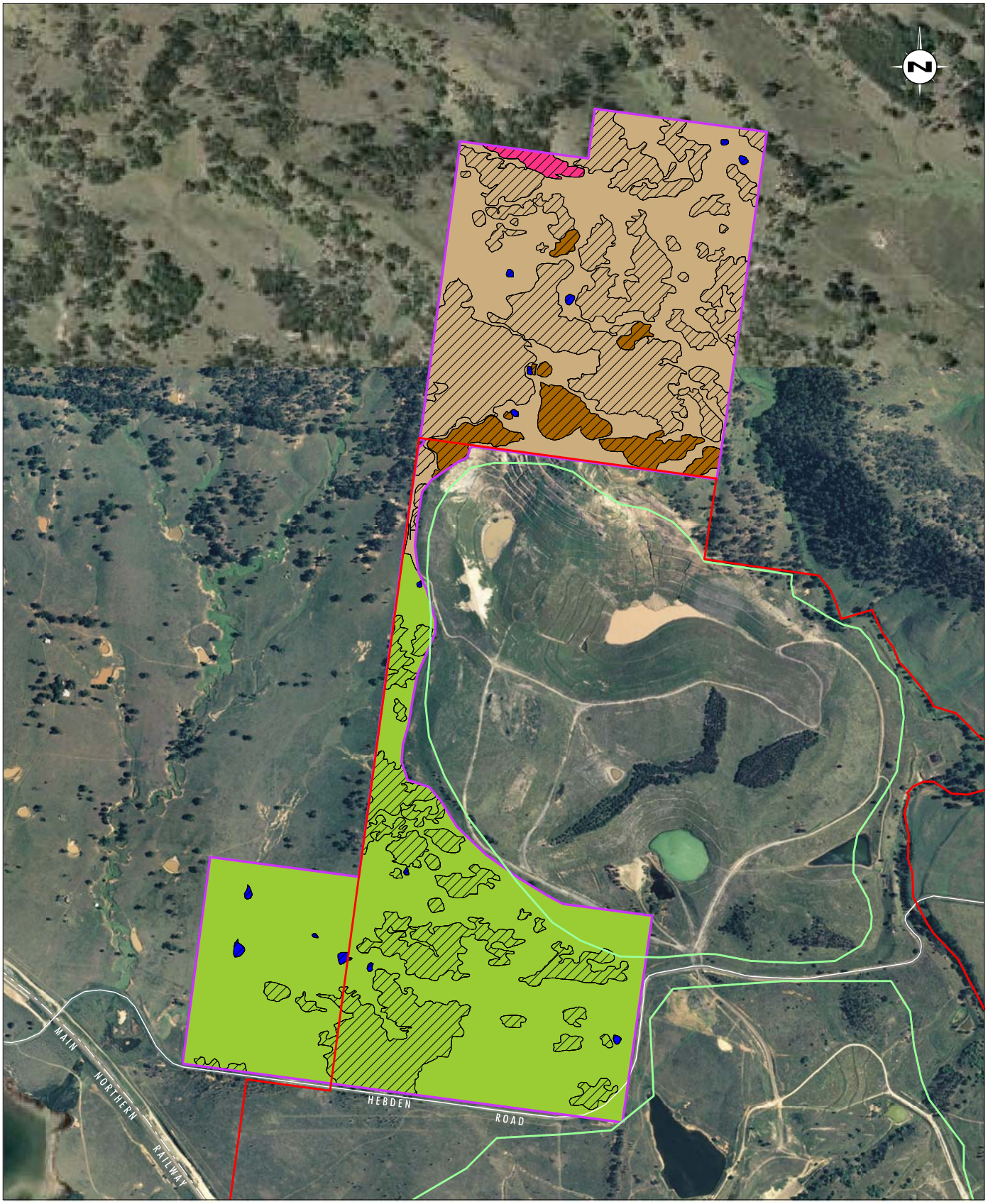



Image Source: Liddell Coal Operations (2013), Google Earth (2008)
Data Source: Liddell Coal Operations (2012), Umwelt (2013), ELA (2012)

0 250 500 750m
1:15 000

## Legend

- Liddell Coal Operations Approved DA Boundary
- Approved Mining Footprint
- Mountain Block Offset Site
- Dam
- Grey Myrtle - Kangaroo Vine Dry Rainforest
- Narrow-leaved Ironbark - Bullook Open Forest
- Narrow-leaved Ironbark - Bullook Open Forest
- Narrow-leaved Ironbark - Spotted Gum Woodland
- Rusty Fig Dry Rainforest
- Unchanged Vegetation

FIGURE 8.4

**Post-Rehabilitation of Mountain Block Offset Area**

## 8.5 Description of How the Offset(s) will Ensure the Protection, Conservation and Management of the Relevant Protected Matters

### 8.5.1 Inputs into in the EPBC Calculator

**Table 8.12** summarises the known and potential habitat areas in the Referral Area for the spotted-tailed quoll, regent honeyeater, swift parrot and large-eared pied bat as well in the proposed offset sites.

**Table 8.12 – Known and Potential Habitat Areas for the Spotted-tailed Quoll, Regent Honeyeater, Swift Parrot and Large-eared Pied Bat across the Proposed Offset Areas**

| Species | Referral Area (ha) | Proposed Offset Area | | |
|---|---|---|---|---|
| | | Mountain Block Offset Area (ha) | Bowmans Creek Riparian Corridor (ha) | Total (ha) |
| Spotted-tailed Quoll | 185 | 65 Woodland | 32.5 Woodland | 342.9 |
| | | 100.7 Grassland | 144.7 Grassland | |
| Regent Honeyeater | 54 | 57 woodland | 2.1 Woodland | 300.8 |
| | | 100.7 Grassland | 141 Grassland | |
| Swift Parrot | 54 | 57 woodland | 2.1 Woodland | 300.8 |
| | | 100.7 Grassland | 141 Grassland | |
| Large-eared Pied Bat | 121 | 65 Woodland | 32.5 Woodland | 342.9 |
| | | 100.7 Grassland | 144.7 Grassland | |

1 = Potential habitat present in 20 years following the return of derived native grassland areas to woodland form.

As indicated in **Table 8.10**, combined the proposed offset areas provide substantial outcomes for each of the relevant EPBC listed species for the Proposed Action.

The value of the proposed offsets for the impacts of the proposed action on the spotted-tailed quoll, regent honeyeater, swift parrot and large-eared pied bat were each assessed using the Offset Assessment Guide. The Offset Assessment Guide aims to provide a decision support framework in order to normalise the judgments associated with the determination of offsets for given impacts.

The use of the Offset Assessment Guide (and its associated offset calculator) requires the input of data on:

- Quality of the habitat for each MNES within the Referral Area;
- Quality of the habitat for each of the MNES within each of the offsets as they are currently and as they are anticipated to be in the future (both with and without their conservation).

The quality of habitat of the Referral Area for each of the MNES was assessed in a manner consistent with the approach outlined by the Commonwealth Department of the Environment (2012). **Table 8.13** below provides a description of the habitats of the Referral Area that were used to determine the quality of habitat present so that the comparative offset value of the Mountain Block Offset Area and Bowmans Creek Riparian Corridor could be determined.

**Table 8.13 – Habitat Quality Scores and Rationalisation in the Referral Area**

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Referral Area Description for Characteristics | Woodland Referral Area Quality | Grassland Referral Area Quality |
|---|---|---|---|---|---|
| **Spotted-tailed Quoll** | | | | | |
| Site Condition | 2 | • provision of a variety of habitat structures | Woodland is dominated by dense bulloak (*Allocasuarina luehmannii*) with small areas of narrow-leaved ironbark (*Eucalyptus crebra*). Creeklines are typically dominated by dense swamp oak (*Casuarina glauca*). Woodland areas have a general paucity of habitat structure as mature and hollow-bearing trees are scarce, as are areas of rocky habitat, rock overhangs, caves, logs and termite mounds. Grasslands essentially devoid of habitat structures, other than occasional paddock trees. | 0.8 | 0.4 |
| | | • provision of prey densities | Prey densities in woodland are greater than grassland due to a greater variety of habitat niches such as hollows for prey species. However woodland areas generally low in habitat complexity due to density and young age of bulloak. | | |
| | | • level of disturbance | Level of disturbance is high across woodland and grassland areas, due to impacts of past and current grazing activity as well as adjacent mining. | | |
| Site Context | 4 | • regional connectivity of habitat areas | Crossing between areas of grassland to reach areas of woodland is not a major issue for this species (as it will use both habitat types); however the surrounding mine activities and presence of roads are a barrier to this species. | 2 | 1.6 |
| | | • importance of the site in relation to the overall species population | The Referral Area is likely to be of low to moderate importance to the overall species population as it is not specifically known to be used for denning or breeding; however a range of available foraging habitat is important for its survival. | | |
| | | • proximity to and intensity of threats to habitat areas | Threats are immediate and immediately adjacent, predominantly in the form of mining activity and agriculture. | | |
| Species Stocking Rate | 4 | • the presence of the species on the site | This species has not been recorded within the Referral Area; however is likely to occur as it has been recorded in adjacent habitat along Bowmans Creek and are known to have large territories. | 1.6 | 0.8 |
| | | • the density of the species on the site | The density of this species were it to use the site, would likely be low and only when foraging. | | |
| | | • the role of the population in regards to the overall species population | The role of the Referral Area is likely to be of reasonable importance for the Foy Brook population for genetic diversity as it provides a foraging resource for known breeding individual and potential areas for future dispersal. | | |
| **Habitat Quality Score (nearest whole number)** | | | | 4 | 3 |
| **Swift Parrot** | | | | | |
| Site Condition | 4 | • provision of mature and regenerating trees with large canopies | Vegetation of woodland areas typically comprised of a dense layer of regenerating bulloak, with only small areas present that consist of winter flowering eucalypt narrow-leaved ironbark (*Eucalyptus crebra*).<br>Grassland areas are devoid of trees. | 2.4 | NA |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Referral Area Description for Characteristics | Woodland Referral Area Quality | Grassland Referral Area Quality |
|---|---|---|---|---|---|
| | | • frequency of eucalypt flowering events | Frequency of flowering events in the small patches of narrow-leaved ironbark would likely occur on a regular basis. | | |
| | | • size and intensity of flowering events recorded | As the patches of winter flowering eucalypts are only small in size, the intensity of flowering events that would occur would only be minor. | | |
| | | • level of local habitat fragmentation and isolation | Woodland areas are moderately fragmented from other areas of appropriate foraging habitat for this species; however the scale of these barriers are not likely to be substantial for this highly mobile species. | | |
| | | • level of disturbance | Level of disturbance is high across woodland and grassland areas, due to impacts of past and current grazing activity as well as adjacent mining. | | |
| Site Context | 2 | • regional connectivity of habitat areas | Regional connectivity is poor as a result of surrounding mining activities and agricultural clearing. | 0.6 | NA |
| | | • importance of the site in relation to the overall species population | The Referral Area is unlikely to be of great importance to this species due to the absence of good quality areas of appropriate foraging habitat. | | |
| | | • proximity to and intensity of threats to habitat areas | Threats are immediate and immediately adjacent, predominantly in the form of mining activity and agriculture. | | |
| Species Stocking Rate | 4 | • the presence of the species on the site | This species has not been recorded in the Referral Area | 0.5 | NA |
| | | • the density of the species on the site | If this species were to occur in the Referral Area, it would likely be in low densities and only in passing to a larger area of more appropriate habitat. | | |
| | | • the role of the population in regards to the overall species population | The role of the Referral Area if this species were to utilise the habitats available would be for foraging purposes only, and only in passing between areas of higher quality habitat. | | |
| **Habitat Quality Score (nearest whole number)** | | | | 3 | NA |
| **Regent Honeyeater** | | | | | |
| Site Condition | 4 | • provision of mature and regenerating trees with large canopies | Vegetation of woodland areas typically comprised of a dense layer of regenerating bulloak, with only small areas present that consist of winter flowering eucalypt narrow-leaved ironbark (*Eucalyptus crebra*).<br>Grassland areas are devoid of trees. | 2.4 | NA |
| | | • frequency of eucalypt flowering events | Frequency of flowering events in the small patches of narrow-leaved ironbark would likely occur on a regular basis. | | |
| | | • size and intensity of flowering events recorded | As the patches of winter flowering eucalypts are only small in size, the intensity of flowering events that would occur would only be minor. | | |
| | | • level of local habitat fragmentation and isolation | Woodland areas are moderately fragmented from other areas of appropriate foraging habitat for this species; however the scale of these barriers are not likely to be substantial for this highly mobile species. | | |
| | | • level of disturbance | Level of disturbance is high across woodland and grassland areas, due to impacts of past and current grazing activity as well as adjacent mining. | | |
| Site Context | 2 | • regional connectivity of habitat areas | Regional connectivity is poor as a result of surrounding mining activities and | 0.6 | NA |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Referral Area Description for Characteristics | Woodland Referral Area Quality | Grassland Referral Area Quality |
|---|---|---|---|---|---|
| | | | agricultural clearing. | | |
| | | • importance of the site in relation to the overall species population | The Referral Area is unlikely to be of great importance to this species due to the absence of good quality areas of appropriate foraging habitat. | | |
| | | • proximity to and intensity of threats to habitat areas | Threats are immediate and immediately adjacent, predominantly in the form of mining activity and agriculture. | | |
| Species Stocking Rate | 4 | • the presence of the species on the site | This species has not been recorded in the Referral Area | 0.5 | NA |
| | | • the density of the species on the site | If this species were to occur in the Referral Area, it would likely be in low densities and only in passing to a larger area of more appropriate habitat. | | |
| | | • the role of the population in regards to the overall species population | The role of the Referral Area if this species were to utilise the habitats available would be for foraging purposes only, and only in passing between areas of higher quality habitat. | | |
| **Habitat Quality Score (nearest whole number)** | | | | 3 | NA |
| **Large-eared Pied Bat** | | | | | |
| Site Condition | 5 | • provision of mature trees and a canopy | Woodland areas typically dominated by dense bulloak (*Allocasuarina luehmannii*) with small pockets of narrow-leaved ironbark (Eucalyptus crebra). Trees are typically middle-aged or regrowth.<br>Grassland areas do not provide mature trees and canopy. | 2 | NA |
| | | • provision of roost sites | No rocky overhangs or caves present in grassland or woodland areas. | | |
| | | • density, structure and diversity of shrub layers | Shrub layers generally absent from grassland areas.<br>Shrub layers present in woodland areas, although not very dense or diverse as shaded out by dense bulloak. | | |
| | | • level of local habitat fragmentation and isolation | Fragmentation between woodland areas is moderate to high. | | |
| | | • level of disturbance | Disturbance of grassland areas is high as the majority are being grazed.<br>Woodland areas have a high degree of edge effect from surrounding agricultural activities as well as adjacent mining. | | |
| Site Context | 3 | • regional connectivity of habitat area | Connectivity of the Referral Area to areas of known or potential habitat are limited due to the extent of surrounding mining activity to the immediate north and west of the Referral Area. | 0.9 | NA |
| | | • importance of the site in relation to the overall species population | The Referral Area is unlikely to be important for the large-eared pied bat as it does not provide known habitat for this species, providers only marginal quality potential foraging habitat and no roosting habitat. | | |
| | | • proximity to and intensity of threats to habitat areas | Threats are immediate and immediately adjacent, predominantly in the form of mining activity and agriculture. | | |
| Species Stocking Rate | 2 | • the presence of the species on the site | This species has not been recorded in the Referral Area. | 0.2 | NA |
| | | • the density of the species on the site | If this species were to occur, densities would be low due to an absence of appropriate areas for roosting and low quality foraging habitat. | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Referral Area Description for Characteristics | Woodland Referral Area Quality | Grassland Referral Area Quality |
|---|---|---|---|---|---|
| | | • the role of the population in regards to the overall species population | The Referral Area is unlikely to be important for the overall species population as it would be unlikely to be using the site for anything other than in passing through to reach an area of greater quality habitat | | |
| **Habitat Quality Score (nearest whole number)** | | | | 3 | NA |

Furthermore, the quality of habitat for each of the MNES is assessed in a manner consistent with the approach outlined by the Commonwealth Department of the Environment (2012) for the proposed offset sites. Habitat quality scores and descriptions of the available habitats that were used to determine the extent of impact that would be offset by the proposed offsets are provided in **Table 8.14** below.

**Table 8.14 - Habitat Quality Scores for the MNES in the Mountain Block Offset Area and the Bowmans Creek Riparian Corridor**

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| **Spotted -tailed Quoll Mountain Block Offset Area** | | | | | | | | | | | |
| Site Condition | 2 | Provision of a variety of habitat structures | Grassland areas have few habitat structures for this species; however have a high regenerative capacity. Wooded areas provide a moderate to high extent of habitat features (particularly in areas of dry rainforest) with reasonable tree, shrub and groundcover in good condition.<br>In the absence of offsetting, the current condition and quality of habitat available for this species will not be likely to alter substantially. Habitat features in grassland areas will substantially improve if allowed to regenerate due to the development of shrub and canopy layer and as well as habitat augmentation works. | 0.8 | 1.2 | 1.2 | 1.2 | 0.4 | 0.4 | 0.4 | 1 |
| | | Provision of prey densities | Prey densities in grasslands are limited due to an absence of habitat features however moderate in the woodland areas with a greater variety of niches for prey species.<br>In the absence of offsetting, prey density is unlikely to change. Prey densities of grassland areas will improve with time if vegetation is allowed to regenerate and provide improved habitat, this will also improve prey densities in woodland areas which will have greater connectivity. | | | | | | | | |
| | | Level of disturbance | Grassland areas are highly modified and disturbed. Wooded areas are much less disturbed, however subject to edge effects from surrounding activities such as agricultural activities and mining. In the absence of offsetting, the level of disturbance to this site may slightly increase. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing and with habitat protection through an offset mechanism. | | | | | | | | |
| Site Context | 4 | Regional connectivity of habitat areas | Fragmentation between areas of woodland habitat is moderate. Fragmentation and connectivity less of an issue in the north than in the south. In the absence of offsetting connectivity may continue to diminish through continuing grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 2 | 2 | 1.6 | 2.8 | 1.6 | 1.6 | 1.6 | 2.4 |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | Importance of the site in relation to the overall species population | Wooded areas provide habitat to a viable male near the known territory of a breeding female. Likely important area of north-south linkage.<br>The importance of this site as a habitat linkage will increase with regeneration works to grassland. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Many threats are acting on the site, with agricultural activities both previously occurring onsite and current activities surrounding it. The offset area is directly adjacent to mining activity and has the potential to be developed for future mining. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 4 | Presence of the species on the site | A male spotted-tailed quoll has been recorded using woodland areas of Mountain Block for denning. Grassland areas are likely to only be utilised for foraging or when moving between areas of habitat. | 1.6 | 2.4 | 2.4 | 2.8 | 0.8 | 1.6 | 1.6 | 2.4 |
| | | Density of the species on the site | The species density is considered high given the territoriality of this species. Grassland areas of the site are likely to be subject to more regular use as a result of grassland regeneration. | | | | | | | | |
| | | Role of the population in regards to the overall species population | Mountain Block is likely to be important for gene flow in the middle Foy Brook local population. The role of the site in terms of connectivity will be improved with regeneration works. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **4** | **6** | **5** | **7** | **3** | **4** | **4** | **6** |
| **Spotted-tailed Quoll Bowmans Creek Riparian Corridor** | | | | | | | | | | | |
| Site Condition | 2 | Provision of a variety of habitat structures | Variety of habitat structures available for quoll in wooded areas in the form of log piles that are known to be utilised as breeding dens. Habitat structures for the quoll are minimal in grassland areas. Habitat features in grassland areas will substantially improve if allowed to regenerate due to the development of shrub and canopy layer and as well as habitat augmentation works. | 0.8 | 1.4 | 1.2 | 1.4 | 0.4 | 0.4 | 0.4 | 1 |
| | | Provision of prey densities | Prey densities are moderate in wooded areas due the variety of niches provided for prey species. Prey densities are virtually absent from grassland areas. In the absence of offsetting, prey density is unlikely to | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | | change. Prey densities of grassland areas will improve with time if vegetation is allowed to regenerate and provide improved habitat, this will also improve prey densities in woodland areas which will have greater connectivity. | | | | | | | | |
| | | Level of disturbance | Edge effects acting on the corridor are high due to its narrow nature, particularly from agriculture and mining. Wooded areas are moderately disturbed and have a largely modified shrub layer. Disturbance and modification of grassland areas is high and has little resemblance to their original state. In the absence of offsetting, the level of disturbance to this site may slightly increase. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing and with habitat protection through an offset mechanism. | | | | | | | | |
| Site Context | 4 | Regional connectivity of habitat areas | Fragmentation between woodland areas of the corridor is moderate; however north-south movement is not a great obstacle for this particular species. Connectivity to the east and west are limited by mining activities that would provide substantial obstacles for this species. In the absence of offsetting connectivity may continue to diminish through continuing grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 2 | 2.4 | 2 | 2.8 | 1.6 | 1.6 | 1.6 | 2.4 |
| | | Importance of the site in relation to the overall species population | This site contains a known breeding den site for the spotted-tailed quoll and is therefore likely to be important to the overall species population, particularly in terms of potential dispersal further south into the Hunter Valley. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | The site is in very close proximity to existing mining operations to the east and west. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 4 | Presence of the species on the site | The species is known to occur and breed in the woodland areas of the corridor. | 1.6 | 3.6 | 3.2 | 3.6 | 0.8 | 1.2 | 1.2 | 3.2 |
| | | Density of the species on the site | Species density is high given territoriality of this species (particularly during breeding events). Grassland areas of the site are likely to be subject to more regular use as a result of grassland regeneration. | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | Role of the population in regards to the overall species population | The role of the woodland areas of the site are high regarding the overall species population as they provide known breeding habitat for this species in an area that is on the southern boundary of the Foy Brook population. The role of the site in terms of connectivity will be improved with regeneration works. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **4** | **7** | **6** | **8** | **3** | **3** | **3** | **7** |
| **Swift Parrot Mountain Block Offset Site** | | | | | | | | | | | |
| Site Condition | 4 | Provision of mature and regenerating trees with large canopies | Grassland areas are virtually devoid of mature trees, however are considered to have a high capacity for regeneration. Woodland areas have abundant mature and regenerating trees with moderate canopy densities. In the absence of offsetting, the current condition and quality of habitat available for this species will not be likely to alter substantially. With regeneration works to grasslands the presence of winter-flowering eucalypt species will be increased. | 2.4 | 2.4 | 2 | 2.4 | NA | 0 | 0 | 2.4 |
| | | Frequency of eucalypt flowering events | Eucalypt flowering events are likely to be regular. With regeneration works to grassland, the likelihood of regular flowering events will be increased. | | | | | | | | |
| | | Size and intensity of flowering events recorded | Size and intensity of flowering events are limited in the woodland areas due to the fragmentation of woodland patches. Flowering events would be virtually absent in grassland areas, with the exception of sporadic paddock trees. In the absence of offsetting; connectivity may continue to diminish through continued grazing practices. If grasslands are regenerated, more winter flowering eucalypts will be present which will increase the scale of flowering events and the likelihood of intense flowering events. | | | | | | | | |
| | | Level of local habitat fragmentation and isolation | Habitat fragmentation and isolation is marginal for this highly mobile species. Connectivity to other eucalypt dominated vegetation to the north is good. Fragmentation of currently connected woodland areas will be reduced with regeneration of grassland areas. | | | | | | | | |
| | | Level of disturbance | Woodland areas are largely unmodified. In the absence of offsetting, the level of disturbance to this site may slightly increase. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | | and with habitat protection through an offset mechanism. | | | | | | | | |
| Site Context | 2 | Regional connectivity of habitat areas | Site is moderately connected to the north to other areas of eucalypt dominated woodland (barriers to this species would not be substantial). Regional connectivity to the south is limited. In the absence of offsetting, connectivity may continue to diminish through continued grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 0.6 | 0.8 | 0.6 | 1 | NA | 0.4 | 0.4 | 1 |
| | | Importance of the site in relation to the overall species population | Importance likely to be low given that it provides potential habitat but not of optimal quality but has not been recorded there. Importance of the site during migration of this species will be slightly increased after regeneration of grassland areas. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Threats to site are immediate and adjacent in the form of agriculture and mining activities. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 4 | Presence of the species on the site | The species would not use the grassland vegetation in its current state. The species has not been recorded using the woodland habitats however there is potential that it would. The likelihood of the presence of the species onsite will slightly increase with regeneration of grassland areas. | 0.4 | 0.8 | 0.8 | 1.2 | NA | 0 | 0 | 1.2 |
| | | Density of the species on the site | There is no currently known density for species using this site. There is potential that the density of species using this site will increase with regeneration of grassland areas. | | | | | | | | |
| | | Role of the population in regards to the overall species population | Grassland areas in their current state have no role for the overall species population, however would provide linkages if allowed to regenerate. Woodland areas have a low potential importance to this species, however his would be higher if adjoining grassland areas regenerated due to the potential for the increase in occurrence of mass flowering events. The role of the site as a potential migration pathway will slightly increase with the regeneration of grassland areas. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **3** | **4** | **3** | **5** | **NA** | **0** | **0** | **5** |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| **Swift Parrot Bowmans Creek Riparian Corridor** | | | | | | | | | | | |
| **Site Condition** | **4** | Provision of mature and regenerating trees with large canopies | Trees of the correct species are virtually absent from woodland areas of this corridor (which typically consists of dense river oak (*Casuarina cunninghamiana)*) and are absent from the grassland areas. In the absence of offsetting, the current condition and quality of habitat available for this species will not be likely to alter substantially. With regeneration works to grasslands the presence of winter-flowering eucalypt species will be increased. | 2.4 | 1.2 | 1.2 | 2 | NA | 0 | 0 | 1.6 |
| | | Frequency of eucalypt flowering events | Flowering event of eucalypt species are likely to be highly limited. With regeneration works to grassland, the likelihood of regular flowering events will be increased. | | | | | | | | |
| | | Size and intensity of flowering events recorded | Vegetation of the corridor is typically dominated by dense river oak (*Casuarina cunninghamiana*) which is not a flowering eucalypt species. Flowering eucalypts are absent from grassland areas. If grasslands are regenerated, more winter flowering eucalypts will be present which will increase the scale of flowering events and the likelihood of intense flowering events. | | | | | | | | |
| | | Level of local habitat fragmentation and isolation | Fragmentation to this species in the north/south would not be a substantial obstacle for this species. Movement to the east-west is highly restricted by mining activity. Fragmentation of currently connected woodland areas will be reduced with regeneration of grassland areas. | | | | | | | | |
| | | Level of disturbance | Level of disturbance is high (largely modified and disturbed by edge effects from mining and agriculture). Woodland areas are moderately disturbed. In the absence of offsetting, the level of disturbance to this site may slightly increase. Grasslands are highly disturbed and bear little resemblance to natural state. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing and with habitat protection through an offset mechanism. | | | | | | | | |
| Site Context | 2 | Regional connectivity of habitat areas | Site has moderate connectivity between the north and south (barriers to this species would not be substantial) and poor connectivity to the east/west. In the absence of offsetting, connectivity may continue to diminish through continued grazing practices. Connectivity will increase as | 0.6 | 0.6 | 0.6 | 1 | NA | 0.2 | 0.2 | 1 |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | | a result of regeneration of grassland areas. | | | | | | | | |
| | | Importance of the site in relation to the overall species population | Importance likely to be low given that it provides very low levels of appropriate feed species and is not known to occur. Importance of the site during migration of this species will be slightly increased with regeneration of grassland areas. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Threats to site are immediate and adjacent in the form of agriculture and mining activities. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 4 | Presence of the species on the site | This species has not been recorded on site, and is unlikely to due to an absence of appropriate habitat. The likelihood of the presence of the species onsite will slightly increase with regeneration of grassland areas. | 0.4 | 0.4 | 0.4 | 1.2 | NA | 0 | 0 | 1.2 |
| | | Density of the species on the site | If this species were to occur the density would be low as it would likely to only be momentarily landing there in passing to an area of higher quality habitat. There is potential that the density of species using this site will increase with regeneration of grassland areas. | | | | | | | | |
| | | Role of the population in regards to the overall species population | The role of the woodland areas of this site would currently play a marginal role at best to the overall species population. The grassland areas in their current state provide no habitat value; however if allowed to regenerate its role would increase in its assistance with dispersal. The role of the site as a potential migration pathway will slightly increase with the regeneration of grassland areas. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **3** | **2** | **2** | **4** | **NA** | **0** | **0** | **4** |
| **Regent Honeyeater Mountain Block Offset Site** | | | | | | | | | | | |
| Site Condition | 4 | Provision of mature and regenerating trees with large canopies | Grassland areas are virtually devoid of mature trees, however are considered to have high capacity for regeneration. Woodland areas have abundant mature and regenerating trees with moderate canopy densities. In the absence of offsetting, current condition and quality of habitat for this species will not be likely to alter substantially. The presence of winter-flowering eucalypts | 2.4 | 2.4 | 2 | 2.4 | NA | 0 | 0 | 2.4 |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | | will increase with grassland regeneration. | | | | | | | | |
| | | Frequency of eucalypt flowering events | Eucalypt flowering events are likely to be regular. With regeneration works to grassland, the likelihood of regular flowering events will be increased. | | | | | | | | |
| | | Size and intensity of flowering events recorded | Size and intensity of flowering events are limited in the woodland areas due to the fragmentation of woodland patches. Flowering events would be virtually absent in grassland areas, with the exception of sporadic paddock trees. If grasslands are regenerated, more winter flowering eucalypts will be present, increasing the scale of flowering events and the likelihood of intense flowering events. | | | | | | | | |
| | | Level of local habitat fragmentation and isolation | Habitat fragmentation and isolation is marginal for this highly mobile species. Connectivity to other eucalypt dominated vegetation to the north is good. Fragmentation of currently connected woodland areas will be reduced with regeneration of grassland areas. | | | | | | | | |
| | | Level of disturbance | Woodland areas are largely unmodified. In the absence of offsetting, the level of disturbance to this site may slightly increase. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing and with habitat protection through an offset mechanism. | | | | | | | | |
| Site Context | 2 | Regional connectivity of habitat areas | Site is moderately connected to the north to other areas of eucalypt dominated woodland (barriers to this species would not be substantial). Regional connectivity to the south is limited. In the absence of offsetting, connectivity may continue to diminish through continued grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 0.6 | 0.8 | 0.6 | 1 | NA | 0.4 | 0.4 | 1 |
| | | Importance of the site in relation to the overall species population | Importance likely to be low given that it provides potential habitat but not of optimal quality but has not been recorded there. Importance of the site during migration of this species will be slightly increased after regeneration of grassland areas. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Threats to site are immediate and adjacent in the form of agriculture and mining activities. In the absence of offsetting, threats are likely to continue encroaching on | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | | available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 4 | Presence of the species on the site | The species would not use the grassland vegetation in its current state. The species has not been recorded using the woodland habitats however there is potential that it would. The likelihood of the presence of the species onsite will slightly increase with regeneration of grassland areas. | 0.4 | 0.8 | 0.8 | 1.2 | NA | 0 | 0 | 1.2 |
| | | Density of the species on the site | There is no currently known density for species using this site. There is potential that the density of species using this site will increase with regeneration of grassland areas. | | | | | | | | |
| | | Role of the population in regards to the overall species population | Grassland areas in their current state have no role for the overall species population, however would provide linkages if allowed to regenerate. Woodland areas have a low potential importance to this species, however his would be higher if adjoining grassland areas regenerated due to the potential for the increase in occurrence of mass flowering events. The role of the site as a potential migration pathway will slightly increase with the regeneration of grassland areas. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **3** | **4** | **3** | **5** | **NA** | **0** | **0** | **5** |
| **Regent Honeyeater Bowmans Creek Riparian Corridor** | | | | | | | | | | | |
| Site Condition | 4 | Provision of mature and regenerating trees with large canopies | Trees of the correct species are virtually absent from woodland areas of this corridor (which typically consists of dense river oak (*Casuarina cunninghamiana)*) and are absent from the grassland areas. In the absence of offsetting, the current condition and quality of habitat available for this species will not be likely to alter substantially. With regeneration works to grasslands the presence of winter-flowering eucalypt species will be increased. | 2.4 | 1.2 | 1.2 | 2 | NA | 0 | 0 | 1.6 |
| | | Frequency of eucalypt flowering events | Flowering event of eucalypt species are likely to be highly limited. With regeneration works to grassland, the likelihood of regular flowering events will be increased. | | | | | | | | |
| | | Size and intensity of flowering events recorded | Vegetation of the corridor is typically dominated by dense river oak (*Casuarina cunninghamiana*) which is not a flowering eucalypt species. Flowering eucalypts are | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | | absent from grassland areas. If grasslands are regenerated, more winter flowering eucalypts will be present which will increase the scale of flowering events and the likelihood of intense flowering events. | | | | | | | | |
| | | Level of local habitat fragmentation and isolation | Fragmentation to this species in the north/south would not be a substantial obstacle for this species. Movement to the east-west is highly restricted by mining activity. Fragmentation of currently connected woodland areas will be reduced with regeneration of grassland areas. | | | | | | | | |
| | | Level of disturbance | Level of disturbance is high (largely modified and disturbed by edge effects from mining and agriculture). Woodland areas are moderately disturbed. Grasslands are highly disturbed and bear little resemblance to natural state. In the absence of offsetting, the level of disturbance to this site may slightly increase. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing and with habitat protection through an offset mechanism. | | | | | | | | |
| Site Context | 2 | Regional connectivity of habitat areas | Site has moderate connectivity between the north and south (barriers to this species would not be substantial) and poor connectivity to the east/west. In the absence of offsetting, connectivity may continue to diminish through continued grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 0.6 | 0.6 | 0.6 | 1 | NA | 0.2 | 0.2 | 1 |
| | | Importance of the site in relation to the overall species population | Importance likely to be low given that it provides very low levels of appropriate feed species and is not known to occur. Importance of the site during migration of this species will be slightly increased after regeneration of grassland areas. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Threats to site are immediate and adjacent in the form of agriculture and mining activities. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 4 | Presence of the species on the site | This species has not been recorded on site, and is unlikely to due to an absence of appropriate habitat. The likelihood of the presence of the species onsite will slightly increase with regeneration of grassland areas. | 0.4 | 0.4 | 0.4 | 1.2 | NA | 0 | 0 | 1.2 |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | Density of the species on the site | If this species were to occur the density would be low as it would likely to only be momentarily landing there in passing to an area of higher quality habitat. There is potential that the density of species using this site will increase with regeneration of grassland areas. | | | | | | | | |
| | | Role of the population in regards to the overall species population | The role of the woodland areas of this site would currently play a marginal role at best to the overall species population. The grassland areas in their current state provide no habitat value; however if allowed to regenerate its role would increase in its assistance with dispersal. The role of the site as a potential migration pathway will slightly increase with the regeneration of grassland areas. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **3** | **2** | **2** | **4** | **NA** | **0** | **0** | **4** |
| **Large-eared Pied Bat Mountain Block Offset Site** | | | | | | | | | | | |
| Site Condition | 5 | Provision of mature trees and a canopy | Wooded areas provide moderate quantities of mature trees and a moderately dense canopy layer (particularly in areas of dry rainforest). Mature trees and canopy are virtually absent from grasslands. In the absence of offsetting, the current condition and quality of habitat available for this species will not be likely to alter substantially. With regeneration of grassland area the canopy presence and connectivity of this site will increase. | 2 | 2.5 | 2 | 2.5 | NA | 0 | 0 | 1.5 |
| | | Provision of roost sites | Roost sites are not present. | | | | | | | | |
| | | Density, structure and diversity of shrub layers | Density, structure and diversity in shrub layers are moderate for wooded areas and virtually absent from grasslands. | | | | | | | | |
| | | Level of local habitat fragmentation and isolation | Site is close to areas that provide escarpment habitat. Connectivity for this species is moderate to the north and low to the south. | | | | | | | | |
| | | Level of disturbance | Grassland areas are largely modified, however woodland areas are largely intact and undisturbed. In the absence of offsetting, the level of disturbance to this site may slightly increase. Level of disturbance for woodland and grassland areas will reduce with the removal of grazing and with habitat protection through an offset mechanism. | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| Site Context | 3 | Regional connectivity of habitat areas | Connectivity to areas of known or potential habitat for this species is moderate. In the absence of offsetting, connectivity may continue to diminish through continued grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 0.9 | 1.2 | 1.2 | 1.8 | NA | 0.3 | 0.3 | 1.8 |
| | | Importance of the site in relation to the overall species population | Site has low importance to overall species population as it is not known to occur and unlikely to occur. If this species was present it is likely that it would only be utilising the site for foraging or in passing between sites. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Site has been subject to agricultural activity (particularly in grassland areas) and is surrounded by both agricultural and mining activity. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 2 | Presence of the species on the site | The large-eared pied bat has not been recorded here and is not likely to occur due to an absence of caves. The likelihood of the species foraging onsite will slightly increase with regeneration of grassland areas. | 0.2 | 0.2 | 0.2 | 0.4 | NA | 0 | 0 | 0.2 |
| | | Density of the species on the site | This species is not known to occur, if it did occur it would likely only be in passing in the wooded areas. There is potential that the density of species using this site will increase with regeneration of grassland areas. | | | | | | | | |
| | | Role of the population in regards to the overall species population | There is no population of this species present on site. The site has no role for the species population. The role of the site as a potential flight way and foraging area will slightly increase with the regeneration of grassland areas. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **3** | **4** | **3** | **5** | **NA** | **0** | **0** | **4** |
| **Large-eared Pied Bat Bowmans Creek Riparian Corridor** | | | | | | | | | | | |
| Site Condition | 5 | Provision of mature trees and a canopy | Wooded areas provide some mature trees and a dense canopy layer. Mature trees and canopy are virtually absent from grasslands. In the absence of offsetting, the current condition and quality of habitat available for this species will not be likely to alter substantially. With regeneration of grassland area the canopy presence and connectivity of this site will increase. | 2 | 2 | 2 | 2 | NA | 0 | 0 | 2.5 |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | Provision of roost sites | No roost sites are present. | | | | | | | | |
| | | Density, structure and diversity of shrub layers | Density, structure and diversity in shrub layers are low for wooded areas (dominated by dense river oak vegetation) and virtually absent from grasslands. | | | | | | | | |
| | | Level of local habitat fragmentation and isolation | Site is a narrow corridor and provides good connectivity in a north-south direction. Fragmentation is high, with wooded areas within the corridor poorly connected. East-west connectivity is poor and likely a substantial obstacle to this species. | | | | | | | | |
| | | Level of disturbance | Level of disturbance in grassland areas are high, largely modified and weed infested. In the absence of offsetting, the level of disturbance to this site may slightly increase. The level of disturbance will decrease if subject to offsetting protection. | | | | | | | | |
| Site Context | 3 | Regional connectivity of habitat areas | Connectivity to areas of known or high potential habitat for this species are limited. Species is mobile, however high distances would be needed to travel. In the absence of offsetting, connectivity may continue to diminish through continued grazing practices. Connectivity will increase as a result of regeneration of grassland areas. | 0.9 | 0.9 | 0.9 | 1.2 | NA | 0.3 | 0.3 | 1.2 |
| | | Importance of the site in relation to the overall species population | Importance of the site is low given that it is not known to occur and provides limited habitat. | | | | | | | | |
| | | Proximity to and intensity of threats to habitat areas | Threats to site are high given narrow, linear nature, agricultural activity and adjacent mining to the east and west. In the absence of offsetting, threats are likely to continue encroaching on available habitats. Threats occurring on site will be reduced by offsetting. | | | | | | | | |
| Species Stocking Rate | 2 | Presence of the species on the site | The large-eared pied bat has not been recorded here and is not likely to occur due to an absence of caves. The likelihood of the species foraging onsite will slightly increase with regeneration of grassland areas. | 0.2 | 0.2 | 02 | 0.4 | NA | 0 | 0 | 0.2 |
| | | Density of the species on the site | This species is not known to occur, if it did occur it would likely only be in passing in the wooded areas. There is potential that the density of species using this site will increase with regeneration of grassland areas. | | | | | | | | |

| Components of Habitat Quality | Weighting | Characteristics of Habitat Quality Components | Offset Habitat Description for Characteristics | Woodland | | | | Grassland/Disturbed Areas | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset | Impact Area Quality | Offset Start Quality | Quality Without Offset | Quality With Offset |
| | | Role of the population in regards to the overall species population | There is no population of this species present on site. The site has no role for the species population. The role of the site as a potential flight way and foraging area will slightly increase with the regeneration of grassland areas. | | | | | | | | |
| **Habitat Quality Score (nearest whole number)** | | | | **3** | **3** | **3** | **4** | **NA** | **0** | **0** | **4** |

#### 8.5.1.1 Estimation and Explanation of Risk of Loss

The risk of loss and the confidence in the risk of loss of the habitats provided for each of the offset areas is provided in **Table 8.15** below.

**Table 8.15 – Risk of Loss for Offset Areas**

| Offset Area | Risk of Loss (%) | | Confidence in Risk of Loss (%) |
|---|---|---|---|
| | Without Offset | With Offset | |
| Bowmans Creek Riparian Corridor | 70 | 5 | 80 |
| Mountain Block Offset Area | 50 | 5 | 80 |

**Presence of Pending Development and Activities**

Without a formal protection mechanism and management in place, the risk of ongoing grazing of both the Bowmans Creek Riparian Corridor and Mountain Block Offset Area is very high. If grazing is permitted to continue, it is likely that both sites will continue to experience degradation, particularly to the understorey vegetation. With offset protection in place, domestic stock will be strategically managed within offset areas in a manner that manages key risks such as weeds and bushfire

Given that Bowmans Creek Riparian Corridor is surrounded both to the east and west by mining activities, there is a very high chance that this area would be subject to mining at some point in the future. The length of the corridor was carefully considered and was truncated to avoid areas that are likely to be subject to future development.

Coal resources extend up and through the Mountain Block Offset Area, and therefore this area has a low to moderate future mining potential. Mining activities previously occurred immediately south of the Mountain Block Offset Area, with agriculture being the dominant land-use to the north. It is considered that the potential for the Mountain Block Offset Area to be developed for the purposes of mining is slightly lower than Bowmans Creek Riparian Corridor.

Based on the above factors, the risk of loss of the current ecological value of the site if LCO do not use Bowmans Creek Riparian Corridor as a biodiversity offset (measured over a 20 year period), was identified at 70 per cent. There is a moderate to high potential that if not protected, this area will be further degraded by ongoing grazing practices or be subject to future mining approvals. As an offset, mining will not be permitted to occur in this area and grazing will be highly regulated; it is considered that under this scenario the risk of loss of habitat is minimal (5 per cent).

Based on the above factors, the risk of loss of the current ecological value of the site if LCO do not use Mountain Block as a biodiversity offset (measured over a 20 year period), was identified at 50 per cent. There is a moderate potential that if not protected, this area will be further degraded by ongoing grazing practices or be subject to future mining approvals. As an offset, mining will not be permitted to occur in this area and grazing will be highly regulated; it is considered that under this scenario the risk of loss of habitat is minimal (5 per cent).

**Average Risk of Loss for Similar Sites**

The average risk of loss of similar sites is unknown. The Bowmans Creek Riparian Corridor and Mountain Block Offset Area are both adjacent to existing operational mining activities. Any expansion of mining or operational areas may result in impacts (once approved) on adjacent land holdings. The average risk of loss for areas of land adjacent to active mine sites is high. Both sites are additionally at a high risk of further degradation though grazing activities.

**Presence and Strength of Formal Protection Mechanisms Currently in Place**

There are no formal protection mechanisms currently in place across the Bowmans Creek Riparian Corridor or Mountain Block Offset Area. Both sites are wholly owned by the Liddell Joint Venture (JV) (67.5% Glencore and 32.5% Mitsui Matsushima Australia Pty Limited) and managed on behalf of the JV by Glencore (Liddell).

### 8.5.2 EPBC Calculator Outputs

A summary of the quality inputs provided in **Table 8.13, Table 8.14** and **Table 8.15** above provided the EPBC Calculator outputs in **Table 8.16** below.

**Table 8.16– Extent of Proposed Action Impacts Offset by Conservation of Mountain Block Offset Area and Bowmans Creek Riparian Corridor**

| | Hectares | Sub-total (%) | Total (%) |
|---|---|---|---|
| **Spotted-tailed Quoll Offsetting** | | | |
| **Extent of Grassland Impact being Offset** | | | |
| Mountain Block Grassland | 76 | 101 | **101** |
| **Extent of Woodland Impact Being Offset** | | | |
| Mountain Block Grassland | 25 | 13 | **183** |
| Mountain Block Woodland | 65 | 36 | |
| Bowmans Creek Grassland | 145 | 113 | |
| Bowmans Creek Woodland | 33 | 21 | |
| **Swift Parrot Offsetting** | | | |
| **Extent of Woodland Impact Being Offset** | | | |
| Mountain Block Grassland | 101 | 192 | **484** |
| Mountain Block Woodland | 57 | 75 | |
| Bowmans Creek Grassland | 141 | 214 | |
| Bowmans Creek Woodland | 2 | 3 | |
| **Regent Honeyeater Offsetting** | | | |
| **Extent of Woodland Impact Being Offset** | | | |
| Mountain Block Grassland | 101 | 192 | **484** |
| Mountain Block Woodland | 57 | 75 | |
| Bowmans Creek Grassland | 141 | 214 | |
| Bowmans Creek Woodland | 2 | 3 | |
| **Large-eared Pied Bat Offsetting** | | | |
| **Extent of Woodland Impact Being Offset** | | | |
| Mountain Block Grassland | 101 | 81 | **261** |
| Mountain Block Woodland | 65 | 45 | |
| Bowmans Creek Grassland | 145 | 117 | |
| Bowmans Creek Woodland | 33 | 18 | |

**Table 8.16** shows that with the quality inputs from offset sites provided in **Table 8.14**, the Mountain Block Offset Area and the Bowmans Creek Riparian corridor provide more than 100% of the required offsetting requirements for the:

- Potential grassland habitat within the Referral Area for the spotted-tailed quoll with 100.92 per cent;
- Potential woodland habitat within the Referral Area for the spotted-tailed quoll with 183.05 per cent;
- Potential woodland habitat within the Referral Area for both the swift parrot and regent honeyeater, each with 483.62 per cent; and
- Potential woodland habitat within the Referral Area for the large-eared pied bat with 261.18 per cent.

The above values are based on the commitment to rehabilitate Grassland and Disturbed Areas into woodland vegetation in the Mountain Block Offset Area and Bowmans Creek Riparian Corridor.

## 8.6 Discussion

Overall the proposed offsets provide a significant opportunity to protect and restore habitat for the MNES likely to be affected by the project, including the avoidance of loss of these habitats. The habitats of the offsets support derived native grassland within a matrix of remnant woodland. There is a large environmental gain, including substantial habitat quality improvement that will be achieved through the regeneration, revegetation and improved connectivity of these areas with adjoining protected habitats.

The Mountain Block Offset Area consists of eucalypt dominated woodland, rainforest and grassland areas, and is well connected to other areas of eucalypt dominated woodland to the north. The woodland and rainforest areas are largely unmodified, although there is some evidence of edge effects on the woodland communities from agriculture and mining activities in the area. The rainforest areas in particular provide high quality habitat in the form of rock/boulder habitat, and abundant fruiting trees and shrubs. The Bowmans Creek Riparian Corridor also consists of woodland and grassland areas, with the river oak dominated wooded areas moderately disturbed and a shrub layer largely absent. Edge effects acting on the corridor, particularly from agriculture and mining, are high due to its narrow nature. Grassland in both areas is highly modified and disturbed, although is considered to have a high capacity for regeneration.

For all four species (spotted-tailed quoll, regent honeyeater, swift parrot and large-eared pied bat), it is expected that management actions will deliver the proposed outcomes over a 20 year period. Improvements in habitat quality will continue beyond 20 years but for the purposes of assessing the value of the improvements for species 20 years was selected as the maximum in accordance with the EPBC calculator guidelines.

The time until the ecological benefit will be provided by the offsets was assessed variably for each MNES and for the different habitat forms of each offset (i.e. Grassland versus Woodland) due to their different habitat requirements of different species, varying between 5 and 15 years. For example, spotted-tailed quolls have broader foraging options than regent honeyeaters and as such these numbers are reflective of these particulars.

Both the Mountain Block Offset Area and the Bowmans Creek Riparian Corridor are surrounded by mining leases and have the potential to be subject to coal mining in the future unless they are protected. If the Proposed Action is approved, protection will be afforded to both offset sites.

Other threats to the offset sites in the absence of any formal protection and/or management include degradation due to ongoing grazing by domestic stock as well as weed and pest species outcompeting and predating on native flora and fauna. Both the Mountain Block Offset Area and the Bowmans Creek Riparian Corridor are subject to grazing and without protection will continue to be degraded by grazing stock. If the Proposed Action is approved, grazing stock will be strategically managed across the offset sites.

Weed species, particularly in the Bowmans Creek Riparian Corridor, are relatively abundant and outcompeting native flora species for resources as well as reducing the quality of habitat available to native fauna. If the Proposed Action is approved, both offset sites will be subject to targeted weed control works as part of an offset management plan.

Feral fauna species levels, particularly in the Bowmans Creek Riparian Corridor, are relatively abundant and causing detriment to the quality of habitats available to threatened and non-threatened species (but in particular the spotted-tailed quoll. If the Proposed Action is approved, both offset sites will be subject to pest species control as part of an offset management plan (with a particular emphasis placed on pest species that would specifically cause detriment to the spotted-tailed quoll being the fox, wild dog and pig).

The offset strategy has been specifically designed to conserve known habitat (including breeding habitat) for the spotted-tailed quoll. It has additionally been designed to conserve likely areas of habitat for the regent honeyeater, swift parrot and large-eared pied bat.

Offset sites will be augmented, restored and rehabilitated in a manner which maximises the quality of habitat provided after a 20 year period by the offset areas for the spotted-tailed quoll, regent honeyeater, swift parrot and large-eared pied bat.

## 8.7 Description of How the Offset(s) are Consistent with the EPBC Act Environmental Offsets Policy (October 2012)

An assessment has been conducted of the proposed biodiversity offset strategy against the Commonwealth Government's EPBC Environmental Offset Policy (DSEWPC 2012). The assessment against the Commonwealth EPBC Act Environmental Offsets Policy and the use of the Environmental Offset Assessment Guide (October 2012) indicates that the proposed offset sites provide between 101 and 484 per cent of the minimum requirements to offset the relevant MNES.

**1. Suitable offsets must deliver an overall conservation outcome that improves or maintains the viability of the protected matter.**

The biodiversity offset strategy for the Proposed Action has been developed with the aim to maintain or improve the biodiversity values of the surrounding region in the medium to long term. With the various impact mitigation and offset strategies to be employed as part of the Proposed Action, it is likely that such an improvement will occur as woodland and derived native grassland areas are managed for conservation and derived native grassland areas are managed to return to woodland condition.

The Mountain Block Offset Area and Bowmans Creek Riparian Corridor will be secured for long term conservation. It is a general condition of approval of most offsets that the landholder provides for appropriate long-term security of the offset to the satisfaction of the Director-General. Glencore has participated in ongoing discussions with both the NSW Government (DPE and OEH) and the DoE regarding appropriate legal mechanisms to protect biodiversity offset areas over at least two years. Glencore understands that the relevant departments are working on a policy relating to appropriate mechanisms. It is the preference of Glencore that the mechanism to secure offset areas in the long-term is via Voluntary Conservation Agreement under the NSW *National Parks and Wildlife Act 1974*.

These steps will ensure a significant increase in area of known and potential habitat for the relevant MNES with the long-term conservation of significant areas of habitat.

In addition, the biodiversity offset package includes a financial contribution (discussed below in dot point 2), which will deliver an improved outcome for the quoll through funding the implementation of recovery actions in accordance with both federal and state recovery plans.

**2. Suitable offsets must be built around direct offsets but may include other compensatory measures.**

The biodiversity offset strategy is based on the use and ongoing management of two direct land-based offsets.

In addition to land based offsets, LCO has negotiated with the NSW OEH and DPE to include a financial contribution of $200,000 over 5 years as part of the biodiversity offset package. This financial contribution will be targeted at funding recovery actions for the spotted-tailed quoll in the Central Hunter Valley, which will be in accordance with the *National Recovery Plan for the Spotted-tailed Quoll, Final Draft* (Long and Nelson, 2008) and with the OEH *Saving Our Species Project Species Action Statement.*

The $200,000 will assist in addressing key knowledge gaps for the spotted-tailed quoll in the central Hunter, including:

- Local population size and demographic structure;
- Local movements and range of animals in the region;
- Genetic distinctiveness of the central Hunter population; and
- Habitat preferences and location of den sites.

To ensure appropriate focus, rigour and governance, the specific project objectives, scope and recovery actions will be developed by all relevant stakeholders (including NSW OEH, the Commonwealth DoE, relevant experts/ecologists and Glencore) to the satisfaction of the NSW DPE.

**3. Suitable offsets must be in proportion to the level of statutory protection that applies to the protected matter.**

The level of statutory protection that applies to the impacted MNES was considered during Proposed Action planning to ensure that an adequate offset was obtained, commensurate with the status of the threatened or migratory species. Assessment against the Commonwealth EPBC Act Environmental Offsets Policy (DSEWPC 2012) and the use of the Offset Assessment Guide (October 2012) indicates that the proposed offset sites provides between 101 and 484 per cent of the minimum requirements to offset the impacts on the spotted-tailed quoll, swift parrot, regent honeyeater and large-eared pied bat. **Section 8.5** outlines the results of the assessment of the offset sites using the EPBC Offset Assessment Guide.

**4. Suitable offsets must be of a size and scale proportionate to the residual impacts on the protected matter.**

The Preliminary Documentation additional information request indicated that the Department of the Environment considers that the residual impacts of the Proposed Action are impacts on the spotted-tailed quoll, swift parrot, regent honeyeater, large-eared pied bat and green and golden bell frog. Assessment of the offset sites using the EPBC Offset Assessment Guide indicated that the size and scale of the proposed offset sites are proportionate or larger than the residual impacts on the MNES. **Section 8.5** outlines the results of the assessment of the offset site using the EPBC Offset Assessment Guide.

**5. Suitable offsets must effectively account for and manage the risks of the offset not succeeding.**

The biodiversity offset strategy is based on the use of two direct land-based offsets which are owned by the Liddell JV, the operator of LCO. Each offset site (Mountain Block Offset Area and Bowmans Creek Riparian Corridor) contains existing woodland vegetation and areas of derived native grassland. Once established and managed as offset sites, the risk of the offsets not succeeding is mostly related to the return of derived native grassland communities to woodland communities, and to the management of threats such as weeds and pests. Glencore has a good record of pest and weed management and current management strategies will be extended across the offset sites. Glencore has a record of successful tree plantings and rehabilitation across its sites and the risk of regeneration areas failing is considered low.

In terms of accounting for risks associated with value of the proposed offsets, the percentages of impacts offset by Mountain Block Offset Area and the Bowmans Creek Riparian Corridor are higher then what is required (i.e. more than 100 per cent for each of the MNES). This allows for some contingency when it comes to assessing the potential for failure of the offsets.

As outlined in **Section 8.4** Glencore will prepare and implement a detailed Biodiversity Offset Management Plan for each site that will include:

- weed and pest control programs;
- access management and strategic management of stock from each of the two offset sites;
- works to encourage passive regeneration of derived native grassland areas with adequate recovery potential;
- planting of derived native grassland areas with poorer recovery potential (e.g. parts of the Bowmans Creek Riparian Corridor);
- habitat augmentation works (in particular denning habitat for the spotted-tailed quoll and to increase prey-densities for the spotted-tailed quoll) to increase the ecological value of offset sites;
- establishment of criteria by which to measure the success/failure of offsetting works undertaken; and
- undertaking ecological monitoring across the two offset sites to monitor the success of plantings and to monitor the recovery of derived native grassland areas that have a high natural recovery potential, and to inform the implementation of additional management measures as required to achieve success.

**6. Suitable offsets must be additional to what is already required, determined by law or planning regulations, or agreed to under other schemes or programs.**

The land-based offsets proposed do not overlap with any other government funded protection or habitat restoration program at any of the proposed offset sites. Each of the offset sites is located on currently non-reserved land and will increase the area of conserved land in the region.

**7. Suitable offsets must be efficient, effective, timely, transparent, scientifically robust and reasonable.**

The biodiversity offset strategy allows for the up-front protection and proactive conservation management of the offset sites, to provide immediate and long term compensation for the loss of vegetation and habitat from the Referral Area. Each of the offset sites is owned by the Liddell JV, and managed on behalf of the JV by Glencore (Liddell).

The area of impact has been derived from detailed GIS mapping of Proposed Action boundaries and impact areas, and the ecological survey, mapping, impact assessments and design of the biodiversity offset strategy have been completed by qualified, experienced ecologists ensuring that the strategy is scientifically robust, transparent and reasonable.

This report clearly documents the survey methods undertaken, the results of all surveys undertaken, and the mitigation and management measures to be undertaken (refer to **Section 8.4**) and the development of and justification for the offset strategy (**Sections 8.1, 8.2 and 8.3**) to compensate for the residual impacts of the Proposed Action.

**8. Suitable offsets must have transparent governance arrangements including being able to be readily measured, monitored, audited and enforced.**

As impact mitigation measures and the biodiversity offset strategy are an integral component of the Proposed Action, it is expected that the offsetting and mitigation commitments will be included within the relevant EPBC Approval and NSW development consent conditions, and any other legally binding consents/approvals. It is anticipated that regular auditing of these requirements for the offset sites will be undertaken, in accordance with these requirements.

As outlined in **Section 8.4**, LCO will prepare and implement a detailed Biodiversity Offset Management Plan for each site that will include weed and pest control programs, access management and exclusion of stock from the offset sites, works to encourage passive regeneration of derived native grassland areas with adequate recovery potential, planting of derived native grassland areas with poor recovery potential, habitat augmentation works and ecological monitoring across the offset sites. This Biodiversity Offset Management Plan will be written in a manner that provides clear objectives for the management of the offset areas, and will provide commitments and actions in a clear and auditable manner. The Biodiversity Offset Management Plans will be prepared in consultation with, and for the approval of, relevant government agencies.

## 8.8 Anticipated Cost (Financial and Other) of Delivery of the Offset(s)

The overall costs of the proposed offsets package are primarily related to the implementation of related management actions (as the lands themselves have already been purchased). The estimated costs of the two proposed offset sites over a 20 year period is approximately $1.7M (approximately $1.1M for the Bowmans Creek Riparian Corridor and a further $0.6M for the Mountain Block Offset Area). This cost includes scope for:

- Completely replanting (high intensity restoration) the areas of Grassland and Disturbed Areas occurring along Bowmans Creek Riparian Corridor;
- 16 ha of moderate/high intensity planting works at the Mountain Block Offset Area;
- 82 ha of low-intensity regeneration works (assisted planting) of the Mountain Block Offset Area;
- Fencing of both the Mountain Block Offset Area and the Bowmans Creek Riparian Corridor; and
- Long-term management costs (including annual feral animal and weed control, conservation signage, fencing maintenance) of both offset sites.

This costing additionally includes scope for a 30 per cent contingency in the event that offsets are not delivered according to plan. This equates to a total additional contingency cost of $0.5M, or approximately $0.3M for the Bowmans Creek Riparian Corridor and a further $0.2M for the Mountain Block Offset Area.

**Table 8.17** provides a breakdown of the estimated management costs for the Mountain Block Offset Area and the Bowmans Creek Riparian Corridor.

**Table 8.17 – Likely Management Costs Associated with the Implementation of Management Actions**

| Offset Site | Management Action | Area (ha) | Perimeter (m) | Offset Fencing (at $13/metre) | Revegetation | | Long-Term Management Costs ($1,262/ha) | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | | | | | Low Intensity ($3,482/ha) | Moderate to High Intensity ($4,565/ha) | | |
| **Bowmans Creek Riparian Corridor** | Full Replanting of Grassland and Disturbed Areas | 143 | 15,800 | 205,400.00 | 0 | 652,795.00 | 180,466.00 | **$1,038,661.00** |
| | | | | | | | 30% contingency for Bowmans Creek Riparian corridor | $315,094.50 |
| Mountain Block Offset Area | Regeneration | 81 | 9,000 | 117,000.00 | 282,042.00 | 0 | 102,222.00 | **$501,264.00** |
| | Full Planting | 16 | 700 | 9,100.00 | 0 | 73,040.00 | 20,192.00 | **$102,332.00** |
| | | | | | | | 30% contingency for Mountain Block Offset Area | $181,078.80 |
| | | | | | | | **TOTAL (without 30% contingency)** | **$1,653,911.00** |
| | | | | | | | **TOTAL (with 30% contingency)** | **$2,150,084.30** |

It should be noted that the estimated values involved with the management actions identified in **Table 8.17** above are as per those that were used and accepted as part of the Bulga Optimisation Project (Umwelt 2013c) and within the LCO EA (SLR 2013).

The above costs additionally assume the following:

- the retention of approximately 7 hectares of existing rehabilitated vegetation and of 4 hectares of introduced vegetation that are currently present in the Bowmans Creek Riparian Corridor;

- the areas of moderate/high planting at the Mountain Block Offset Area are based on 8 hectares of existing Disturbed Land and some smaller areas (8 hectares nominally) of rehabilitated patches to assist the regeneration of large areas of grassland that are isolated from existing vegetation as a source of recruitment; and

- the costs associated with fencing assume that all areas will require fencing. The values associated with fencing will likely decrease where adequate fencing already exists.

Both offset sites will also be subject to ongoing monitoring and reporting to analyse the effectiveness of management actions undertaken. The scope of the ecological and rehabilitation monitoring program will be finalised as part of the preparation and approval of the proposed Biodiversity and Offset Management Plans for each offset area.

The effectiveness of management measures in the proposed offset sites would also be the subject of mandatory auditing requirements which are typically included as a condition of approval/consent for mining activities.

# LIDDELL COAL OPERATIONS

PART 3

## Water Resources

# 9.0 DESCRIPTION OF THE ENVIRONMENT

Information regarding the existing environment in relation to water resources and water related assets is provided in the sections below. The information presented is in accordance with the requirements set out in Section 8 of the "Guidelines for Additional Information – Assessment by Preliminary Documentation" (DoE), with the relevant requirement in ***italics*** and the information presented below.

## 9.1 Water Resources

### 9.1.1 Description of the water resources of the site and region

***Including maps of all surface water and ground water resources that are relevant to the project;***

Surface water features in the region are predominantly comprised of the Hunter River and its tributaries and local dams and lakes associated with mining and power generation activities. The Hunter River forms the primary surface water drainage system in the region in terms of physical size and flow rate, with its catchment area covering approximately 22,000 square km.

LCO is located within two sub-catchments of the Hunter River catchment, with surface water features in each forming the boundary of the LCO DA area, as shown in **Figure 9.1**. Lake Liddell bounds LCO to the west and is an artificial lake constructed to supply water to several coal-fired power stations in the area. The lake was created by damming Bayswater Creek and collects runoff from the upper three quarters of the creek's catchment. Bayswater Creek is a highly modified system, designed in its upper reaches to take flow from Lake Liddell and the Hunter River Salinity Trading Scheme (HRSTS), with its lower reaches realigned to allow mining at Ravensworth South and Narama mines.

Bowmans Creek bounds LCO to the east and drains a catchment area of approximately 250 square km, which is enough to maintain flow under most rainfall conditions (Umwelt, 2006). LCO's proposed extension to the open cut Entrance Pit is in close proximity to Bowmans Creek and its associated alluvial deposits. Neither Bayswater Creek nor Bowmans Creek have been diverted or realigned by LCO.

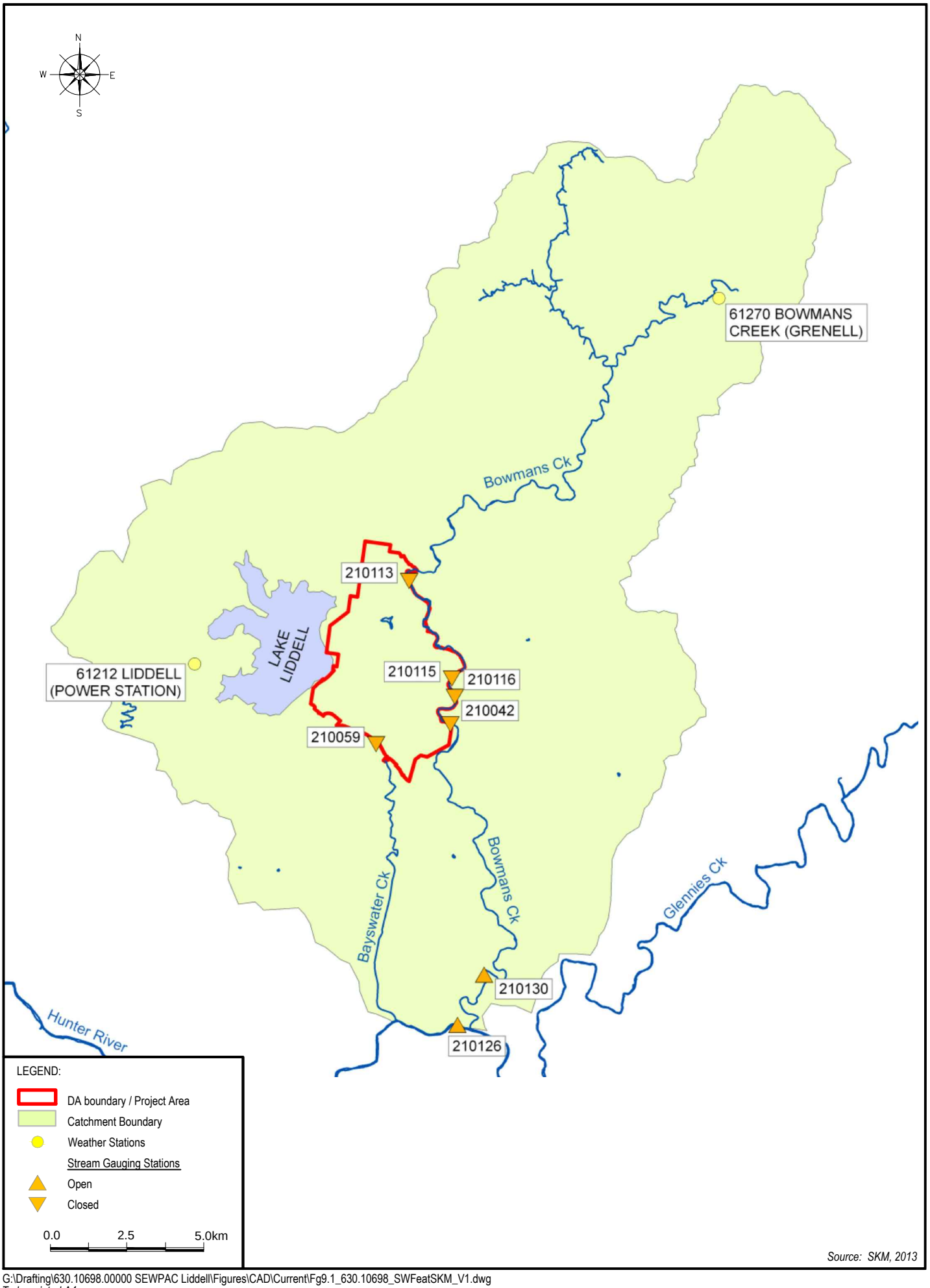
A section of Chain of Ponds Creek is also within the Referral Area, with a portion of this creek already removed as part of approved mining activities in the South Pit. The remaining natural section traverses the south western portion of LCO, and drains to Bayswater Creek. Both Bowmans Creek and Bayswater Creek are tributaries of the Hunter River, and are within the Hunter subregion of the Hunter-Central Rivers Catchment Management Authority (CMA).

Information on the groundwater resources in the region are discussed in detail in **Section 9.1.2**.

### 9.1.2 Geology and Hydrogeology

***This should include definition of the geological sequences in the area, descriptions of formations, descriptions of hydrogeological units (including aquifers, aquitards, and aquicludes) and mapping showing faults and key features;***

LCO is located within the Hunter Coalfield of the Permian and Triassic Sydney Basin. The geology comprises Permian coal measures hosted within an eroded valley that has been infilled with Quaternary to Recent alluvial sediments associated with the Hunter River and its tributaries (Mackie, 2009). To the west and southwest of the Hunter River Valley is steeply incised terrain of the younger Triassic Narrabeen Group, and to the east and northeast are older Carboniferous rocks. The depositional environment is interpreted by a varying cyclic pattern of fluvial to marine deltaic conditions (Mackie, 2009).




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Local Surface Water Features

**FIGURE 9.1**

The lower elevations of the Hunter Valley sit within an area of gently folded Permian rocks, with the folds generally on a N-S and NNW-SSE axis and plunging gently to the south at 2 to 5 degrees. Structural features in the area include the Muswellbrook Anticline in the west, the Bayswater Syncline, Camberwell Anticline, and Glennies Creek Syncline. To the north and northeast along the flank of the Hunter Valley a series of northwest to southeast trending faults and thrusts, including the minor Hebden Thrust and the major Hunter Thrust, bring older Permian and Carboniferous rocks to the surface. In these thrust areas coal bearing Permian-aged rocks found elsewhere in the valley are not present. **Figure 9.2** shows the geology and the locations of major structural features within the region.

LCO is located above the Bayswater Syncline and Camberwell Anticline. An impervious, north-easterly striking dyke, which has previously affected underground mining, is present in the southeast of the LCO DA area (MER, 2001). Further south the dyke zone is known to become faulted and south of LCO the zone is identified as the Davis Creek fault. The locations of old underground workings previously mined at LCO are presented in **Figure 9.7** later in this report (refer **Section 9.1.4**).

**Alluvial Deposits**

Quaternary and Recent alluvial sediments are deposited along major and minor surface water drainages in the region. The thickness of these alluvial deposits is variable, with Mackie (2009) reporting a maximum thickness of 18 m in the region.

The alluvial deposits are generally characterised by a succession of three units, grading from a basal coarse grained bed load comprising sand to cobble size deposits, a middle unit comprising finer grained levee deposits, and finally an upper unit comprising floodplain deposits (Beckett, 1987). The basal unit varies in thickness across the region, ranging from zero to 12 m thickness, whilst the middle and upper units are generally between 1 m and 3 m thickness. The sediments within the upper tributaries of Bowmans Creek are expected to have similar lithology, perhaps with a thinner intersection of the basal coarse grained unit.

**Permian Coal Measures**

The main coal-bearing strata in the region are the Permian aged Wittingham Coal Measures of the Singleton Super Group which are summarised in **Table 9.1**. These strata were deposited at a time when global sea levels and tectonism led to widespread deltaic conditions favourable for the development of coal (Mackie, 2009).

The basal unit of the Wittingham Coal Measures is the Saltwater Creek Formation which comprises siltstones and sandstones and minor coal seams. The Saltwater Creek Formation resides at depth beneath most of the Hunter Valley; however it subcrops approximately 5 km northeast of LCO where it is upthrown between the Hebden and Hunter Thrusts.

Above the Saltwater Creek Formation, the remaining Wittingham Coal Measures can be divided into two coal bearing subgroups, the Vane Subgroup and the Jerrys Plains Subgroup with a marker bed known as the Archerfield Sandstone separating them. These two subgroups comprise up to six primary coal bearing units with each containing multiple seams. The coal seams are separated by interburden units comprised of sandstone, siltstone, conglomerate, mudstone and shale.

Stratigraphic cross sections have been developed for LCO, with particular focus on the coal seams of the Wittingham Coal Measures. The locations of the cross sections are shown in **Figure 9.2**, and the cross sections presented in **Figures 9.3, 9.4** and **9.5**. As shown in the cross sections the Liddell seam starts as a single seam in the vicinity of LCO before splitting into three seams to the south and southeast. The Foybrook Formation is the basal coal-bearing unit of the Wittingham Coal Measures and forms the main subcropping and outcropping unit in the vicinity of LCO. **Table 9.2** provides a summary of the thickness of coal seams and interburden strata in the vicinity of LCO, derived from the Glencore LCO coal exploration drillhole database.

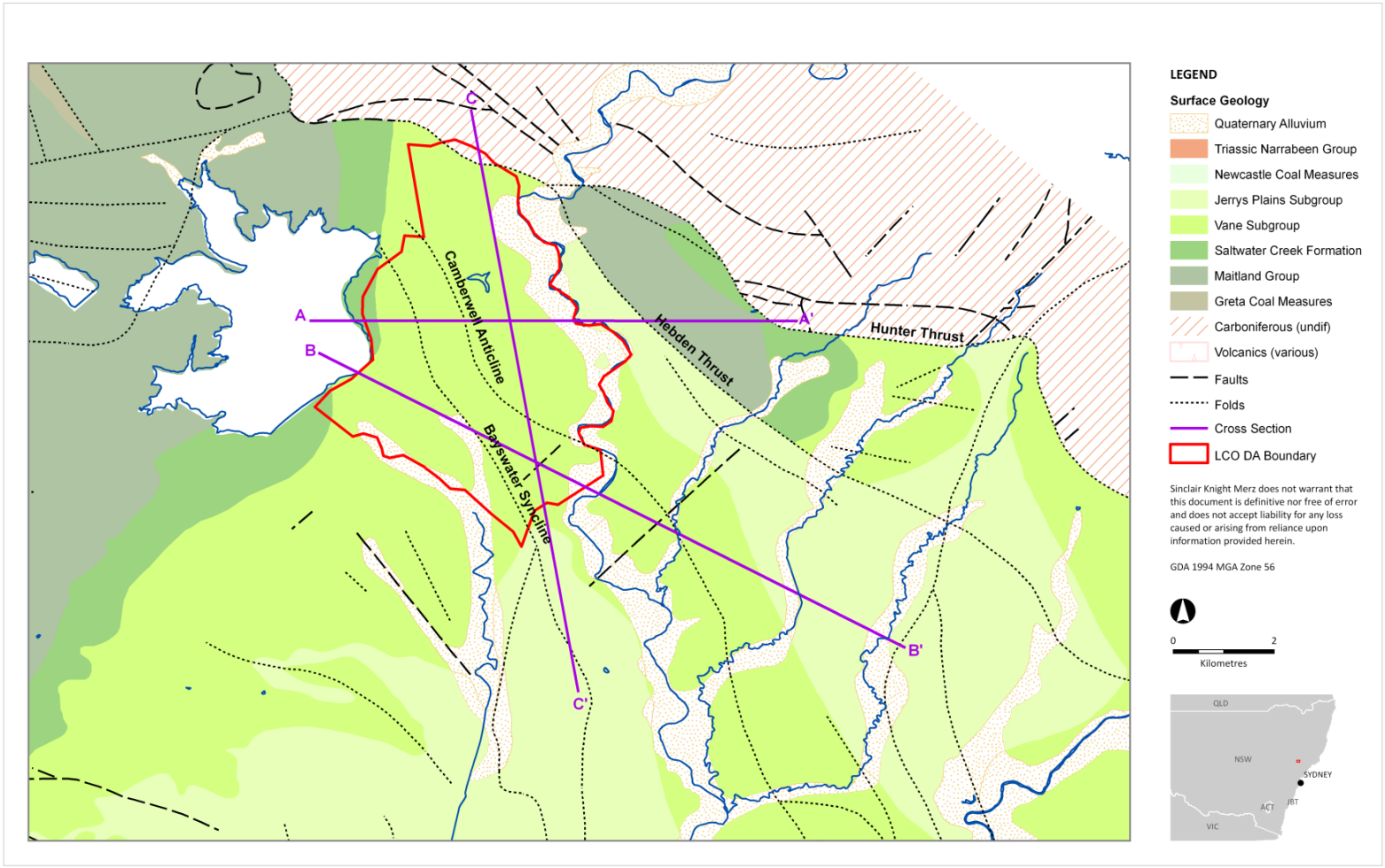



**Figure 9.2 – Regional Geology and Structural Features**

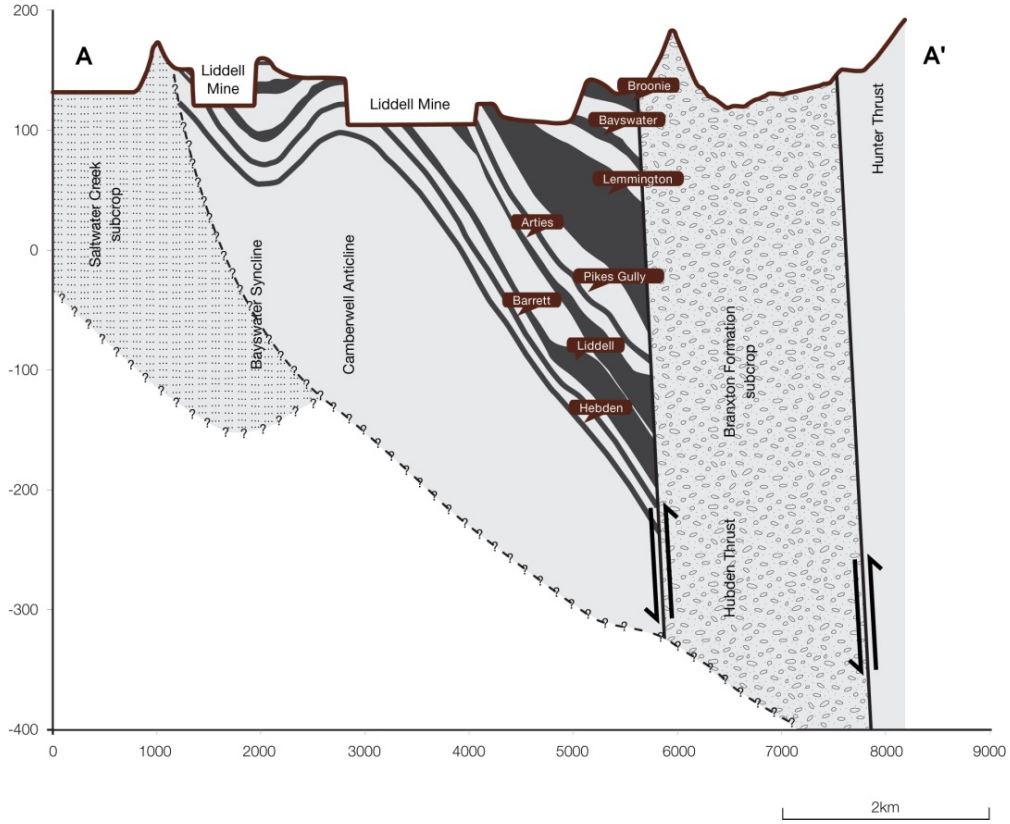



**Figure 9.3 – Geologic Cross Section A-A'**

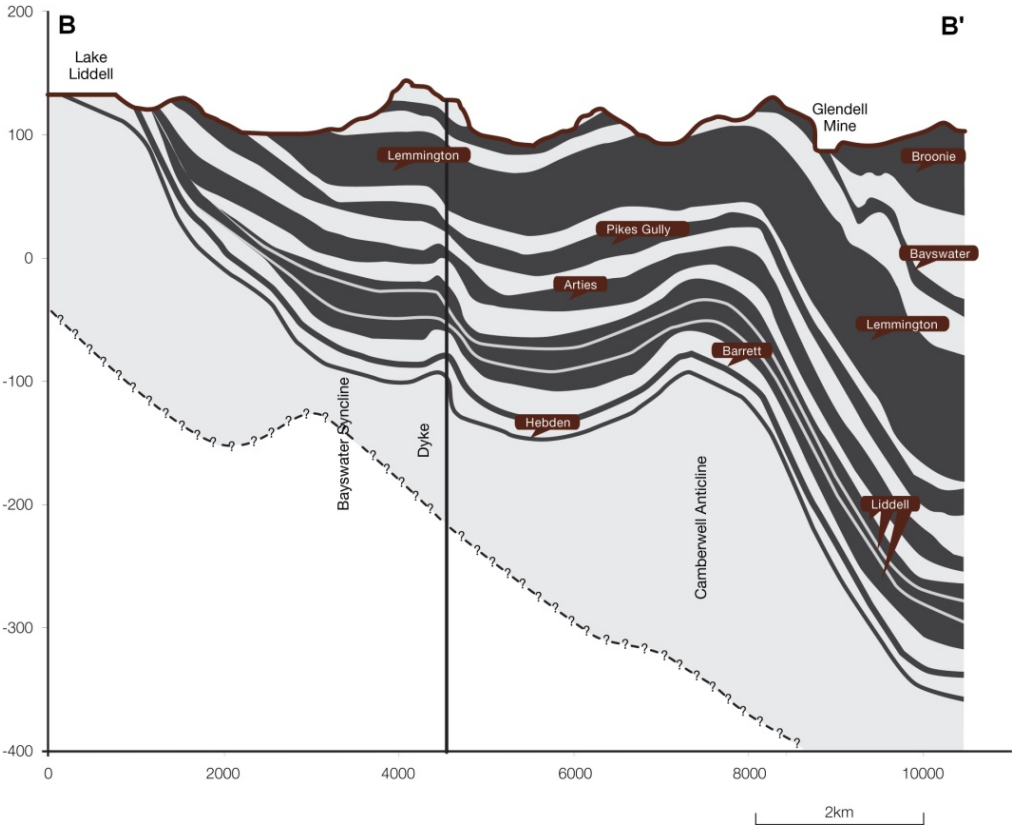



**Figure 9.4 – Geologic Cross Section B-B'**

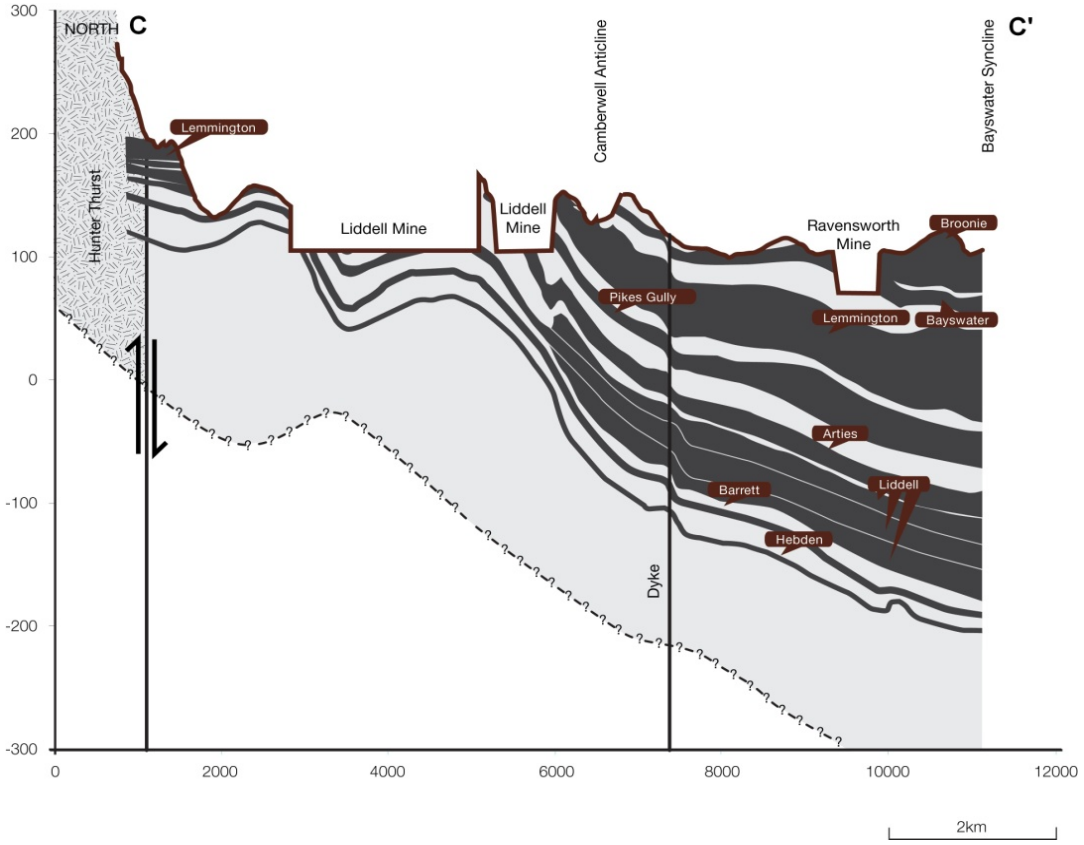



**Figure 9.5 – Geologic Cross Section C-C'**

**Table 9.1 - Stratigraphic Table of the Wittingham Coal Measures (SKM, 2014)**

| | | | |
|---|---|---|---|
| Singleton Supergroup | Wittingham Coal Measures | *Denman Formation (sandstone and siltstone)* | |
| | Jerrys Plains Subgroup | **Mount Leonard Formation** | Whybrow Seam |
| | | *Allthorp Formation (claystone)* | |
| | | **Malabar Formation** | Redbank Creek Seam |
| | | | Wambo Seam |
| | | | Whynot Seam |
| | | | Blakefield Seam |
| | | *Saxonvale Member (siltstone and claystone)* | |
| | | **Mount Ogilvie Formation** | Glen Munro Seam |
| | | | Woodlands Hill Seam |
| | | *Milbrodale Formation (claystone)* | |
| | | **Mount Thurney Formation** | Arrowfield Seam |
| | | | Bowfield Seam |
| | | | Warkworth Seam |
| | | *Fairford Formation (claystone)* | |
| | | **Burnamwood Formation** | Mt Arthur Seam |
| | | | Piercefield Seam |
| | | | Vaux Seam |
| | | | Broonie Seam |
| | | | Bayswater Seam |
| | | *Archerfield Sandstone* | |
| | Vane Subgroup | *Bulga Formation (siltstone and claystone)* | |
| | | **Foybrook Formation** | Lemington Seam |
| | | | Pikes Gully Seam |
| | | | Arties Seam |
| | | | Liddell-Ramrod Creek Seam |
| | | | Barrett Seam |
| | | | Hebden Seam |
| | | *Saltwater Creek Formation (sandstone and siltstone)* | |

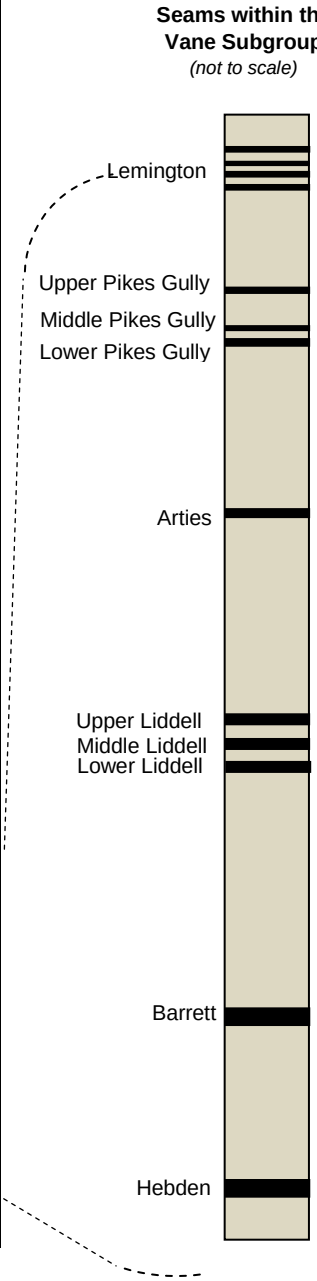


**Table 9.2 – Thickness of Coal Seams and Interburden Strata at LCO (Source LCO Coal Exploration Drillhole Database))**

| Subgroup | Coal Bearing Unit | Coal Seams | Avg (m) | Min (m) | Max (m) |
|---|---|---|---|---|---|
| **Jerrys Plains Subgroup** | Burnamwood Formation | Broonie Seam | 0.3 | 0 | 0.7 |
| | | Broonie-Bayswater interburden | 3.7 | 0 | 122 |
| | | Bayswater Seam | 9.2 | 0 | 25 |
| | | Bayswater-Lemington interburden | 14 | 0 | 92 |
| **Vane SubGroup** | Foybrook Formation | Lemington Seam | 53 | 0 | 128 |
| | | Lemington-Pikes Gully interburden | 7.5 | 0 | 43 |
| | | Pikes Gully Seam | 6.0 | 0 | 34 |
| | | Pikes Gully-Arties interburden | 8.3 | 0 | 52 |
| | | Arties Seam | 14 | 0 | 42 |
| | | Arties- Liddell interburden | 8.2 | 0 | 36 |
| | | Liddell Seam | 33 | 0 | 81 |
| | | Liddell-Barrett interburden | 17 | 0 | 54 |
| | | Barrett Seam | 3.5 | 0 | 14 |
| | | Barrett-Hebden interburden | 19 | 0 | 50 |
| | | Hebden Seam | 2.1 | 0 | 3.0 |

**Hydrogeology - Aquifer Systems**

Previous environmental assessments undertaken in the area (MER, 2001; ERM, 2008; Umwelt, 2006; Umwelt, 2008; MER, 2011a; Aquaterra, 2009b) provide a consistent description of the local and regional hydrogeological regime being comprised of two distinct aquifer systems:

- Shallow unconfined aquifers of limited extent within the unconsolidated alluvium associated with the Hunter River and its tributaries, and
- A regional hard rock aquifer system associated with the Permian coal measures.

The alluvial aquifers associated with the Hunter River and its tributaries are generally characterised by unconsolidated deposits of silts, sands, and gravels of varying permeability. MER (2011a) describes the morphology of the alluvial deposits as a vertical succession of three distinct units, including basal coarse grained sand and cobble size deposits, finer grained levee deposits, and floodplain deposits. The basal coarse grained sand and gravel unit forms the main aquifer of the alluvium and in places may be confined by the overlying finer grained terrace deposits. These unconsolidated deposits support baseflow to surface water features in the region, with the varying morphology and extent of the deposits leading to complex and variable flow regimes (Aquaterra, 2009a).

The hard rock aquifer associated with the Permian coal measures exhibits varying levels of groundwater storage and transmission. The most permeable horizons are the coal seams themselves; non-coal interburden strata generally exhibit permeabilities at least one to two orders of magnitude less than the coal seams. Secondary porosity in the non-coal strata may be developed within fractures and joints, however the degree to which this occurs is quite variable and generally unpredictable.

Coal seams typically represent the more permeable hard rock strata through the presence of cleating and jointing, although there is little evidence of structure-related fracturing. Horizontal permeabilities (i.e. parallel to bedding) are generally significantly higher than vertical permeabilities within the coal seams, although subsidence-related cracking may enhance vertical permeabilities of both coal seams and interburden strata in areas of underground workings. Regionally, the coal seam aquifers are generally confined above and below by the interburden strata.

For LCO and its vicinity, the two aquifer systems are present as the localised alluvial aquifers associated with the surface water of Bowmans and Bayswater Creeks, and the regional hard rock aquifer found within the Permian-aged coal seams (the Wittingham Coal Measures) (Umwelt, 2001; Umwelt, 2008). Of particular relevance for this Project and Referral is the alluvial aquifer associated with Bowmans Creek given the proximity of the proposed mine extension to the Creek (refer **Figure 1.2**).

In an effort to delineate the lateral extent of the alluvial aquifer and to optimise groundwater monitoring locations, Light Detection and Ranging (LiDAR) remote sensing was flown along Bowmans Creek in 2011. Combining LiDAR data with bedrock depth from borehole logs along the creek allows an estimation of the extent and volume of alluvium, as shown in **Figure 9.6**, and can provide an indication of the contribution of alluvial groundwater to stream baseflow.

In relation to Bayswater Creek, this creek represents a highly modified and regulated system that now acts effectively as an overflow drain for Lake Liddell. The southern extent of Bayswater Creek (area of no alluvial mapping down to the Hunter River on **Figure 9.6**) constitutes a diversion of the original channel. Further, along the southern margin of the LCO mining area, a series of bentonite clay walls have been constructed to isolate Bayswater Creek from the activities of the mine.

### 9.1.3 Hydraulic characteristics

***(including hydraulic conductivity and storage characteristics) for each formation, including confined and unconfined aquifers and aquitards;***

The hydraulic properties that govern groundwater storage and flow in the region vary considerably between the unconsolidated alluvial systems and the confined hard rock aquifer system associated with the coal measures. Aquifer testing has been undertaken as part of previous environmental investigations for various mining projects in the region using a variety of techniques, including airlifting, packer tests, and laboratory core tests, with the majority of data collected for hard rock aquifers associated with the coal measures. **Table 9.3** provides a summary of hydraulic conductivity and storativity values reported in previous environmental assessments within the region. Recent slug test data collected from LCO monitoring bores targeting the Bowmans Creek alluvial aquifer are also included.

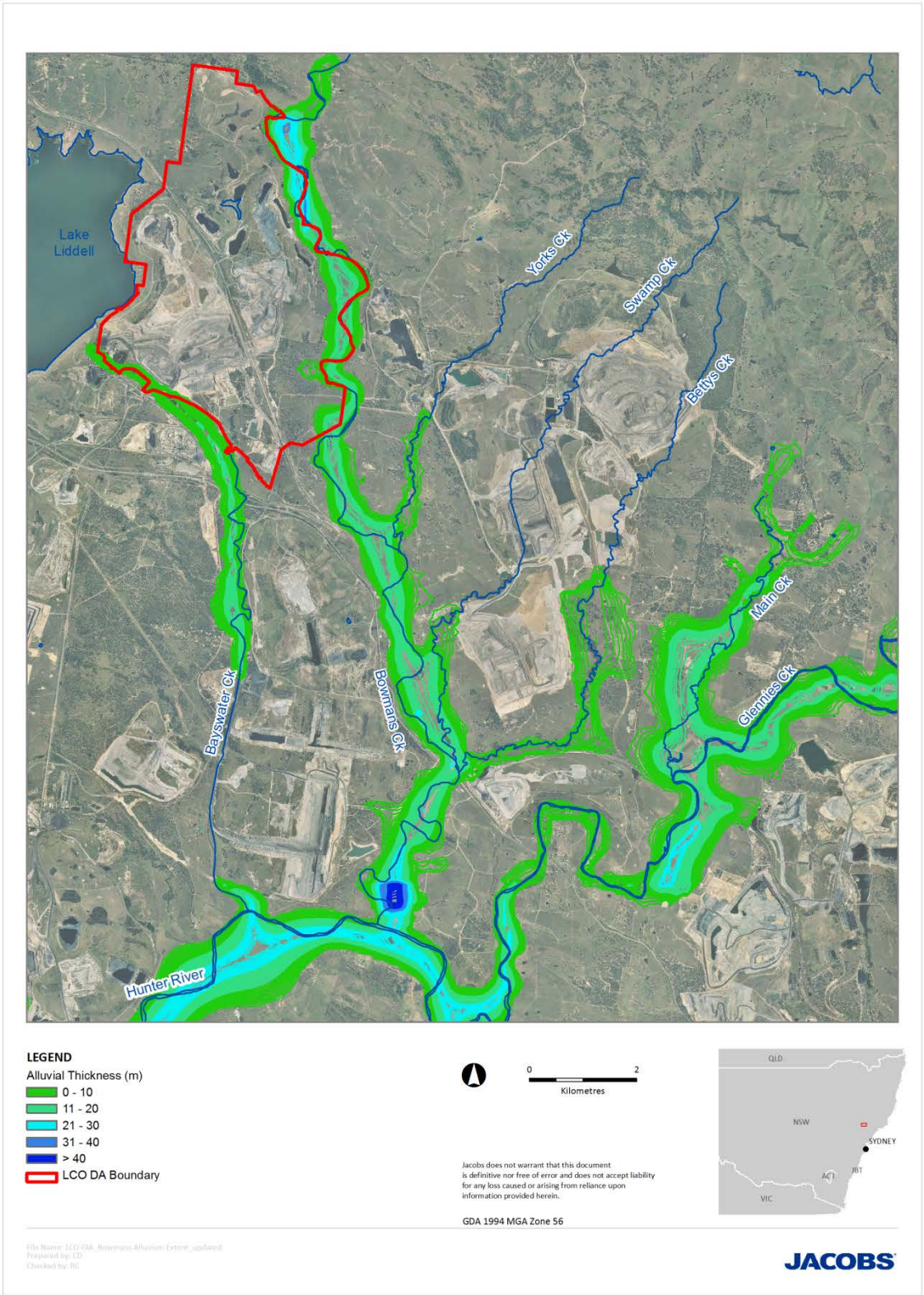



**Figure 9.6 – Estimated Extent of Alluvial Aquifers in the Vicinity of LCO**

**Table 9.3 – Range of Hydraulic Properties**

| Lithology | Hydraulic Conductivity ($K_{xy}$; m/day) | Storage[1] | Source |
|---|---|---|---|
| Alluvium | 0.5 – 50 | -- | MER (2001) |
| | 2.4 | $S_s = 8.67 \times 10^{-2}$<br>$S_y = 0.25$ | ERM (2008) |
| | 10 | $S_s = 1 \times 10^{-5}$<br>$S_y = 0.05$ | MER (2011b)[2] |
| Alluvium (Hunter River) | 50 | $S_s = 1 \times 10^{-4}$<br>$S_y = 0.1$ | Aquaterra (2009b) |
| | 14.5 | $S_s = 8.67 \times 10^{-2}$<br>$S_y = 0.25$ | ERM (2008) |
| Alluvium (Bowmans Ck) | $2 \times 10^{-4}$ – 15 | $S_s = 1 \times 10^{-4}$<br>$S_y = 0.05$ | Aquaterra (2009b) |
| | 1 – 60 | -- | LCC (2013)[3] |
| Alluvium (Glennies Ck) | 0.04 – 80 | -- | Aquaterra (2009a) |
| | 0.07 – 180 | $S_s = 1 \times 10^{-4}$<br>$S_y = 0.05$ | Aquaterra (2009b) |
| Coal Seams | $1 \times 10^{-5}$ – $1 \times 10^{-1}$ | -- | MER (2001) |
| | 0.052 | $S_s = 1.55 \times 10^{-3}$<br>$S_y = 0.02$ | ERM (2008) |
| | 0.04 – 7 | -- | Aquaterra (2009a) |
| | 0.002 – 0.03 | $S_s = 1 \times 10^{-4}$<br>$S_y = 0.005$ | Aquaterra (2009b) |
| | $1 \times 10^{-4}$ – $2 \times 10^{-2}$ | $S_s = 4 \times 10^{-6}$<br>$S_y = 0.002 – 0.1$ | MER (2011b)[2] |
| Interburden / Overburden | 0.007 | $S_s = 2.25 \times 10^{-5} – 0.2$<br>$S_y = 0.02$ | ERM (2008) |
| | $1 \times 10^{-6}$ – $8 \times 10^{-3}$ | $S_s = 1 \times 10^{-5}$<br>$S_y = 0.005$ | Aquaterra (2009b) |
| | $4 \times 10^{-6}$ – $5 \times 10^{-3}$ | $S_s = 1 \times 10^{-6}$<br>$S_y = 3 \times 10^{-4} – 0.001$ | MER (2011b)[2] |

Notes

1) $S_s$ = Specific Storage or Storativity (1/m); $S_y$ = Specific Yield (dimensionless)
2) Modelled values
3) Calculated from slug test data collected by Larry Cook Consulting (LCC) for LCO monitoring bores ALV1L through ALV8L in March 2013

The range of hydraulic conductivity values reported in **Table 9.3** reflects the properties of the aquifer systems present in the region, with the permeability of the coal measures generally orders of magnitude lower than the alluvial aquifer system. Within the coal measures hydraulic conductivity values are higher for the coal seams compared to the intervening siltstones, shales, and sandstone units (interburden). Due to the laminar nature of the coal measures groundwater flow generally occurs within the stratigraphic layers, and vertical conductivity (Kz) has been reported to be orders of magnitude lower than horizontal hydraulic conductivity (Kxy) (ERM, 2008; Aquaterra, 2009b).

Hydraulic conductivity values reported for alluvial aquifers associated with different surface water features in the region reflects the varying morphology and depositional characteristics observed between the Hunter River sediments and its tributaries. Reported hydraulic conductivity values for the Hunter River alluvium are higher than those for the tributaries of Bowmans Creek and Glennies Creek (ERM, 2008), with investigations revealing a clear distinction between these alluvial deposits (Aquaterra, 2009b).

### 9.1.4 Baseline water quality for all relevant surface and ground water resources

**Groundwater**

Groundwater quality in the alluvial and hard rock aquifers in the region varies, with water quality in the alluvium generally slightly less saline than in the coal measures. Alluvial groundwater in the region is generally classified as fresh to brackish, while the coal seam aquifers are generally brackish. Groundwater quality data is available for both aquifer systems throughout the region as a result of monitoring programs associated with the various mines in the area.

At LCO the groundwater monitoring program includes bi-monthly in situ pH and electrical conductivity (EC) measurements and six monthly analysis of samples for total suspended solids (TSS), total dissolved solids (TDS), heavy metals, cations and anions (AECOM, 2012). The monitoring network includes seven locations targeting the Bowmans Creek alluvial aquifer and shallow bedrock aquifer, and five bores within the deeper coal measures (refer **Figure 9.7**). **Figures 9.8** and **9.9** show pH and EC data for piezometers in the alluvial and shallow bedrock aquifer, and **Figure 9.10** shows data for the regional hard rock aquifer associated with the coal measures.

pH readings in the alluvium and shallow basement aquifer generally fall between 6.5 and 8, values typically found in natural waters, while pH readings for the deeper hard rock aquifer were slightly higher, generally ranging between pH 7 and 9. Occasional pH measurements for both aquifers fell well outside these typical ranges, though the consistency in readings before and after such measurements suggests these are erroneous.

EC values for the alluvial and shallow bedrock aquifer indicate brackish waters, with values generally below 3000 uS/cm except for piezometer ALV4S, where higher EC values in the range 4000 to 5000 uS/cm are consistently observed. Analysis of EC data for dual piezometers indicates waters extracted from the shallow bedrock (bores with the suffix = S) consistently recorded higher EC readings compared to the alluvial bores (suffix = L).

No major trends are apparent in the pH and conductivity data presented in **Figures 9.8**, **9.9** and **9.10**, with the exception of a significant decrease in EC values for the hard rock piezometer HAZ 4 between July 2006 and July 2007. This decrease in conductivity at HAZ 4 was accompanied by a slight decrease in pH readings and may be related to adjustments in mining operations during this period, though further investigations are required to determine the cause. Conductivity readings also decreased slightly in the alluvial bore ALV8L soon after July 2007, though this may be attributable to the heavy rainfall and flooding that occurred at that time.

In addition to pH and EC, data for additional water quality parameters such as TSS, TDS, heavy metals, cations and anions has been collected as part of the monitoring program. Appendix A of the Liddell Groundwater Impact Assessment (SKM, 2014, refer **Appendix C**) summarises the data collected for these water quality parameters and these are updated yearly for the Annual Environmental Management Report. The water management plan (Umwelt, 2013d) and groundwater monitoring program (Umwelt, 2013e) currently in place at LCO references the trigger values provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) as default criteria. The 80th percentile trigger values provided in the ANZECC (2000) guidelines have been adopted due to the highly disturbed nature of the site (Umwelt, 2013e).

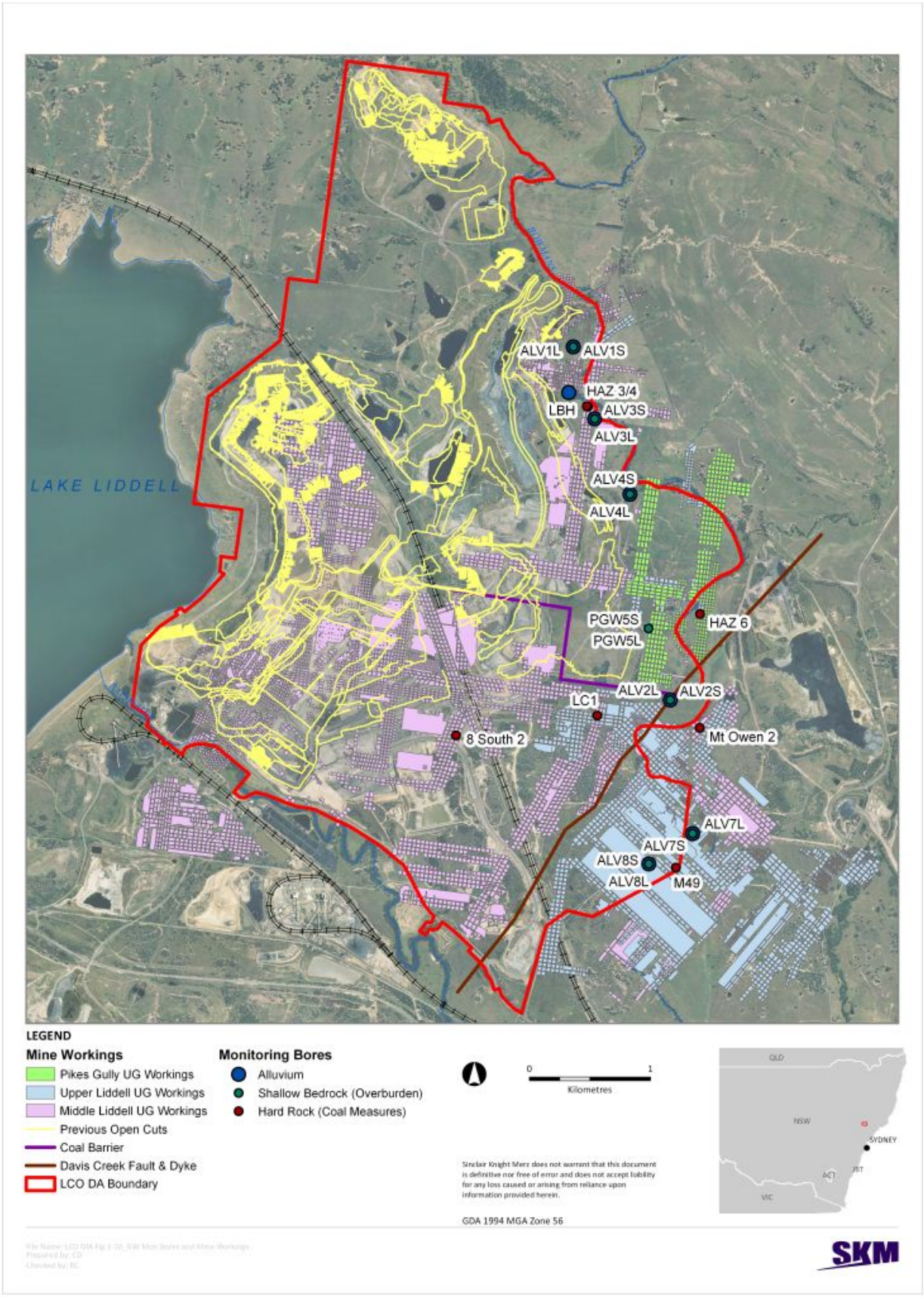



**Figure 9.7 - Groundwater Monitoring Locations, Mine Workings and Structural Features at LCO**




**Figure 9.8 - pH Data for Piezometers Targeting Alluvium and Shallow Bedrock**

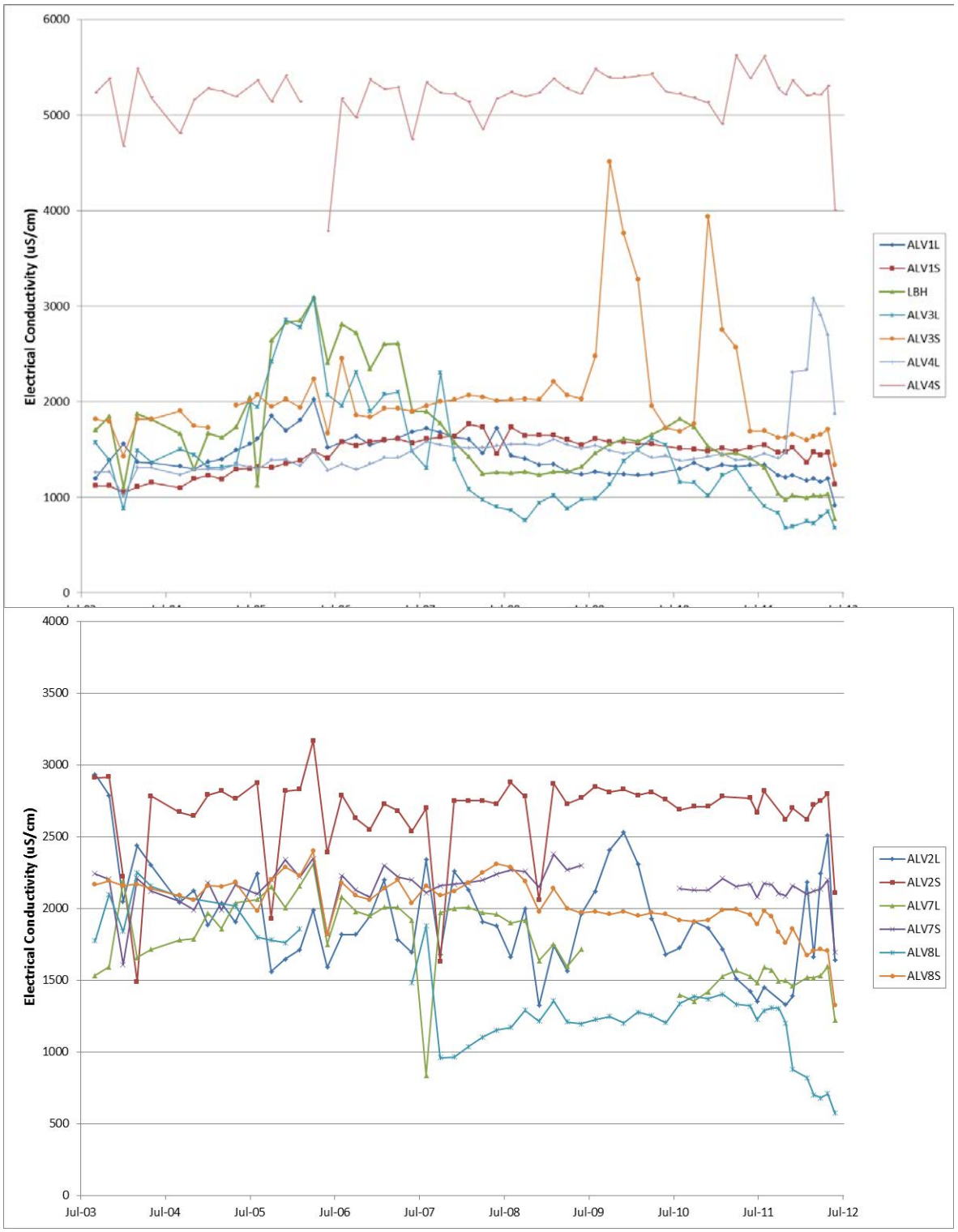



**Figure 9.9 - Conductivity Data for Piezometers Targeting Alluvium and Shallow Bedrock**

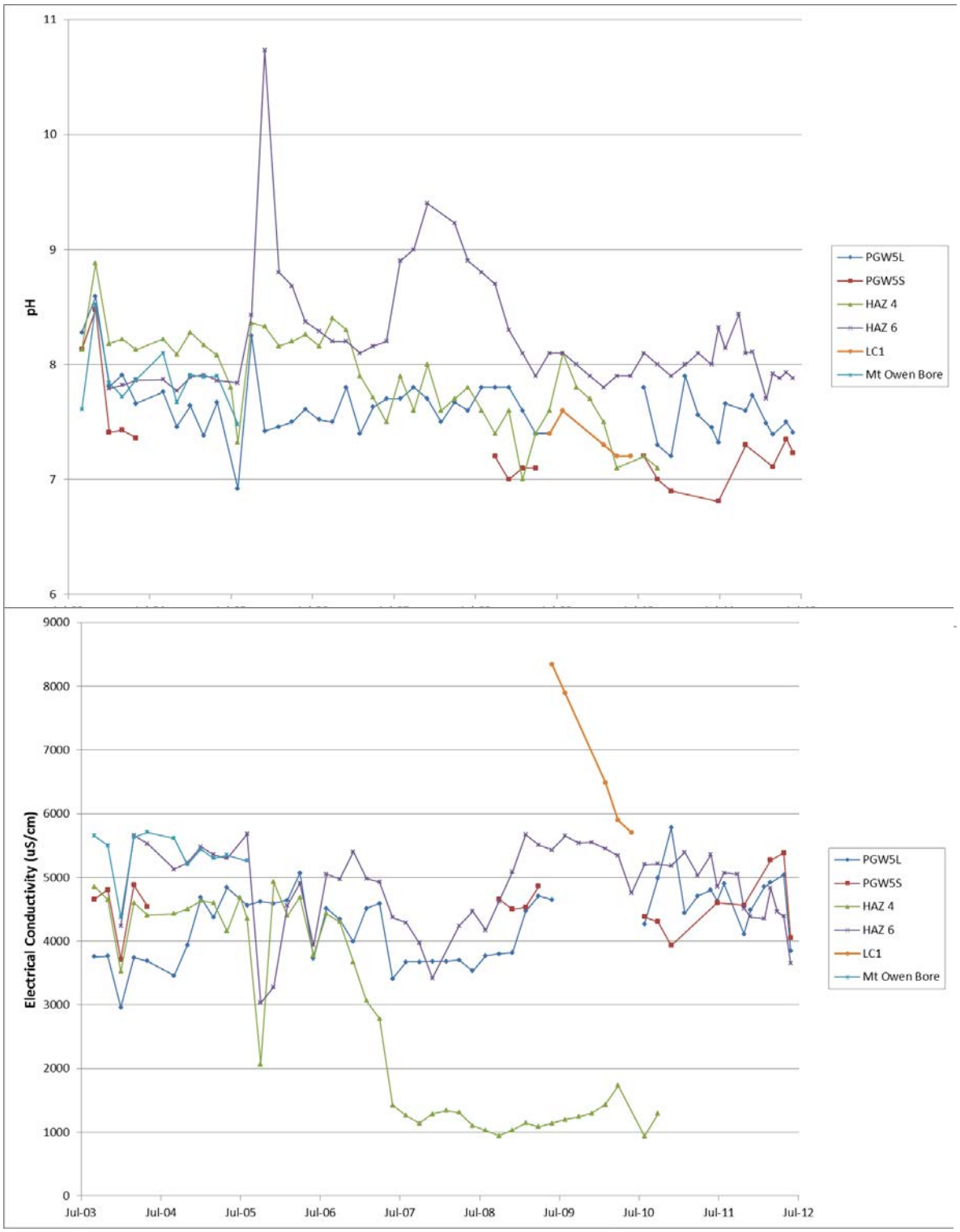



**Figure 9.10 - pH and Conductivity Data for Piezometers Targeting Regional Hard Rock Aquifer (Coal Measures)**

The data indicates that analyte concentrations in groundwater samples at LCO generally fall below the adopted criteria. Exceedances of the default criteria are observed for heavy metals (copper and zinc and to a lesser extent aluminium, lead and nickel). No major trends are apparent for these species during the monitoring period however, indicating minimal impact on groundwater quality as a result of mining activities.

**Surface water**

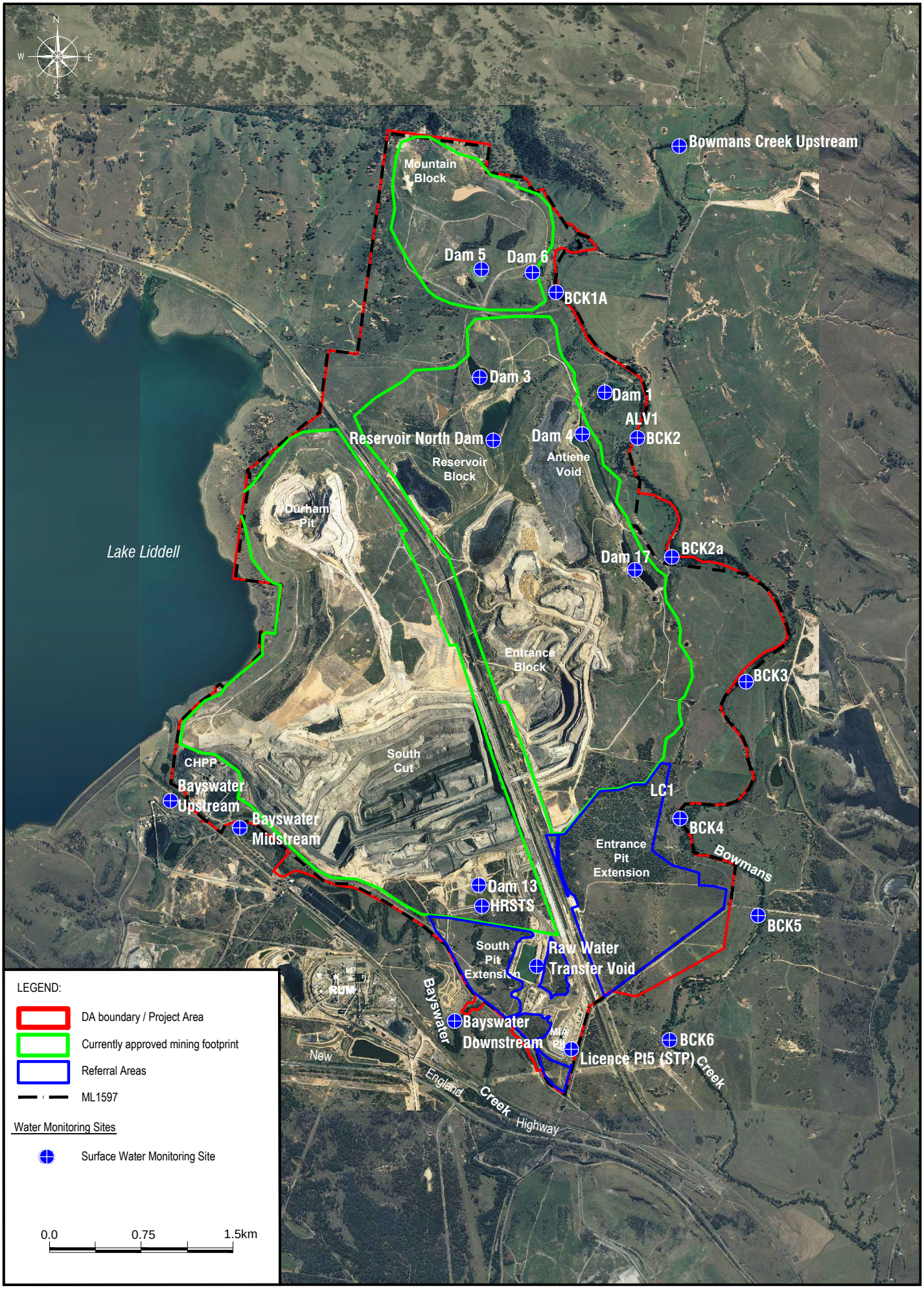
Surface water quality is monitored on a monthly basis at LCO across a number of sites, including Bowmans and Bayswater Creeks, as shown in **Figure 9.11**.

Due to the highly disturbed nature of the site, as recommended by ANZECC Water Quality Guidelines (ANZECC, 2012), site specific historical monitoring data has been used to define trigger values for EC, TDS and upper bound pH at LCO. The trigger values for TSS and the lower bound for pH have been adopted from the default trigger value defined by ANZECC Water Quality Guidelines. These trigger values are provided in **Table 9.4** below.

**Table 9.4 – Trigger Values for Surface Water Quality**

| Analyte | Bayswater Creek Surface Water | | Bowmans Creek Surface Water | |
|---|---|---|---|---|
| | 80$^{th}$ Percentile | Maximum | 80$^{th}$ Percentile | Maximum |
| pH | 6.5-8.3 | 6.5-8.7 | 6.5-8.0 | 6.5-7.9 |
| Conductivity (µS/cm) | 5,024 | 7,110 | 2,270 | 2,450 |
| TSS (mg/L) | 50 | 235 | 50 | 50 |
| TDS (mg/L) | 3,460 | 6,845 | 1,420 | 1,168 |

Annual average water quality results for last three recent AEMR reporting periods (2010, 2011 and 2012) in Bowmans and Bayswater Creeks are presented in **Tables 9.5** and **9.6** respectively.




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*To be printed A4*

Surface Water Monitoring Sites

**FIGURE 9.11**

**Table 9.5 – Annual Average Surface Water Monitoring Results in Bayswater Creek for pH, EC, TSS and TDS**

| | Bayswater Creek Upstream | | | | Bayswater Creek Midstream | | | | Bayswater Creek Downstream | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) |
| July 2010 – Dec 2010 | 7.8 | 2858 | 11 | 1967 | 8.0 | 3020 | 4 | 2063 | 7.9 | 4308 | 12 | 2912 |
| January 2011 –Dec 2011 | 7.7 | 3101 | 13 | 2037 | 8.1 | 3451 | 13 | 2020 | 7.8 | 3780 | 10 | 2395 |
| January 2012 –Dec 2012 | 8.0 | 3000 | 24 | 1960 | 8.0 | 3517 | 147 | 2274 | 8 | 3425 | 28 | 2287 |

**Table 9.6 – Annual Average Surface Water Monitoring Results in Bowmans Creek for pH, EC, TSS and TDS**

| | BCK1 (Bowmans Creek Upstream) | | | | BCK1A | | | | BCK2 | | | | BCK2A | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) |
| July 2010 – Dec 2010 | 8.2 | 654.0 | 5.7 | 392.3 | 8.1 | 885.0 | 6.5 | 451.0 | 7.9 | 1000.5 | 5.5 | 565.0 | 8.1 | 890.0 | 9.0 | 527.0 |
| January 2011 – Dec 2011 | 7.8 | 1019.5 | 10.0 | 653.2 | 7.9 | 1667.8 | 8.3 | 1087.0 | 8.0 | 871.5 | 39.3 | 490.0 | 8.0 | 775.3 | 19.3 | 417.3 |
| January 2012 – Dec 2012 | 8 | 762 | 21 | 441 | 8 | 1324 | 5 | 804 | 8 | 877 | 6 | 517 | 8 | 877 | 21 | 502 |
| | BCK3 | | | | BCK4 | | | | BCK5 | | | | BCK6 (Bowmans Creek Downstream) | | | |
| | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) | pH | EC (µS/cm) | TSS (mg/L) | TDS (mg/L) |
| July 2010 – Dec 2010 | 8.2 | 875.0 | 13.5 | 507.0 | 8.1 | 1075.0 | 8.5 | 644.0 | 8.1 | 1058.5 | 11.0 | 612.0 | 8.1 | 959.8 | 15.6 | 581.3 |
| January 2011 – Dec 2011 | 8.0 | 880.5 | 23.0 | 501.5 | 8.0 | 1094.0 | 12.0 | 630.0 | 8.1 | 1036.0 | 18.0 | 600.5 | 7.8 | 903.2 | 13.1 | 772.0 |
| January 2012 – Dec 2012 | 8 | 1022 | 24 | 599 | 8 | 1061 | 35 | 609 | 8 | 1084 | 21 | 643 | 8 | 991 | 22 | 572 |

### 9.1.5 Water and salt balances for the proposed site and region

***Based on the results of numerical modelling, and detailing the set of stores and the movement between those stores under current conditions, taking into account seasonal and long term climate variation. These balances should account for the inputs and outputs of water. The water balance should include information on the recharge and discharge sources and rates of each hydrogeological unit, the extent of hydrological and hydrogeological interactions between water sources including surface/surface, surface/ground water, and inter-aquifer connectivity, as well as connectivity with sea water;***

#### 9.1.5.1 Site Water Balance

Gilbert & Associates Pty Ltd (2014) developed a Site Water Balance Model for LCO, which simulates changes in stored volumes of water in all storages as a result of inflows (rainfall, groundwater, pumped inflows and leakage), and outflows (evaporation, CHPP makeup, release spill (if any), seepage and pumped outflows) as illustrated on **Figure 9.12**. The model was setup using the GoldSim® simulation package; a model which operates on a sub-daily time-step. Whilst year 1 of the Project is 2014, the simulation commences in December 2012 so that it starts using actual monitored stored water volumes.

The model simulates 120, 11½-year realisations, derived using the climatic record from 1892 to 2011. The first realisation uses climatic data from 1892-1904, the second 1893-1905, the third 1894-1906, and so on. This method effectively includes all recorded historical climatic events in the water balance model, including high, low, and median rainfall periods.

The full Surface Water Assessment Report (Gilbert & Associates Pty Ltd (2014) is include in **Appendix I**, however the key model inputs, assumptions and results are all reproduced below.

**Model Input/Assumptions**

Inputs and assumptions to the model are discussed below.

Rainfall and Evaporation

A record of 118 years (1892 - 2011 inclusive) of rainfall data and pan evaporation data was obtained from the Queensland Department of Environment and Resource Management Silo Data Drill (http://www.longpaddock.qld.gov.au/silo).

Catchment Areas

Dam and storage catchment areas used in the model are summarised below in **Table 9.7** (Gilbert & Associates, 2014).

Rainfall-Runoff Estimation

A simulation of daily rainfall-runoff calculated from rainfall data has been included in the water balance model. Rainfall-runoff was simulated in two ways; for dam storage surface areas, rainfall was assumed to add directly to storage volume with no losses, and for other sub-catchments, the Australian Water Balance Model (AWBM) (Boughton, 2004) was used to estimate stream flow from rainfall and evaporation.

Evaporation from Storage Surfaces: evaporation from storages was calculated by multiplying storage surface area by daily pan evaporation rate. Water storages at LCO are listed below in **Table 9.7**.

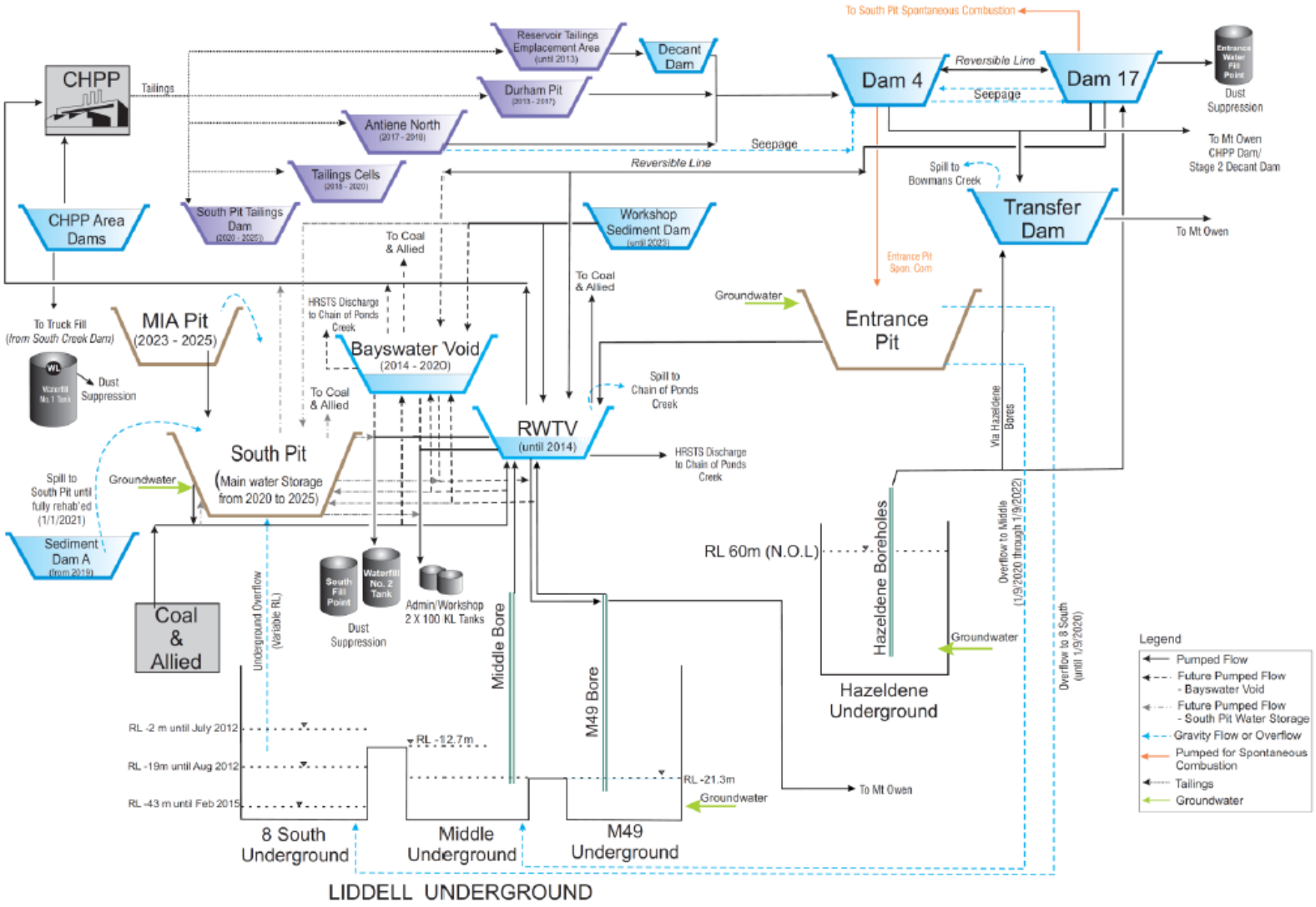



**Figure 9.12 - Schematic of Existing and Future Water Management System at LCO (Gilbert & Associates 2014)**

**Table 9.7 - Modelled Catchment Areas**

| Storage | Total Catchment Area (ha) | | | |
|---|---|---|---|---|
| | Jun -2014 | Jun-2017 | Jun-2021 | Jun-2025 |
| Antiene Void | 87 | 87 | 0 | 0 |
| Entrance Pit | 82 | 110 | 154 | 136 |
| Bayswater Void | 26 | 26 | 0 | 0 |
| CHPP Settling Pond | 20 | 20 | 20 | 20 |
| CHPP South Dam | 1 | 1 | 1 | 1 |
| Dam 17 | 73 | 95 | 102 | 107 |
| Dam 4 | 26 | 26 | 46 | 46 |
| Durham Tailings Emplacement Area | 35 | 35 | 35 | 0 |
| South Pit (incl. MIA Pit) | 533 | 634 | 118 | 142 |
| Sediment Dam A | 0 | 0 | 523 | 530 |
| Reservoir West | 33 | 0 | 0 | 0 |
| Reservoir South | 40 | 0 | 0 | 0 |
| Decant Dam | 20 | 0 | 0 | 0 |
| Tailings Cells | 26 | 26 | 26 | 0 |
| South Pit Tailings | 0 | 0 | 9 | 0 |
| Workshop Sediment Dam | 13 | 13 | 13 | 0 |

Groundwater Inflow Rates: it was assumed that inflows occurred from surface rainfall recharge and groundwater inflow from surrounding strata. The following rainfall recharge estimates were used in the model:

- Recharge = 1.3ML/day when rainfall in the given year was less than 77% of the long term average;
- Recharge = 3.7ML/day when rainfall in the given year exceeded 123% of the long term average;
- Recharge = 2.4ML/day for all other cases. A groundwater inflow rate of 1ML/day was also assumed for the Liddell underground.

Groundwater inflow rate estimates to the open cut operations and underground workings were provided by SKM (2014). Groundwater inflows to the South Pit are predicted up to and including 2021 with inflow rates up to 8.2 ML/d. Groundwater inflows into the Entrance Pit were predicted only in 2021 with an average inflow rate for that year of 15.3 ML/d. Inflows to the open cut pits were distinct from water which would be pumped from the underground workings to the surface.

The groundwater model predicted inflow rates to the Hazeldene, Middle and M49 former underground workings were based on predicted inflow rates to these undergrounds from surrounding strata. For the Hazeldene underground, groundwater inflows were predicted to range between 0.07 and 0.09 ML/d. Inflow rates ranged between 0 and 0.27 ML/d for the 8 South Underground, 0 and 3.4 ML/d for the M49 Underground and 0 to 0.05 ML/d for the Middle Underground. The predicted groundwater inflow rates are summarised in **Table 9.8**.

**Table 9.8 – Predicted Groundwater Inflow Rates**

| Year | Predicted Groundwater Inflow Rate (ML/d) | | | | | |
|---|---|---|---|---|---|---|
| | South Pit | Entrance Pit | 8 South | Middle | M49 | Hazeldene |
| 2014 | 3.94 | 0 | 0.00 | 0.02 | 0.63 | 0.08 |
| 2015 | 3.31 | 0 | 0.00 | 0.02 | 0.57 | 0.08 |
| 2016 | 2.66 | 0 | 0.00 | 0.01 | 0.47 | 0.07 |
| 2017 | 2.93 | 0 | 0.00 | 0.01 | 0.44 | 0.07 |
| 2018 | 2.37 | 0 | 0.01 | 0.00 | 0.36 | 0.07 |
| 2019 | 1.92 | 0 | 0.01 | 0.01 | 0.24 | 0.07 |
| 2020 | 1.71 | 0 | 0.01 | 0.01 | 0.26 | 0.07 |
| 2021 | 0.1 | 15.29 | 0.27 | 0.03 | 3.36 | 0.09 |
| 2022 | 0 | 0 | 0.00 | 0.01 | 0.00 | 0.08 |

The groundwater model only provided inflow rates up to the end of 2022 (which corresponds to the maximum extent of mining in the Referral Area in terms of pit shell extent and depth of mining), and is when mining in the Entrance Pit is scheduled to be completed. The site water balance model was required to simulate the remaining mine life up to mid-2025 to allow for mining in the MIA Pit (into which zero groundwater inflow was predicted). Therefore after 2022, the groundwater inflow rates to the open cut pits were based on modelled final void (post-mining, long-term) groundwater inflow rates, which were estimated separately from the life-of-mine inflows by SKM (2014).

For the open cut pits, based on advice from SKM, it was assumed that it would take approximately 50 years for the surrounding aquifers to recover to a 'steady-state'. Therefore the predicted inflow rates at any time between the end of 2022 and mid-2025 were calculated by linearly interpolating between the values predicted at the end of 2022 (**Table 9.8** above) and the fully recovered post-mining values which were assumed would apply at the end of year 2072. For the MIA Pit, the predicted groundwater inflow rates were negligible post-mining. For the former underground workings, the predicted groundwater inflow rates from 2023 onwards were taken as the average for the period from 2012 to 2022, based on advice from SKM.

Pumping Rates: **Table 9.9** presents the modelled default pumping rates from storages.

**Table 9.9 – Pumping Rates (Gilbert & Associates, 2014)**

| From | To | Pump Capacity (L/s) |
|---|---|---|
| CHPP Area Dams | CHPP | 165 |
| Dam 4 | Dam 17* | 100† |
| Dam 4 | Transfer Dam | 100 |
| Dam 17 | Main Water Storage*^ | 150† |
| Dam 17 | Transfer | 100 |
| Dam 17 | Mt Owen | 100 |
| Entrance Pit | Main Water Storage^ | 200 |
| Hazeldene Underground | Dam 17 | 100† |
| Hazeldene Underground | Transfer Dam | 100† |
| M49 | Main Water Storage^ | 85 |
| M49 | Mt Owen | 85 |
| Middle Liddell | Main Water Storage^ | 45 |
| Main Water Storage^ | CHPP | 150 |
| Main Water Storage^ | Coal & Allied | 200 |

| From | To | Pump Capacity (L/s) |
|---|---|---|
| MIA Pit | Main Water Storage^ | 90† |
| South Pit | Main Water Storage^ | 500† |
| Tailings Dams | Dam 4 | 80 |
| Tailings Dams | CHPP | 80 |
| Transfer Dam | Mt Owen | 100 |
| Workshop Sediment Dam | Main Water Storage^ | 150 |

** Reversible pump line*

*^ Main water storage changes between Raw Water Transfer Void, Bayswater Void and the South Pit*

*† Pump rate assumed in the absence of any other information*

Water Demands: The five primary water demands at LCO, as modelled in the site water balance, are:

- Make-up water to the CHPP;
- Haul road supply for dust suppression;
- Water used to control spontaneous combustion;
- Water used for the administration and the workshop; and
- Water supplied to neighbouring mining operations under agreement.

CHPP make-up demand depends upon the future ROM coal washing (CHPP feed) rate as summarised in **Table 9.10**. Water is supplied to the CHPP to make-up water lost to tailings, coarse reject and in increased moisture in product coal (above that in ROM coal). The following key assumptions were made in this regard in the site water balance model:

- ROM coal moisture 3% (by weight).
- Product coal comprises 65% of ROM coal.
- Product coal moisture 8% (by weight).
- Tailings comprise 9% of ROM coal.
- Tailings pumped at 25% solids concentration (by weight).
- Coarse rejects moisture 12% (by weight).

**Table 9.10 - CHPP Feed Demand Rate**

| Year | CHPP Feed Rate (Mtpa) | CHPP Water Demand (ML/d) |
|---|---|---|
| 2014 | 7.1 | 6.0 |
| 2015 | 6.9 | 6.0 |
| 2016 | 7.2 | 6.3 |
| 2017 | 7.0 | 6.2 |
| 2018 | 7.0 | 6.2 |
| 2019 | 7.0 | 6.2 |
| 2020 | 7.2 | 6.3 |
| 2021 | 5.3 | 4.7 |
| 2022 | 5.3 | 4.7 |
| 2023 | 4.3 | 3.8 |
| 2024 | 4.6 | 4.1 |
| 2025 | 2.0 | 1.8 |

Haul road demand was derived for each month of the year (i.e. seasonally varying) from recorded usage data supplied by LCO. Future demands were calculated based on the estimated future haul road length (from future mine stage plans) compared with haul road length during the period of recorded data. The estimated haul road demand is summarised in **Table 9.11**. The haul road demand is first satisfied from Dam 17 in the model, then the CHPP area dams and then the main water storage.

**Table 9.11 - Haul Road Demand**

| Years | 2014-2015 | 2015 - 2017 | 2017 - 2020 | 2020 - 2025 |
|---|---|---|---|---|
| Estimated Total Length (km) | 13.0 | 13.3 | 16.3 | 9.0 |
| **Month** | **Haul Road Water Demand Rate (ML/d)** | | | |
| January | 29 | 29 | 36 | 20 |
| February | 22 | 23 | 28 | 15 |
| March | 29 | 30 | 37 | 20 |
| April | 23 | 24 | 29 | 16 |
| May | 30 | 30 | 38 | 21 |
| June | 18 | 19 | 23 | 12 |
| July | 24 | 24 | 30 | 16 |
| August | 24 | 25 | 31 | 17 |
| September | 24 | 25 | 31 | 17 |
| October | 29 | 30 | 37 | 20 |
| November | 32 | 33 | 41 | 22 |
| December | 31 | 32 | 39 | 21 |

The water demand to control spontaneous combustion was set at 7.5 L/s (0.65 ML/d) in the model, evenly split between the South Pit and Entrance Pit overburden emplacements, with 10% lost and the remainder reporting to the respective open cut pit. The average demand for the administration and workshop area was set to 0.11 ML/d.

Water demand by Coal & Allied (i.e. water supplied to operations off site) was set at 0.3 ML/d. Whilst an agreement is in place between LCO and Coal & Allied for LCO to supply up to 35 ML/week (5 ML/d), this maximum volume of water has not been requested by Coal & Allied since the agreement has been in place since 2003. Therefore, to best represent this demand in the water balance, the average of the actual volumes of water historically supplied was used. The demand for water by the other Glencore operations in the region was set at 4.32 ML/d (1577 ML/yr) based on historical supply records. Water was modelled as provided to other Glencore operations only if the water stored in the main LCO water storage at LCO was greater than 500 ML.

**Water Balance Model Results**

Model results for high rainfall (90$^{th}$ percentile), median and low rainfall (10$^{th}$ percentile) 11½-year periods throughout the mine life at LCO were extracted from model outputs and are summarised in **Table 9.12**.

**Table 9.12 – Median Water Balance (Gilbert & Associates, 2014)**

| | 10th Percentile Rainfall Sequence (Dry) (ML/yr) | Average (Over All Rainfall Sequences) (ML/yr) | 90th Percentile Rainfall Sequence (Wet) (ML/yr) |
|---|---|---|---|
| ***Inflows*** | | | |
| Catchment Runoff | 1,075 | 1,209 | 1,313 |
| Groundwater | 1,499 | 1,499 | 1,498 |
| Tailings Water | 865 | 864 | 865 |
| *Total Inflows* | *3,439* | *3,572* | *3,679* |
| ***Outflows*** | | | |
| CHPP Use | 1,975 | 1,973 | 1,975 |
| Truckfill (Haul Road Dust Suppression) Use | 246 | 246 | 261 |
| Evaporation | 233 | 245 | 253 |
| Release to Hunter River via the LDP | 196 | 223 | 55 |
| Spills* | 142 | 180 | 251 |
| Spontaneous Combustion Use | 14 | 15 | 14 |
| Coal & Allied Supply | 109 | 108 | 109 |
| Other Glencore Operations | 702 | 771 | 871 |
| Administration | 42 | 42 | 42 |
| *Total Outflows* | *3,659* | *3,803* | *3,831* |

* Spills were from Sediment Dam A once it was receiving fully rehabilitated runoff.

The outcomes of the Site Water Balance with regard to potential impacts on water resources are discussed in **Section 10**.

#### 9.1.5.2 Groundwater Water Balance

A regional numerical groundwater flow model was developed by SKM for the Jerrys and Glennies water sources of the Hunter Unregulated and Alluvial WSP to predict the likely impacts of the Proposed Action. The model was developed in accordance with the *Australian Groundwater Modelling Guidelines* (Barnett et. al., 2012), and predicts potential changes in groundwater levels that may occur as a result of mine dewatering as well as any associated losses in baseflow in the Bowmans Creek alluvium and associated surface water features.

The regional nature of the model provides Glencore a tool to evaluate potential groundwater impacts of a number of their operations in the area, including LCO. The model extent measures 20.5 km in the north-south direction and 27.4 km in the east-west direction, incorporating the Mount Owen Complex, Ravensworth Underground Mine, Ravensworth Surface Operations, Hunter Valley Operations and Ashton Coal, ensuring cumulative impacts are considered.

A detailed local groundwater water balance was then extracted from the groundwater model for the years 5 and 9 of the Proposed Action. These represent average mine fluxes prior to encroachment over a major fault structure (the Davis Fault zone – which is thought to enhance vertical connectivity) in approximately year 5 of the Project and end of mining fluxes in approximately year 9. These fluxes feed directly into the local groundwater water balance for the mine. Representation of these water balance snapshots and results are shown in **Figures 9.13a and 9.13b**.

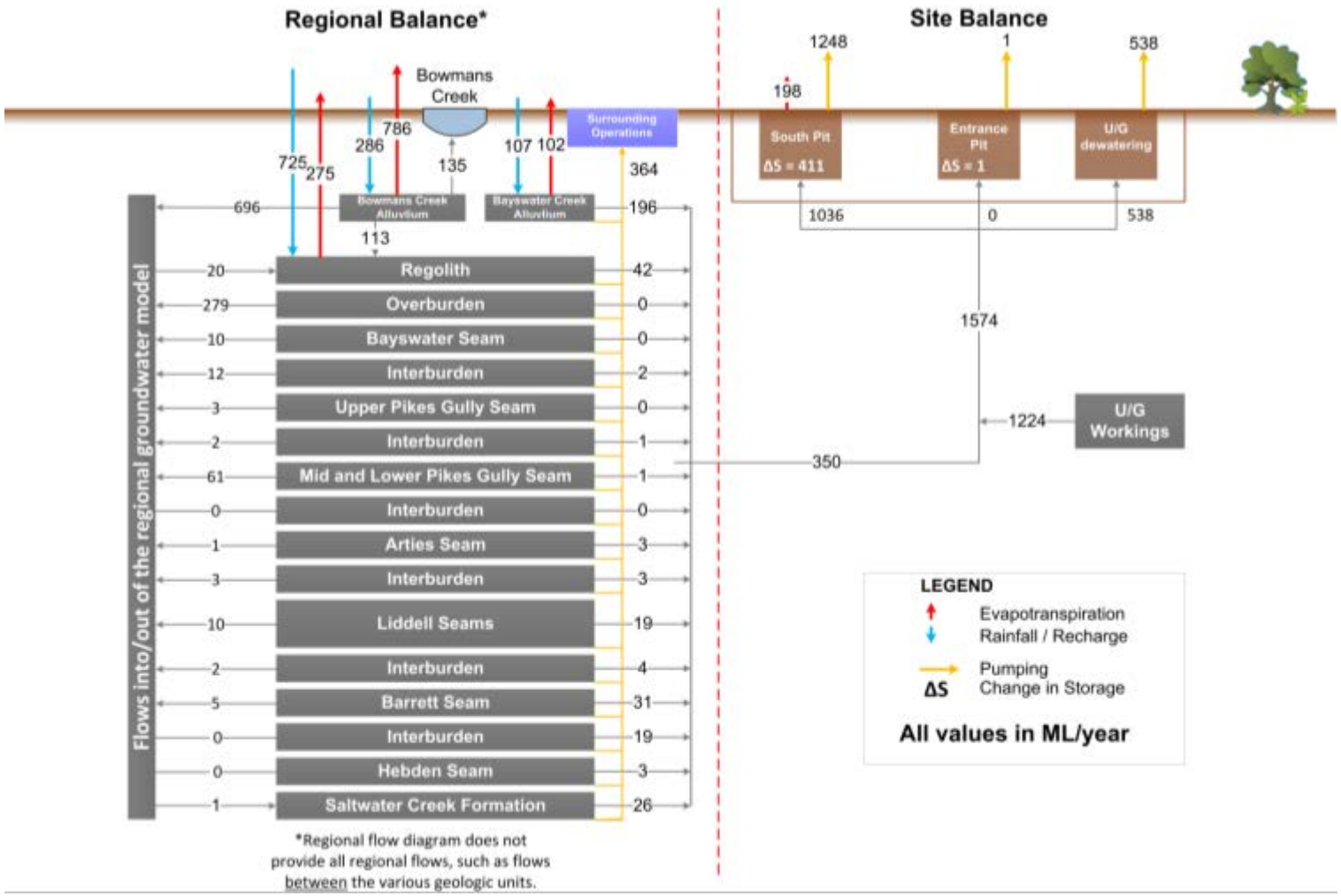



**Figure 9.13a - Modelled regional and local water balance for LCO in Year 5 (approximately 2018)**

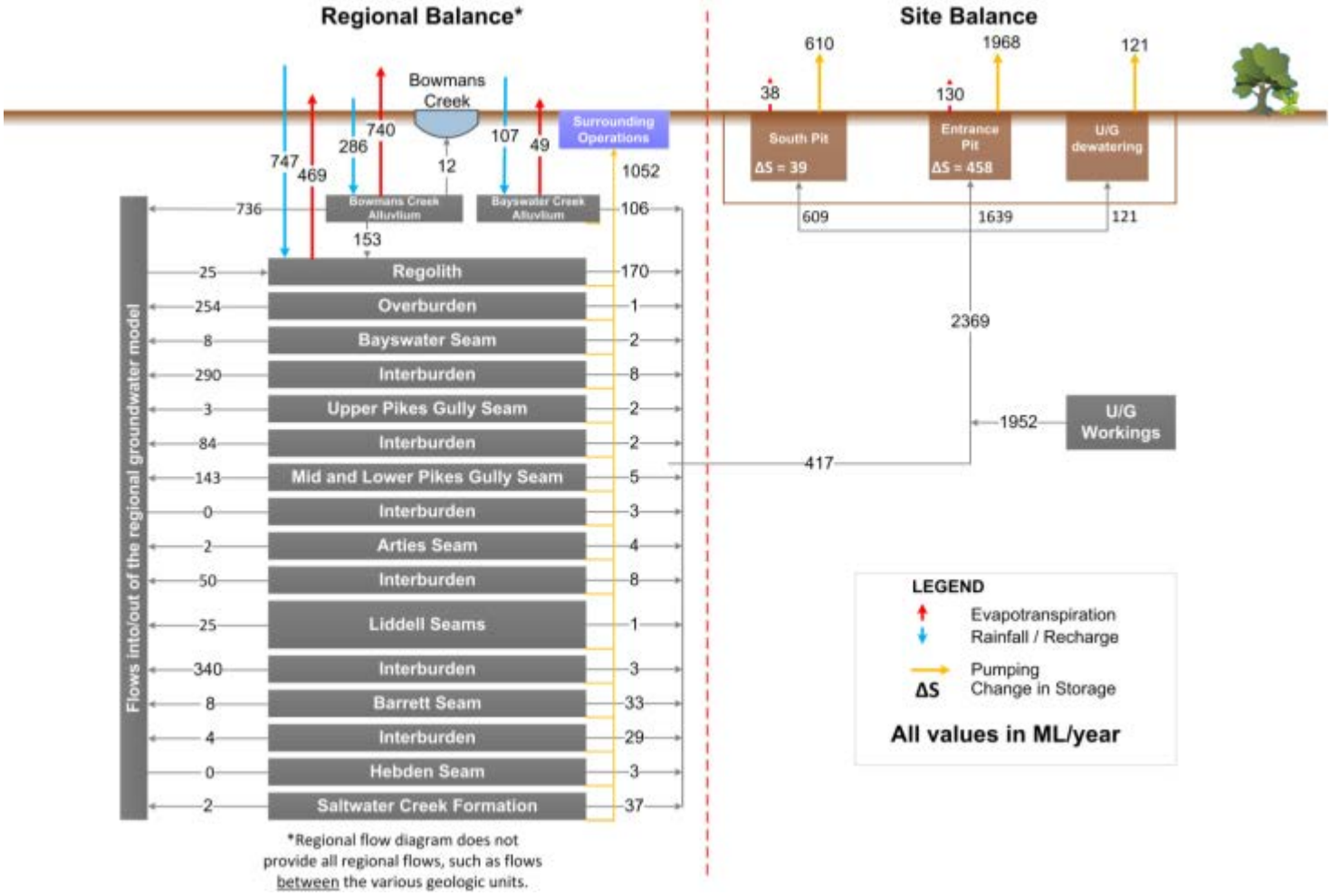



**Figure 9.13b - Modelled regional and local water balance for LCO in Year 9 (approximately 2022)**

Further information on the modelling of groundwater impacts including discussion on the results of the water balance is provided in **Section 10** – **Relevant impacts** (modelling surface and ground water impacts.)

Predictions for final groundwater levels during recovery have not been modelled in the current version of the numerical model. Rather, the system is assumed to recover to a new equilibrium (steady-state) subsequent to cessation of mining activities and incorporating a final void and an indicative period of recovery is estimated from modelled void filling and indicative groundwater hydraulic parameters. In particular, the alluvium would be expected to recover on a time-frame comparable to that of the void filling.

#### 9.1.5.3 Void Salt Water Balance

A salt balance was also developed by Gilbert & Associates (2014) to simulate conditions post-mining at LCO. In this salt and water balance, modelled inflows to the voids comprise direct rainfall over the void water surface, runoff from the void catchment area and groundwater inflow. Outflows comprise evaporation and groundwater outflow. In addition, water can be transferred between the voids via the remnant Middle Underground workings at an elevation of approximately -60 m AHD. Final void groundwater inflow and outflow rates were based on outputs of the groundwater water balance for long-term end of mine conditions.

For simulation of void salinity, the salinity of runoff was set to 800 mg/L based on the mean monitored salinity at existing dams at LCO which solely capture runoff from rehabilitated areas. The groundwater salinity was estimated to be 3,000 mg/L based on the average groundwater salinity presented in SKM (2014). The results of the salinity balance are presented in **Section 10.2.6**.

### 9.1.6 Direction of ground water flow and potentiometric surfaces

***for each hydrogeological unit likely to be impacted by the proposed action. The measured potentiometric heads (standing water levels) on which the potentiometric surfaces are based should also be presented;***

Groundwater level data for LCO is available from the existing groundwater monitoring network shown in **Figure 9.7**. The monitoring network targets both the Bowmans Creek alluvial aquifer and the hard rock aquifer of the coal measures. Piezometers targeting the alluvium are paired and monitor both the alluvial aquifer and the underlying shallow bedrock strata (where the bore name suffix L = alluvium (Large diameter casing) and S = shallow bedrock or overburden (Small diameter casing).

Hydrographs for piezometers targeting the alluvium and shallow bedrock are displayed in **Figure 9.14**. Groundwater elevations at these bores decrease with distance along Bowmans Creek, and the similar water level responses observed in the paired bores indicates these two units are hydraulically connected. **Figure 9.14** indicates groundwater levels generally decreased from 2001 to 2006 before rebounding to 2001 levels following the June 2007 floods. Since then groundwater levels have remained fairly stable. A sympathetic relationship exists between shallow water levels and the cumulative rainfall deviation (**Figure 9.14**), reflecting the direct impact of rainfall on water levels in the alluvium.

The modelled watertable for the Bowmans Creek alluvium is shown in **Figure 9.15**. This constituted the starting water level for comparison of drawdowns as a consequence of the project.

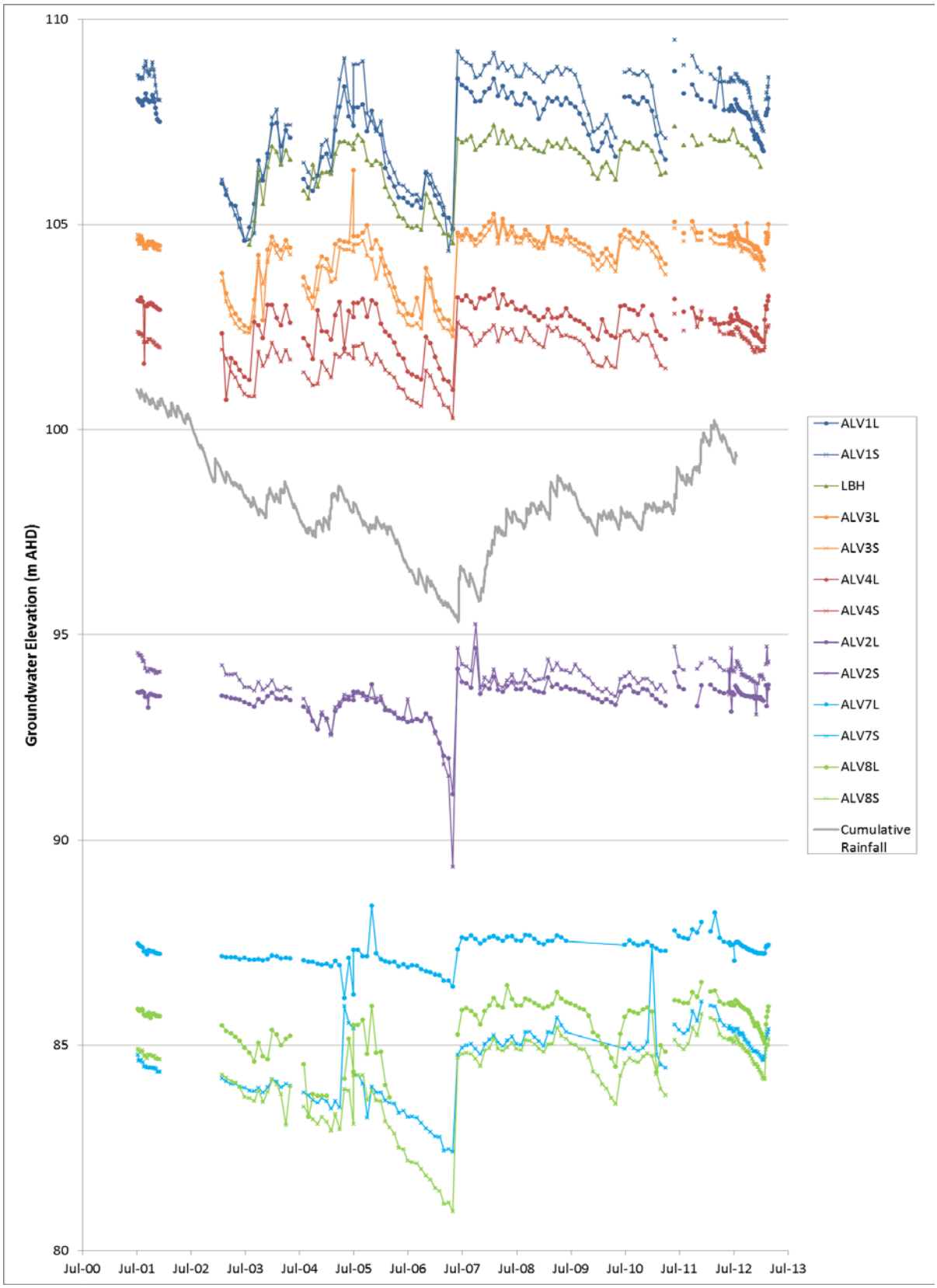



**Figure 9.14 - Hydrographs for Piezometers Targeting Alluvium and Shallow Bedrock**

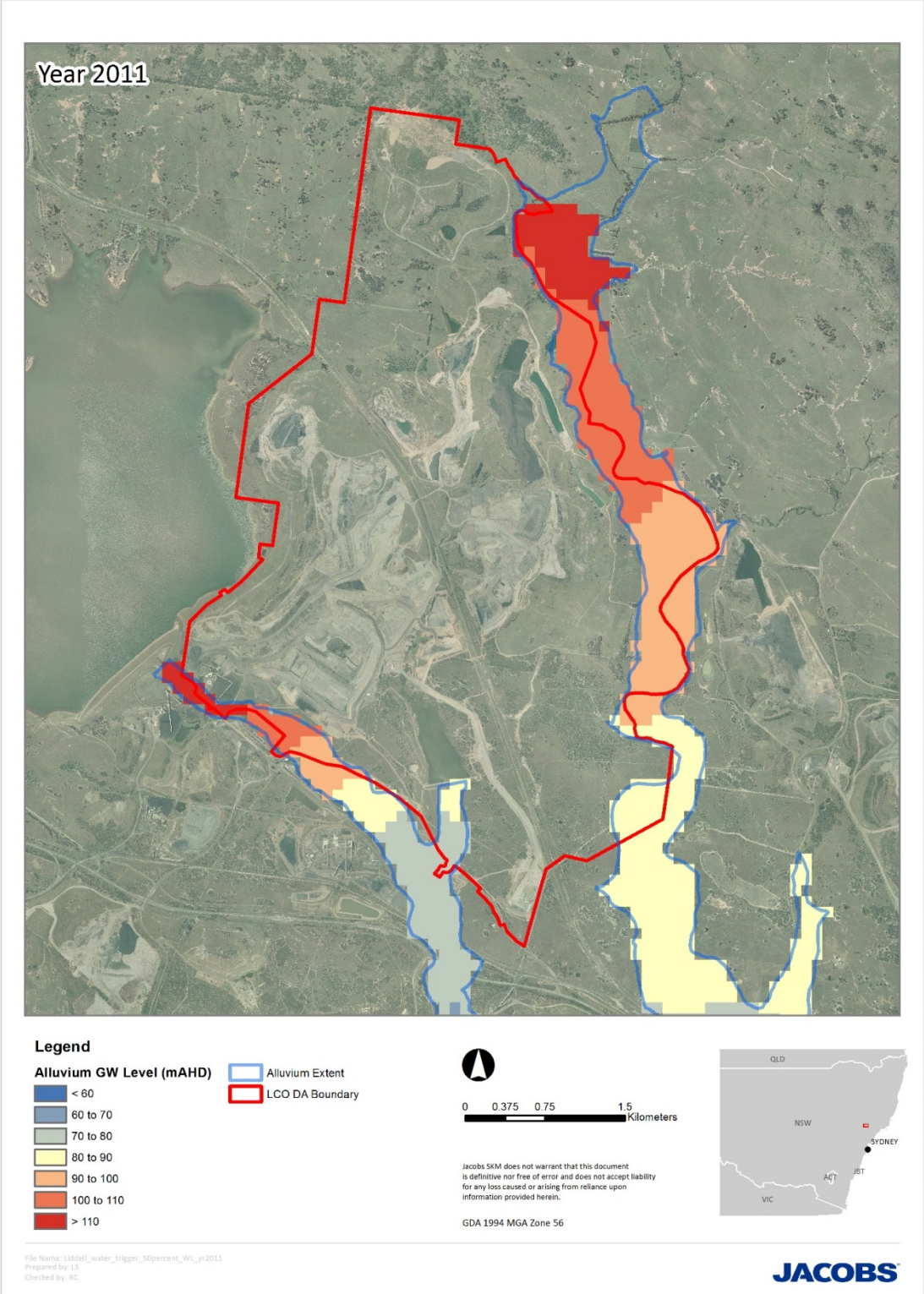



**Figure 9.15 – Modelled Current Median Alluvium Groundwater Levels**

To the north of the mine (ALV1 and ALV3) pressures in the overburden exceed those in the alluvial aquifer, indicating a potential for upward leakage to the alluvial aquifer. As the system progresses south, this differential decreases and to the south of operations (ALV7 and ALV8) the pressures reverse, with potential for leakage from the alluvial aquifer to the underlying beds. There has been no discernible change in the magnitudes of the pressure differentials between the alluvial and overburden aquifers over the duration of the monitoring, indicating that there has been no disruption to the interaction over that period.

Groundwater in the coal measures moves in a general downdip direction towards the south and east, from areas of recharge where individual seams subcrop and outcrop in the north near the Hunter Thrust and in the west near Lake Liddell. Rates of recharge through unweathered Permian bedrock are very low, with estimates varying from near zero to no more than 1% of annual rainfall (MER, 2011b). Recharge can be expected to be slightly higher where more permeable rocks (i.e. coal seams) subcrop and outcrop.

The groundwater flow regime within the coal measures around LCO is influenced by major structural controls shown in **Figure 9.7**, including:

- A northeast to southwest trending dyke, located in the southeast part of the LCO DA boundary but west of Bowmans Creek;
- The Davis Creek Fault, which strikes in a similar direction and is located adjacent to the dyke; and
- A coal barrier left in place between the historical Liddell and Hazeldene underground workings in the east of the LCO operational area.

Vertical groundwater fluxes between the hardrock aquifers and the overlying alluvial aquifers can be described through consideration of groundwater pressures at nested piezometer sites along the main alluvial channels. Thus, to the north of the mine (nested sites ALV1 and ALV3) pressures in the overburden exceed those in the alluvial aquifer, indicating a potential for upward leakage to the alluvial aquifer. As the system progresses south, this differential decreases and to the south of operations (ALV7 and ALV8) the pressures reverse, with potential for leakage from the alluvial aquifer to the underlying beds. There has been no discernible change in the magnitudes of the pressure differentials between the alluvial and overburden aquifers over the duration of the monitoring, indicating that there has been no disruption to the interactions over that period, being the last 12 years.

Hydrographs for piezometers targeting the regional hard rock aquifer associated with the coal measures are shown in **Figure 9.16**. The groundwater elevations vary significantly between the different piezometers shown, reflecting differences in groundwater levels between stratigraphic layers and groundwater response due to current and historical mining and dewatering activities. Current and historical open pit development has created groundwater sinks while underground workings act as both sinks and storage areas for regional groundwater.

Groundwater levels observed for the paired piezometers PGW5L and PGW5S, which target the overburden and Pikes Gully coal seam respectively, have been relatively stable since 2001. PGW5 is located above the former Hazeldene underground workings, which have been subject to periodic dewatering to accommodate mining operations at LCO. Hydrographs for piezometers Haz 3/4 and Haz 6 reflect these dewatering activities (and subsequent recovery) for the Hazeldene workings. The lack of response in groundwater levels for PGW5L and PGW5S indicates the intervening strata between the deeper Hazeldene underground workings and the Pikes Gully seam and overburden effectively confines any depressurization (and recovery) of the deeper strata, with little effect on groundwater pressures in the overlying strata. The similar hydrographs for Haz 3/4 and Haz 6 also reflect their hydraulic connectivity via the Hazeldene workings, with the fluctuations in water levels correlating to pumping schedules for these bores.

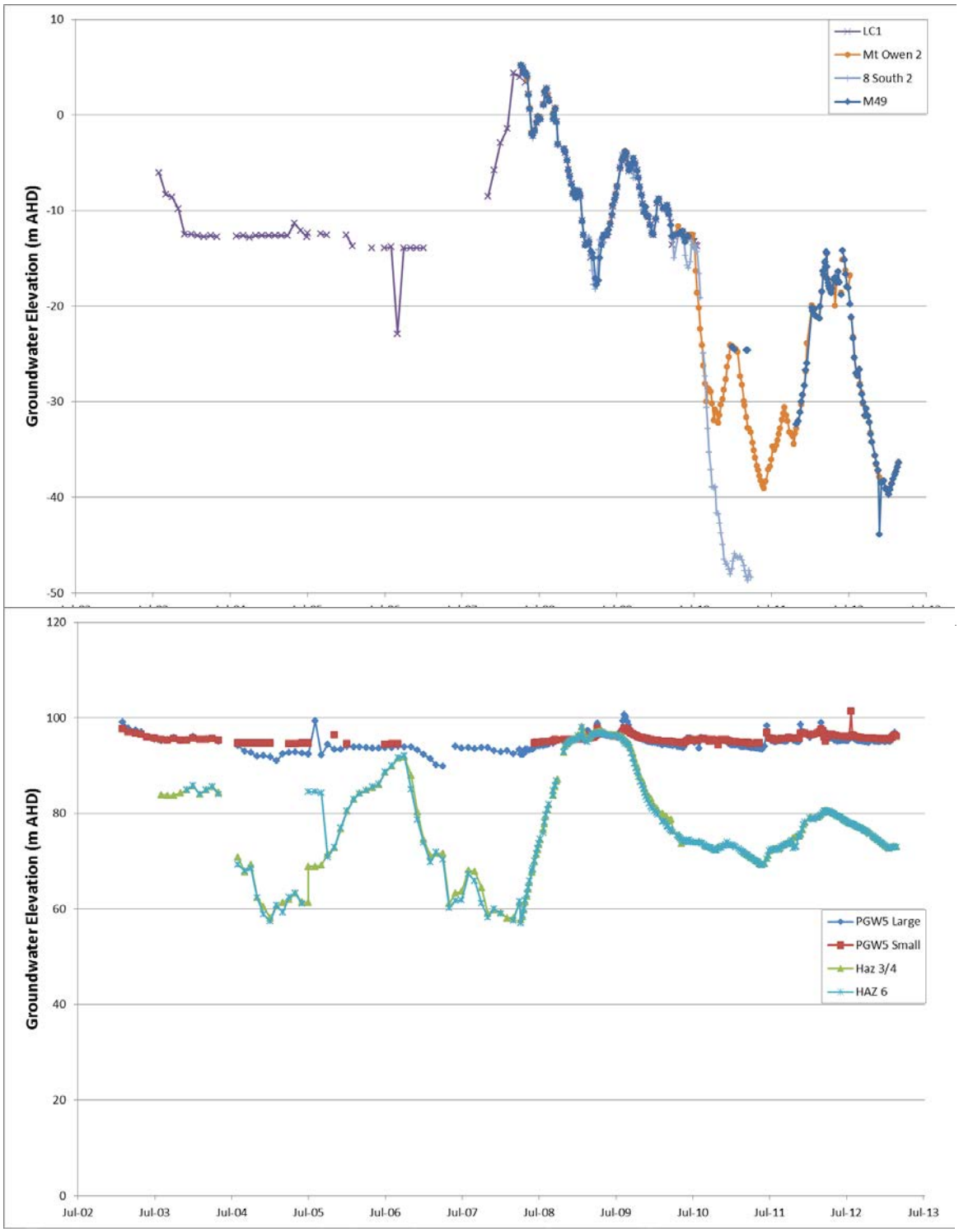



**Figure 9.16 - Hydrographs for Piezometers Targeting Regional Hard Rock Aquifer (Coal Measures)**

Hydrographs for piezometers LC1, Mt Owen 2, 8 South 2 and M49 display similar groundwater levels at all four locations, a product of mining operations at LCO and hydraulic connection between these bores through the Upper and Middle Liddell coal seams. Decreases in groundwater levels have occurred since 2007, largely due to pumping at the 8 South 2, Mt Owen 2, and M49 bores to accommodate open cut mining in the South Pit and Entrance Pit.

The combination of pumping from bores 8 South 2 and Mt Owen 2, and the NE-SW trending dyke and Davis Creek Fault located east of LC1, has resulted in the separation of groundwater within the Upper and Middle Liddell seams into two distinct underground water bodies. Groundwater levels decreased as a result of pumping, and once levels were lowered below approximately -22 m AHD in 2010 the dyke effectively separated groundwater into two separate water bodies east and west of the dyke (Umwelt, 2013d). The decrease in water levels in the Upper Liddell seam has also led to the drying of LC1 (invert level approximately 5 m AHD), explaining the absence of water level measurements at LC1 since July 2010.

Current operations at LCO include dewatering at the Mt Owen 2 and M49 bores to accommodate open cut mining in the South Pit and Entrance Pit, leading to significant lowering of water levels at these bores since 2007, as shown in **Figure 9.16**. Despite the depressurization of the Upper and Middle Liddell seams resulting from this dewatering, groundwater elevations in the overlying Bowmans Creek alluvium and shallow bedrock overburden do not appear to have been affected, as demonstrated by the hydrographs for dual piezometers ALV7 and ALV8 in **Figure 9.14**. The data indicate minimal (if any) effects on the Bowmans Creek alluvial aquifer and shallow bedrock as a result of current dewatering operations at LCO.

The coal barrier left in place between the historical Liddell and Hazeldene underground workings allows groundwater levels to be maintained in the Hazeldene underground workings above 60 m AHD even as groundwater levels in the Liddell underground workings falls below 0 m AHD (Umwelt, 2006). Comparing hydrographs for piezometers Haz 3/4 and Haz 6, located within the Hazeldene, with piezometers intercepting the Liddell underground (LC1, Mt Owen 2 and M49), indicates the coal barrier effectively limits hydraulic connectivity between these two former underground workings.

The complexity of the region with respect to groundwater interactions with mining operations means that water tables derived from available data does not provide a reasonable surface to interpret groundwater flow directions as shallow movement is dominated by flow towards major drawdown areas, namely the open cut pits. Further, outside the alluvium aquifers, shallow water tables occur as perched, discrete lenses in the regolith and there is not a contiguous water table across the region. For modelling purposes, however, a continuous surface is required. Hence, the modelled, end of calibration, surface is illustrated in **Figure 9.17a** for contextual information only. Also shown are current (as modelled) potentiometric surfaces for the coal measures aquifers for the targeted seams (**Figures 9.18-9.20**). These can be compared to the drawdown impact maps in **Figure 10.3**

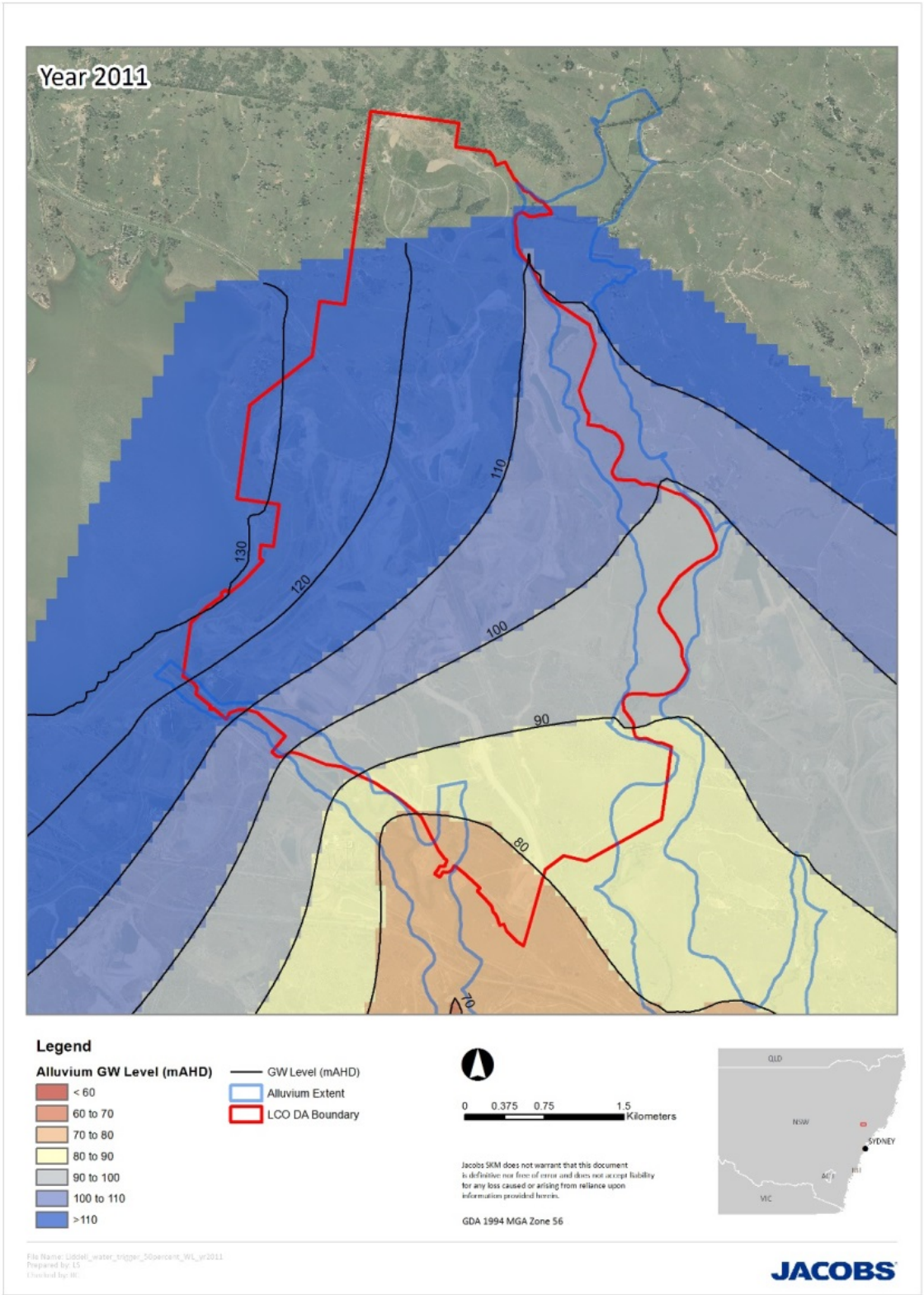



**Figure 9.17a – As modelled current water table surface for the model area**

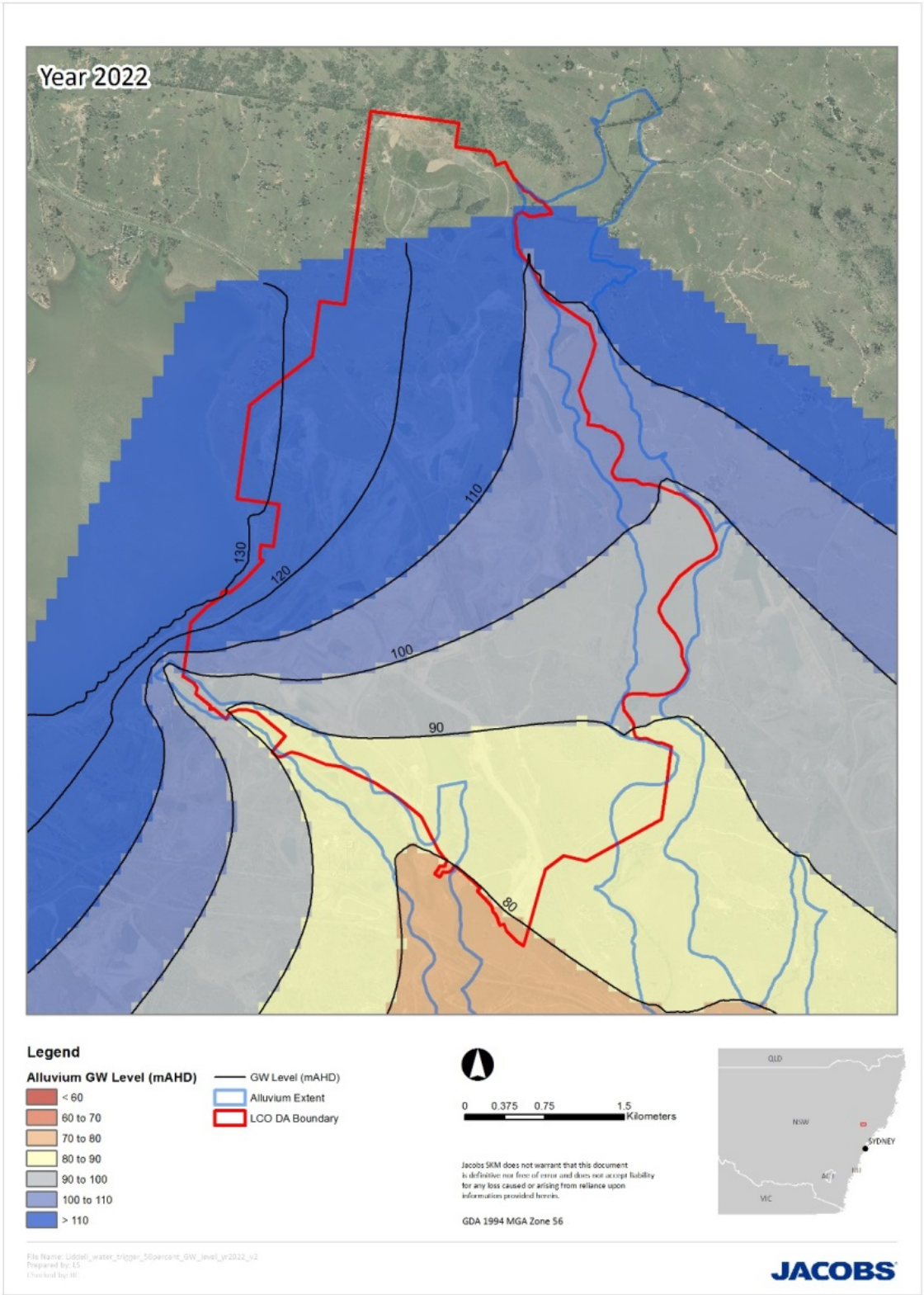



**Figure 9.17b – Modelled water table surface for the model area at the end of mining in the Entrance Pit (2022)**

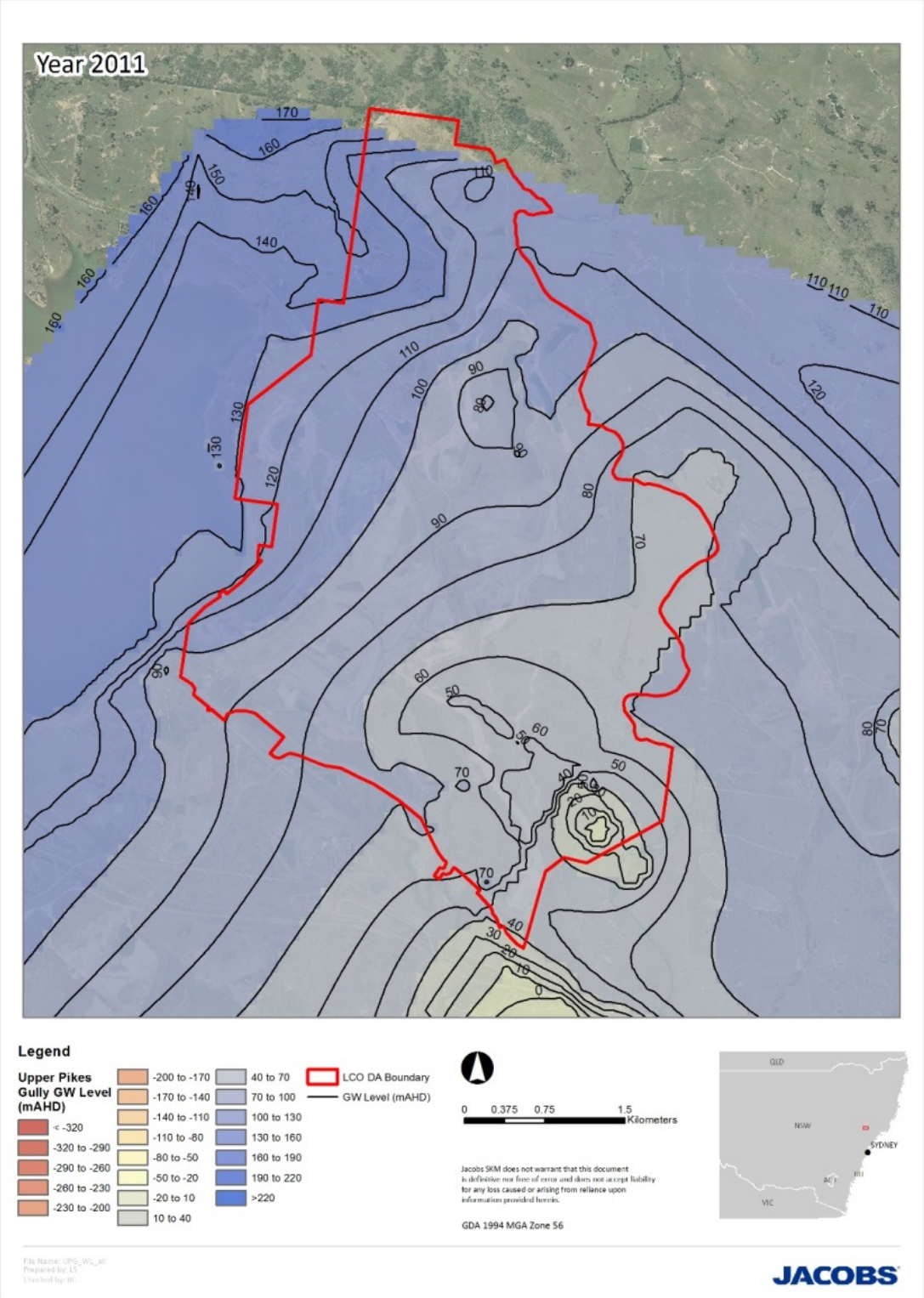



**Figure 9.18a – Modelled current potentiometric surface for the Upper Pikes Gully Seam**

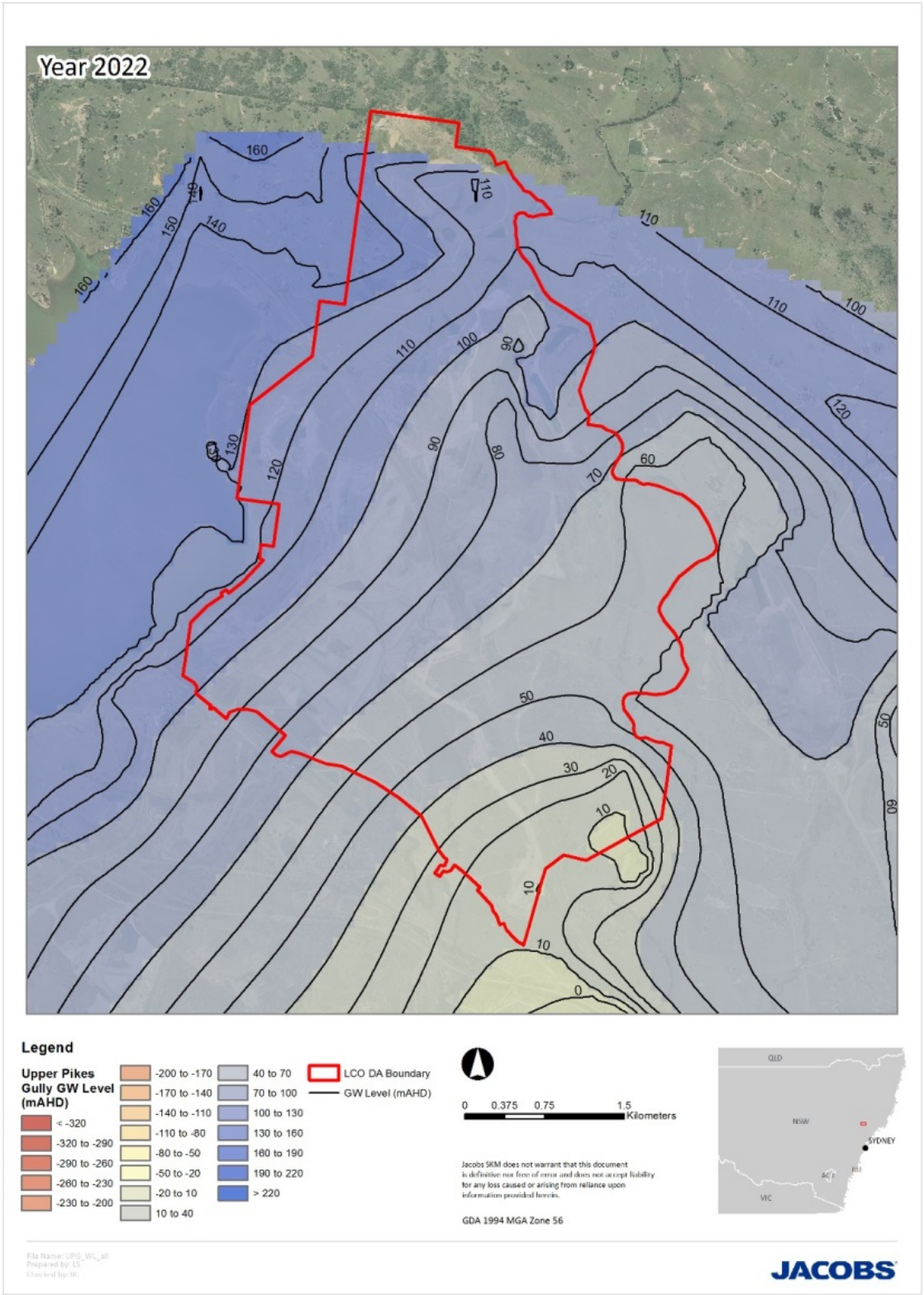



**Figure 9.18b – Modelled potentiometric surface for the Upper Pikes Gully Seam at the end of mining in the Entrance Pit (2022)**

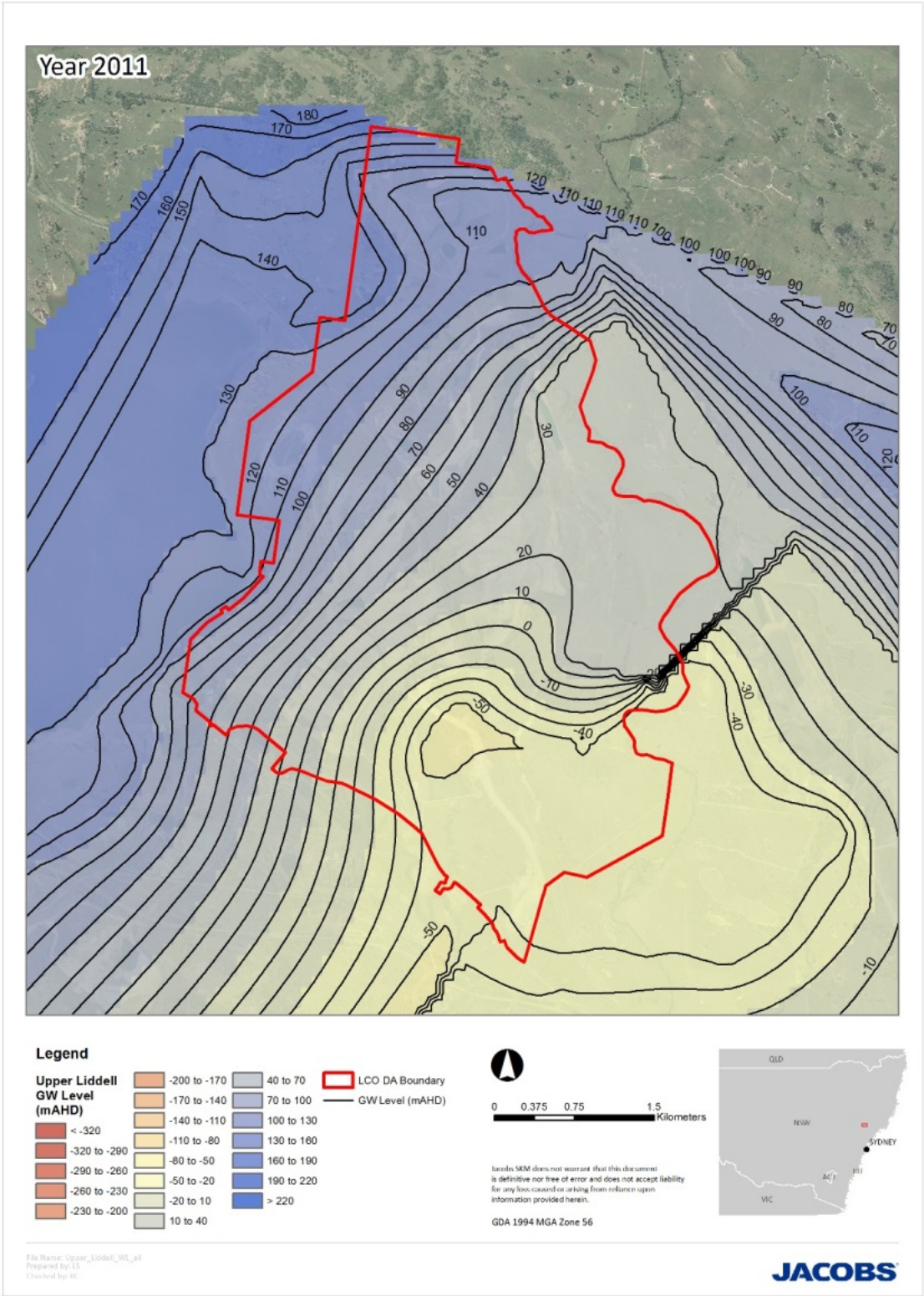



**Figure 9.19a – Modelled current potentiometric surface for the Liddell Seam**

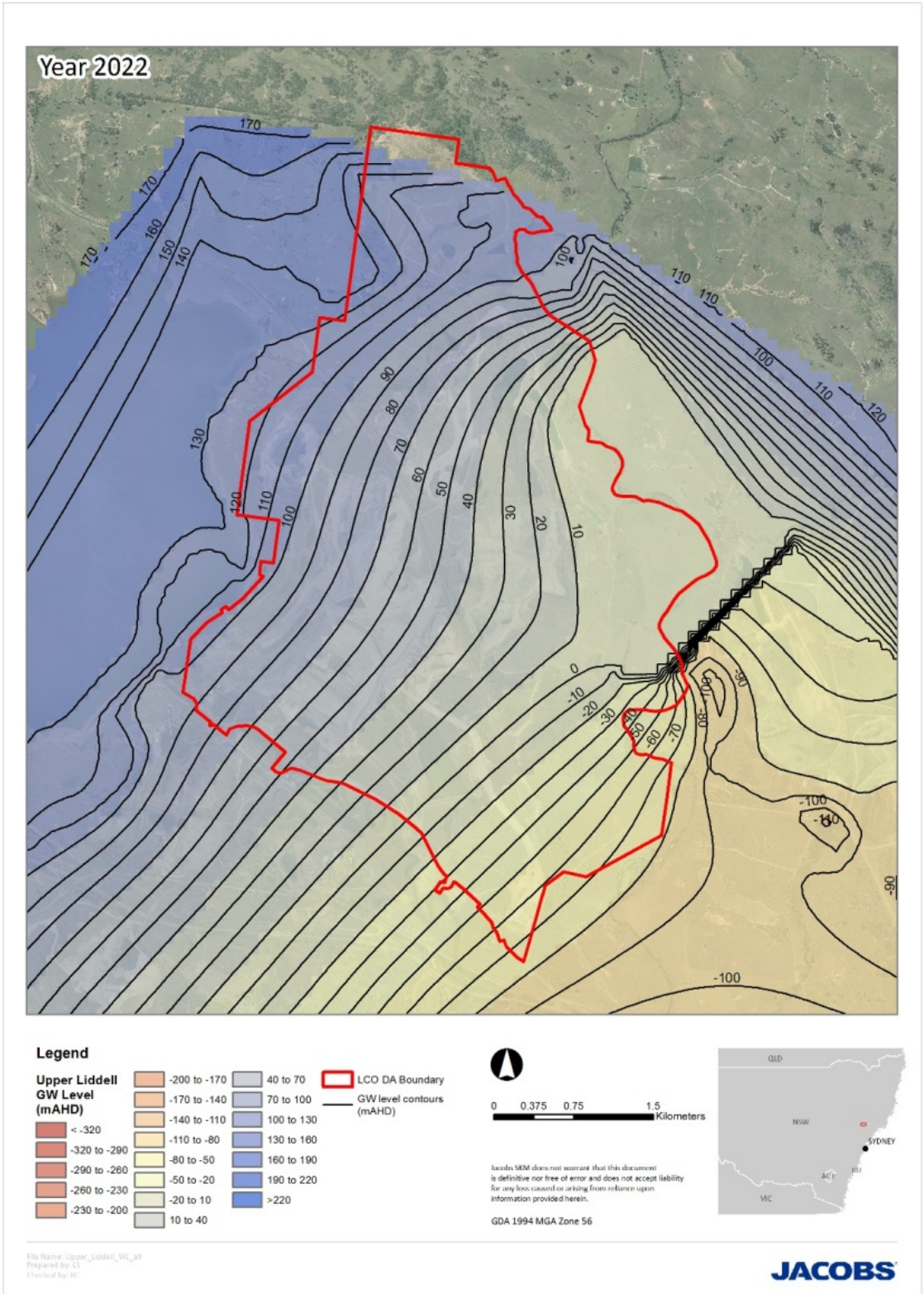



**Figure 9.19b – Modelled potentiometric surface for the Liddell Seam at the end of mining in the Entrance Pit (2022)**

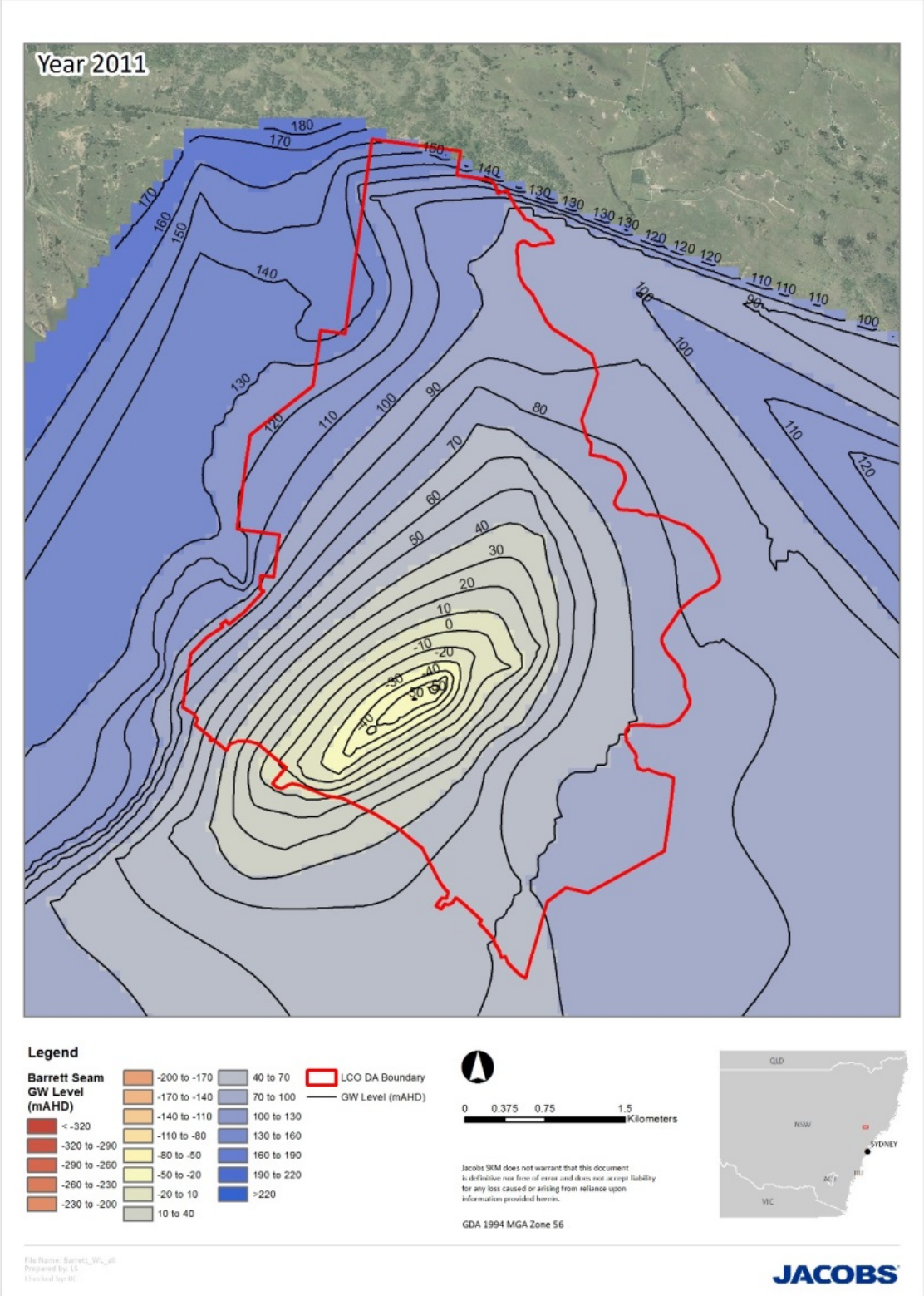



**Figure 9.20a – Modelled current potentiometric surface for the Barrett Seam**

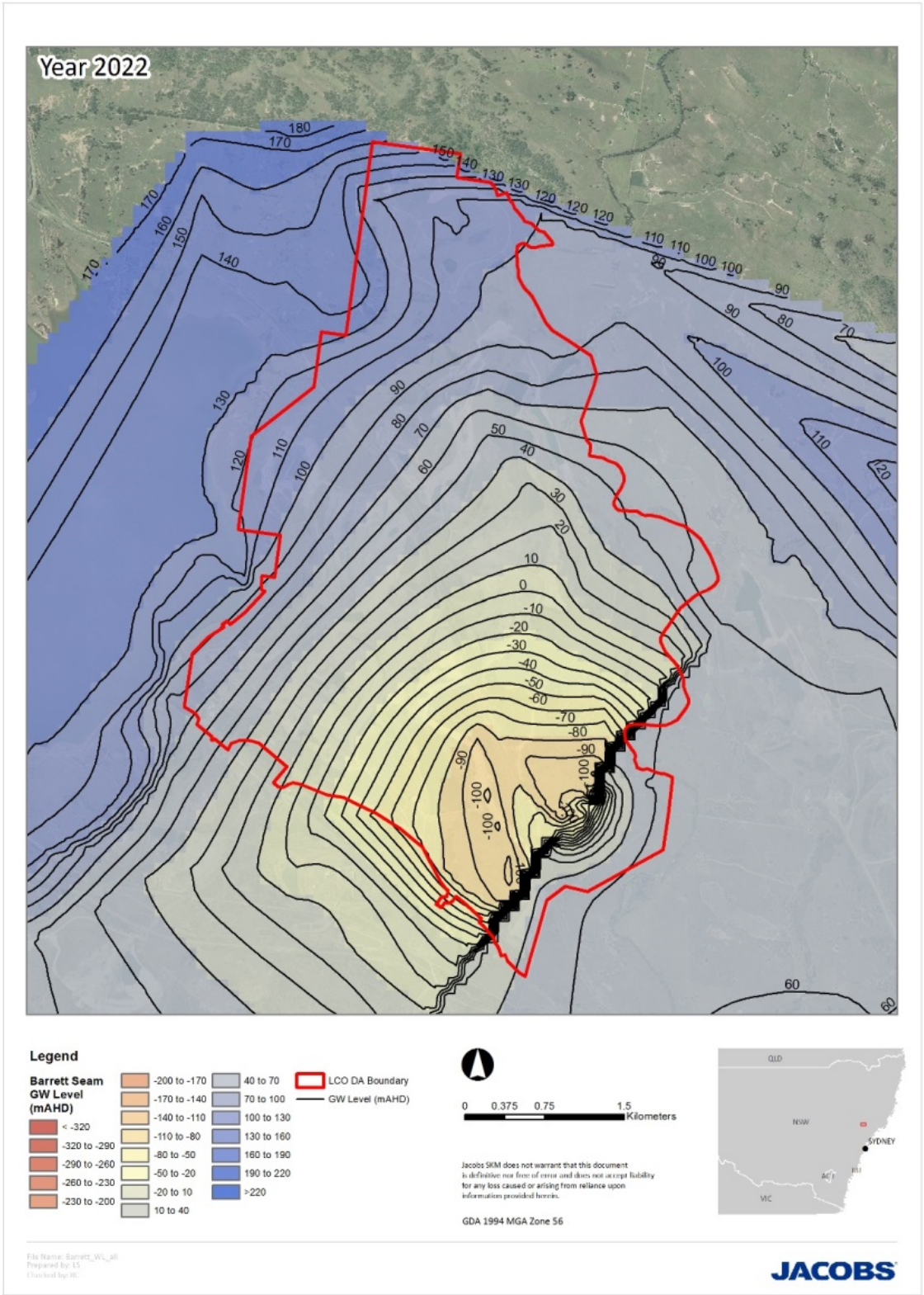



**Figure 9.20b – Modelled potentiometric surface for the Barrett Seam at the end of mining in the Entrance Pit (2022)**

### 9.1.7 Surface water flow regimes and flow directions

Flow duration curves extracted from stream gauges on the Hunter River (station 210126), Bowmans Creek (stations 210042 and 210130), and Bayswater Creek (station 210059), shown in **Figure 9.21**, reflect the relative contribution of these features to surface water drainage in the region. The low median annual flow rate for station 210059 (approximately one ML/day) reflects the impact of Lake Liddell and the significantly altered flow system of Bayswater Creek. The flow rates and duration profile for station 210126 are indicative of the Hunter River as the major surface water feature in the region. The two stream gauges on Bowmans Creek show markedly different flow duration curves, with the gauge located near LCO (station 210042, refer **Figure 9.1**) recording measurable stream flow only 65% of the time, while further downstream near the confluence of the Hunter River data from station 210130 indicates near perennial flow. The stream flow data recorded at station 210042 corresponds with historical observations of intermittent flow in Bowmans Creek in the vicinity of LCO. Station 210059 is located on Bayswater Creek and operated between 1966 and 2002.

The flow records for Bayswater indicate that the creek flows for a greater duration, but at lower volumes than would be expected for similar creeks in the area (compare gauge 210059 (Bayswater) with 210042 (Bowmans Creek at Liddell), reflecting the highly regulated nature of this creek.

### 9.1.8 Baseline water quality, including for stressors and toxicants;

No major trends are apparent in the pH and conductivity data presented in **Figure 9.8** through **Figure 9.10**, with the exception of a significant decrease in EC values for the hard rock piezometer HAZ 4 between July 2006 and July 2007. This decrease in conductivity at HAZ 4 was accompanied by a slight decrease in pH readings. Conductivity readings also decreased slightly in the alluvial bore ALV8L soon after July 2007, though this may be attributable to the heavy rainfall and flooding that occurred at that time.

In addition to pH and EC, data for additional water quality parameters such as TSS, TDS, heavy metals, cations and anions has been collected as part of the monitoring program. Appendix A of the Liddell Groundwater Impact Assessment (SKM 2014, refer **Appendix C**) summarises the data collected for these water quality parameters. The water management plan (Umwelt, 2013d) and groundwater monitoring program (Umwelt, 2013e) currently in place at LCO references the trigger values provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) as default criteria. The 80th percentile trigger values provided in the ANZECC (2000) guidelines have been adopted due to the highly disturbed nature of the site (Umwelt, 2013d). The data indicates that analyte concentrations in groundwater samples at LCO generally fall below the adopted criteria. Exceedances of the default criteria are observed for heavy metals copper and zinc and to a lesser extent aluminium, lead and nickel. No major trends are apparent for these species during the monitoring period, however, indicating minimal impact on groundwater quality as a result of current mining activities.

### 9.1.9 Local drainages and estimates of baseflow to each local watercourse;

In order to evaluate the potential effects of mining activities on groundwater within the Bowmans Creek alluvium, historical streamflow and climactic data can be used to estimate contributions of groundwater baseflow to the creek. SKM's BaseJumper (Murphy et al, 2008) program analyses streamflow data through a digital recursive filter to estimate groundwater contributions to baseflow. **Table 9.13** summarises the data record for stream gauges along Bowmans Creek, and includes the estimated baseflow component for each of the gauges as determined using BaseJumper. The data provides order of magnitude estimates of the reduction in baseflow required for impacts to streamflow to be seen along Bowmans Creek.

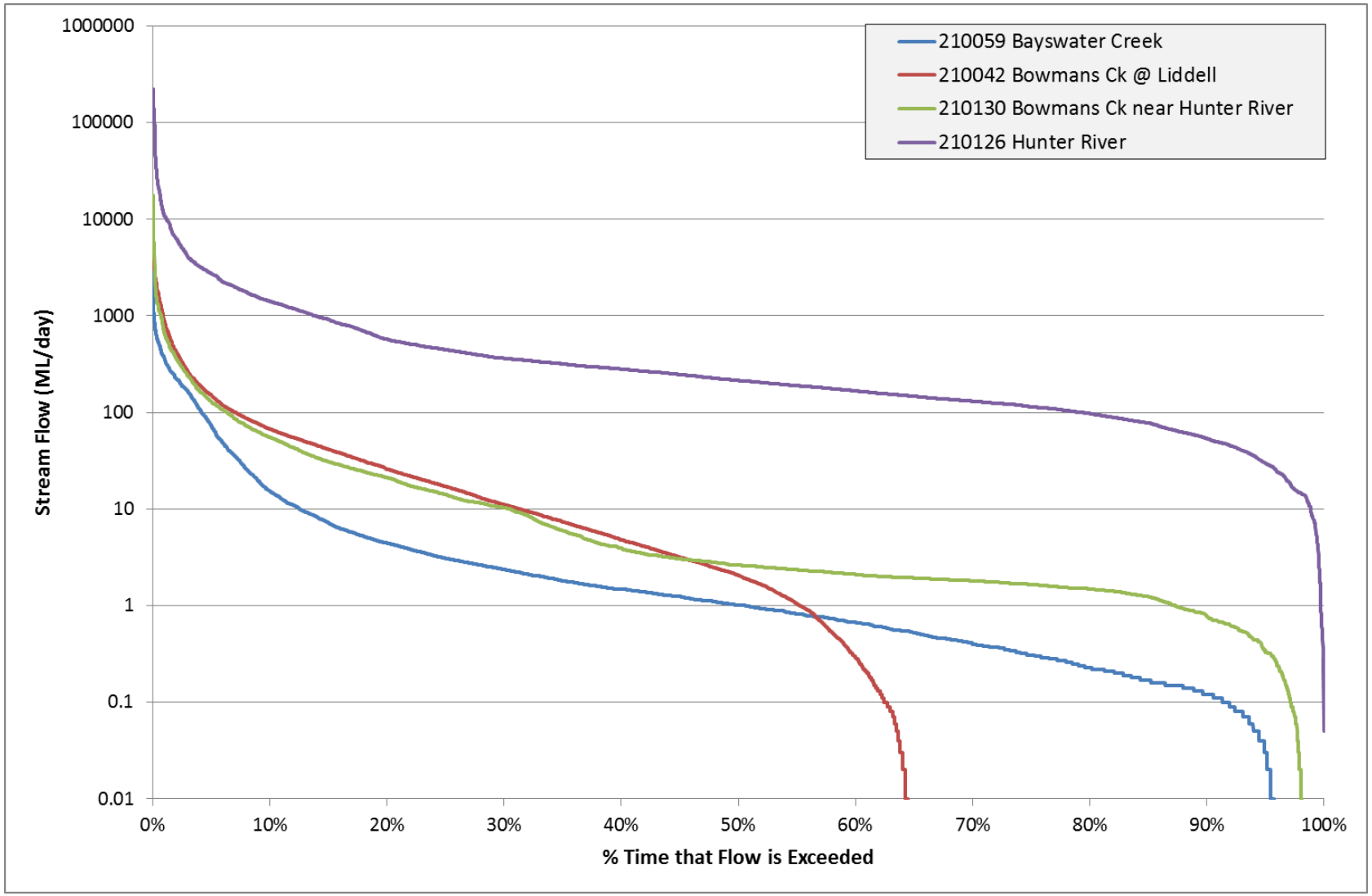



**Figure 9.21 - Flow Duration Curves for Surface Water Features**

**Table 9.13 – Summary of Streamflow Data[1] for Gauges on Bowmans Creek**

| Stream Gauge | 210113 | 210115 | 210116 | 210042 | 210121 | 210130 |
|---|---|---|---|---|---|---|
| Start of Record | 2/07/1980 | 16/12/1981 | 1/01/1982 | 23/03/1956 | 2/04/1988 | 29/10/1993 |
| End of Record | 1/01/1986 | 1/01/1986 | 1/01/1986 | 23/11/1999 | 3/01/1992 | 29/07/2009 |
| Number of days over record | 2010 | 1478 | 1461 | 15950 | 1372 | 5753 |
| Number of years over record | 5.5 | 4.0 | 4.0 | 43.7 | 3.8 | 15.8 |
| Number of days with data | 2010 | 1478 | 1461 | 14869 | 1372 | 5130 |
| Number of days missing data | 0 | 0 | 0 | 1081 | 0 | 623 |
| % missing | 0.0% | 0.0% | 0.0% | 6.8% | 0.0% | 10.8% |
| Number of days with zero flow | 418 | 60 | 151 | 5244 | 572 | 97 |
| % of time zero flow | 20.8% | 4.1% | 10.3% | 35.3% | 41.7% | 1.9% |
| Avg. Streamflow (ML/day) | 27.1 | 35.1 | 34.6 | 46.2 | 72.8 | 45.2 |
| Avg. Streamflow (ML/year) | 9890 | 12,800 | 12,600 | 16,900 | 26,600 | 16,500 |
| Est. Baseflow[2] (ML/day) | 4.2 | 7.5 | 13.7 | 9.6 | 16.3 | 10.8 |
| Est. Baseflow[2] (ML/year) | 1530 | 2740 | 5000 | 3500 | 5950 | 3940 |
| Pct Streamflow as Baseflow | 15.5% | 21.3% | 39.6% | 20.8% | 22.4% | 23.9% |

Notes

1. Streamflow data from NSW Office of Water's PINEENA CM database, http://waterinfo.nsw.gov.au/pinneena/cm.shtml.
2. Baseflow estimated using BaseJumper software analysis package (Murphy et al., 2008)

**Table 9.13** shows the estimated annual baseflow for stream gauges most likely to be impacted by current and future mining operations at LCO (e.g. gauges 210115, 210116, 210042, 210121 and 210130) range from 2,740 ML/year to 5,950 ML/year. These baseflow estimates amount to between 15% and 40% of average streamflow rates measured at the stream gauges, though it is noted that the 40% contribution was measured at only one gauge (station 210116) and the estimated baseflow contribution at the adjacent gauge (station 210115) was only 21% over the same period. The data suggest groundwater baseflow likely contributes between 20% and 25% of total streamflow along Bowmans Creek in the vicinity of LCO.

**Figure 9.22** shows baseflow estimates for selected stream gauges along Bowmans Creek together with cumulative rainfall trends since 1983. Downward rainfall trends reflect dry weather periods (i.e. less than annual average), and upward trends indicate wetter than average conditions. The figure shows correlation between rainfall and baseflow estimates, as expected for shallow unconfined alluvial systems with high transmissivity. Trends in baseflow follow comparable trends in rainfall, demonstrating the significant natural climatic impact on flow in Bowmans Creek. **Figure 9.22** also provides an indication of the magnitude of variance in the baseflow estimates, with rates often ranging between one and 100 ML/day (365 to 36,500 ML/year).

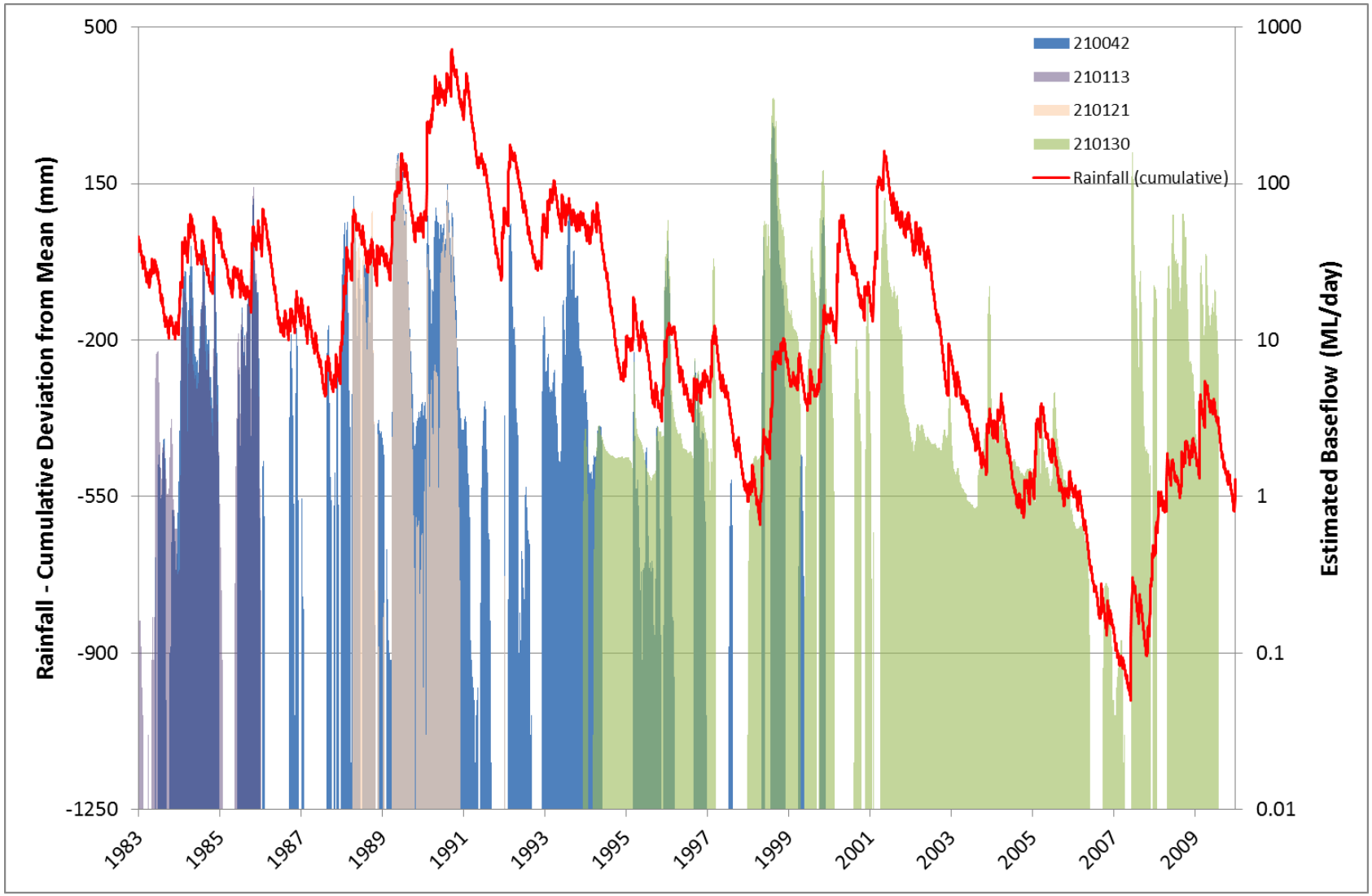



**Figure 9.22 - Estimated Baseflow Contributions and Rainfall for Bowmans Creek**

### 9.1.10 Identification of relevant water plans that may apply to the area

Under the WSPs distinct water sources are identified as the primary unit of water management and are used to define and limit surface and groundwater allocations for a given area. The WSP relevant to operations at LCO is the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*, which includes unregulated rivers and creeks, highly connected alluvial groundwater, and tidal pool areas within the Hunter region. In total the Hunter Unregulated and Alluvial WSP covers 39 different water sources, nine of which are further sub-divided into management zones (DWE, 2009). The Hunter Unregulated and Alluvial WSP commenced in August 2009.

Bowmans Creek and its associated alluvial aquifer is located within the Jerrys Management Zone of the Hunter Unregulated and Alluvial WSP. The Jerrys Management Zone and Appletree Flat Management Zone are used to manage separate areas of the Jerrys Water Source. Water sharing rules for Jerrys Water Source are governed by the WSP and include access and trading rules and restrictions on alluvial groundwater bores. Interference with surface waters or alluvial groundwaters associated with Bowmans Creek requires accounting in accordance with this WSP and an understanding of the importance of Bowmans Creek and its alluvial groundwater to the Jerrys Water Source.

### 9.1.11 The ecological characteristics and processes of the water resources

***Including the biological diversity, species composition and ecosystem function;***

An aquatic ecology and groundwater dependent ecosystem (GDE) assessment was undertaken by Eco Logical Australia (ELA) for the Proposed Action, and is attached in **Appendix J**. Sampling was conducted at a number of sites along Bayswater and Bowmans Creek, as illustrated in **Figure 9.23**. The findings of this assessment with regard to ecological characteristics of water resources in the vicinity of LCO are provided below.

**Ecological Condition of Bayswater Creek**

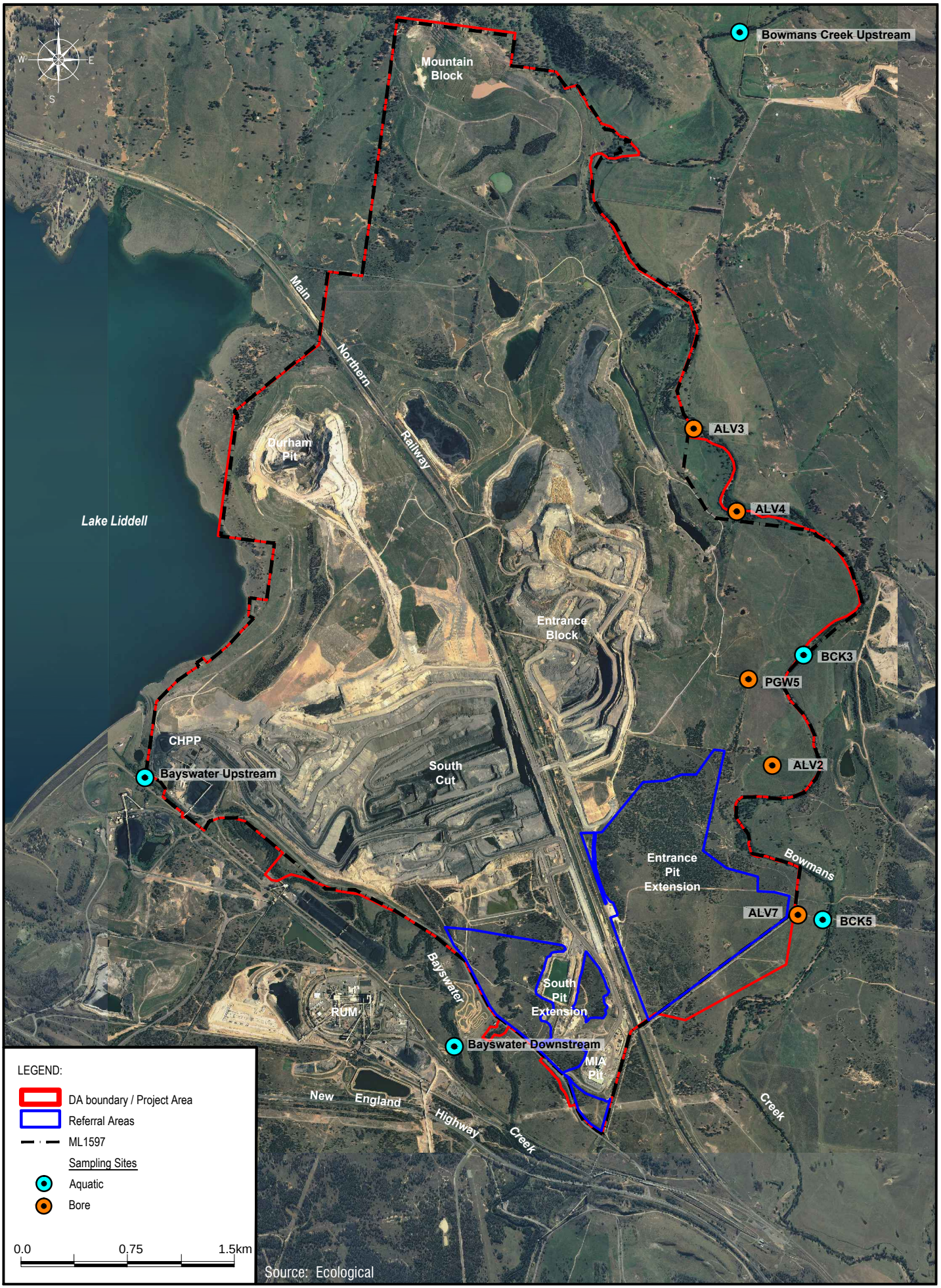
Bayswater Creek was deemed to be in poor condition by ELA (2013), with heavy loads of fine sediment on the bottom and evidence of erosion along the banks. The main factor influencing the ecological condition along the creek in the vicinity of LCO appears to be the control of flow from Lake Liddell.

Both the upstream and downstream sites monitored by ELA (2013) on Bayswater Creek had SIGNAL 2 scores less than 4, indicating by the macroinvertebrate community that the ecological community is in poor condition. The downstream site had the highest biological diversity, with 17 invertebrate taxa.

The fish community of Bayswater Creek was dominated by the exotic *Gambusia holbrooki* (Mosquitofish), with two native species *Anguilla reinhardtii* (Marbled Eel) and *Philypnodon grandiceps* (Flathead Gudgeon) also found at the upstream site. All three species identified are tolerant of relatively poor conditions and have been found in similar streams throughout the Hunter Valley.

The riparian zone of Bayswater Creek was deemed to be in moderate condition, with RCE scores of 30 and 34, and is dominated by dense growths of *Casuarina cunninghamiana.* Exotic species *Sida rhombifolia* and *Ricinus communis* were also present in the understorey at both sample sites. Almost no groundcover was present at the downstream site.

With regards to water quality, electrical conductivity (EC) at the two sites sampled during the field survey was greater than 4,000 µS/cm which, whilst exceeding the maximum Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines for lowland rivers of 2,200 µS/cm (ANZECC, 2000), is within the range previously measured for this creek as reported in the 2010/2011 LCO AEMR (AECOM, 2012). The high EC is likely due to releases of water from Lake Liddell with a moderate salt content.




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Aquatic and Groundwater Dependent Ecosystems Sampling Sites

**FIGURE 9.23**

Dissolved oxygen concentration in Bayswater Creek was outside the recommended ANZECC trigger values for aquatic ecosystems (85 to 110 % saturation), being 47% at the downstream site. This was probably due to the large volume of fine anaerobic sediments at the bottom of the pool, and the large amount of organic matter in the stream.

**Ecological Condition of Bowmans Creek**

Bowmans Creek was found to be in relatively good condition by ELA (2013), with all physico-chemical variables falling within ANZECC guidelines for lowland rivers in NSW. Turbidity in the upstream site was below the limit for lowland rivers and the water was clearer than the ANZECC guidelines for upland rivers.

The main impacts on the stream appeared to be from cattle access to the banks and creek. Evidence of erosion was present at all three sites monitored by ELA, although this was less visible upstream.

The average SIGNAL 2 scores for the three sites were all between 4 and 5, indicating moderate ecological condition. BCK3 (upstream of the proposed extension to the Entrance Pit) had the lowest SIGNAL 2 score, and the fewest invertebrate taxa, with the invertebrate community dominated by the tolerant taxa *Corixidae* water boatmen and *Copepoda*. BCK5 had the most diverse invertebrate community, with high numbers of *Baetidae* mayflies and *Leptoceridae caddisflies*. Both of these families are moderately sensitive to pollution, with SIGNAL 2 scores of 6 and 8 respectively.

Bowmans Creek upstream had the highest SIGNAL 2 score, indicating that the site was in good ecological condition. The dominant invertebrate taxa collected from this site were water boatmen, *Baetidae* mayflies, and *Leptoceridae caddisflies*.

The low electrical conductivity, low turbidity, high dissolved oxygen concentration, and complexity of habitat at the site made conditions suitable to the diverse macroinvertebrate community present. According to ELA (2013b), the upstream site appeared in good physical condition, with an emergent cobble bar immediately downstream of the bridge, and clearly defined riffle, pool and edge habitats. A pool downstream of the main riffle contained a variety of structure for macroinvertebrates, including fallen logs, steep banks with root structure, and gently sloping beds.

The three fish species collected at Bowmans Creek were the same as those in Bayswater Creek, and all were collected only from BCK5. An additional species, Carp (*Cyprinus carpio*) was also regularly observed at BCK3 and other reaches of the creek.

**Threatened Aquatic Communities**

No threatened aquatic species were collected during the field survey by ELA (2013b), and none are known from the reach of Bowmans Creek.

Although not a threatened species, Platypus (*Ornithorhyncus anatinus*) are a protected species in NSW. One platypus was collected at the downstream site at BCK5. No other platypus were observed in Bowmans Creek, but suitable habitat was present at the Bowmans Creek upstream site and at BCK3.

## 9.2 Water Related Assets

### 9.2.1 Aquatic and terrestrial ecosystems that are dependent on the water resource

***Including those dependent upon the particular geomorphology of a water resource;***

In general there are four types of GDEs:

- Terrestrial ecosystems;
- Baseflow supported aquatic ecosystems;
- Wetlands; and
- Aquifer ecosystems.

The aquatic ecosystem of Bowmans Creek and its associated riparian vegetation represent potential environmental receptors in the vicinity of the Proposed Action. There are no known groundwater supported wetlands or recognised aquifer ecosystems in the area.

**Groundwater Communities of Bowmans Creek Alluvial Aquifer**

Although alluvial aquifers along the Hunter River and some of its tributaries are known habitat for stygofauna, the field survey undertaken by ELA (2013b) was the first to collect stygofauna from the Bowmans Creek alluvial aquifer.

Ten taxa were collected by ELA (2013b), demonstrating that a diverse ecological community is present, and indicating that other species are probably present. None of the stygofauna taxa collected in the Bowmans Creek alluvial aquifer are endemic. *Notobathynella* sp. and *Bathynella* sp. occur along the Hunter River alluvial aquifer, and in the aquifers associated with many tributary streams. The amphipod *Chillagoe* sp. is also distributed widely in alluvial aquifers of the Hunter Valley, as are *Heterias* sp. isopods. A Paramelitidae amphipod from ALV2 can be seen in **Plate 1**.

A single specimen of a Troglofaunal Zygentoma (subterranean silverfish) was collected from bore ALV3, and can be seen in **Plate 2**.

It is likely that most of the alluvial aquifer of Bowmans Creek contains stygofauna, and therefore has been classified as a groundwater dependent ecosystem by ELA (2013b).



**Plate 1 - A Paramelitidae amphipod from ALV2**



**Plate 2 - Troglofaunal Zygentoma from bore ALV3**

**Other Groundwater Dependent Ecosystems**

The degree of dependence of Bowmans Creek on groundwater will vary with distance and time, as will the direction and magnitude of exchange between surface and groundwater. When there is a large volume of surface water in the creek, water will flow through the stream bed and recharge the aquifer. Conversely, during periods of low surface runoff, a large proportion of water in Bowmans Creek will come from the aquifer. During these periods, all aquatic flora and fauna become groundwater dependent.

Stands of *Eucalyptus camaldulensis* (river red gum) occur downstream of the Referral Area, which usually occur on river floodplains with some dependence on alluvial groundwater. However, there are no stands of river red gum or other groundwater dependent vegetation communities within the Referral Area.

### 9.2.2 Ecosystems that are dependent on springs and ground water

Refer **Section 9.2.1**.

### 9.2.3 Regional communities, industrial and/or agricultural activities, and indigenous cultural needs or assets that are dependent on the water resource

A search of NSW Office of Water's PINEENA groundwater database identified 12 registered groundwater bores within 2 km of the LCO Development Consent boundary. **Table 9.14** summarises bore information from the database.

**Table 9.14 – Registered Groundwater Bores within 2 km of LCO**

| Work No. | Licence | Owner | Purpose | Date Completed | Depth (m) |
|---|---|---|---|---|---|
| GW027690 | 20BL020923 | Liddell Tenements | Irrigation | 1/01/1966 | 6 |
| GW028247 | 20BL020924 | Liddell Tenements | Irrigation | 1/01/1962 | 2 |
| GW080212 | 20BL168065 | Liddell Tenements | Monitoring | 31/05/2002 | -- |
| GW080245 | 20BL168066 | Liddell Tenements | Monitoring | 7/08/2002 | -- |
| GW080213 | 20BL168064 | Liddell Tenements | Monitoring | 31/05/2002 | -- |
| GW080172 | 20BL168209 | Xstrata Mt Owen Pty | Industrial | 28/03/2002 | -- |
| GW078085 | 20BL166608 | -- | Stock | 23/06/1997 | 13 |
| GW080725 | 20BL168240 | -- | Mining | 10/08/2000 | 130 |
| GW080176 | -- | -- | Unknown | 4/02/2002 | -- |
| GW080173 | -- | -- | Unknown | 4/02/2002 | -- |
| GW035474 | 20BL028920 | Private | Exploration | -- | -- |
| GW079793 | -- | -- | Mining | -- | 3 |
| Source: NSW Office of Water's PINEENA GW database, version 3.2 (October 2010), http://waterinfo.nsw.gov.au/pinneena/gw.shtml | | | | | |

Amongst the 12 registered bores presented in **Table 9.14**, six of the bores are owned by LCO or Glencore's neighbouring Mount Owen mine and three are identified for exploration or mining purposes. Bore GW078085 is registered for stock purposes; however the bore is located to the northeast of LCO and beyond the area of predicted impacts from the Proposed Action. The PINEENA database did not contain any ownership or purpose information for bores GW080176 and GW080173, however further research revealed the lots these bores are located on are owned by Ravensworth Operations P/L and Glencore Mount Owen P/L, respectively. Both of these entities are Glencore mining operations.

Based on this information and model predictions of groundwater depressurisation in the regional hard rock aquifer extending beyond the LCO DA boundary (refer **Figure 10.5** below), neighbouring mining operations are considered the only potential economic receptors of any groundwater impacts caused by the Proposed Action at LCO. No other economic users of groundwater within the local area are considered potential receptors to impacts resulting from the Proposed Action. Predicted depressurisation within the regional hard rock aquifer is predicted to be at a maximum in the Liddell and Barrett seams at the end of mining. **Figure 10.5** shows the predicted maximum depressurisation falls within the LCO DA boundary; however the zone of influence extends beyond the LCO boundary to the southeast. While this depressurisation extends beneath neighbouring mines, these other operations also require depressurisation and dewatering of the coal seams for their own mining purposes. As a result the depressurisation of the hard rock aquifer caused by the LCO modification is not expected to adversely impact neighbouring mining operations.

In addition, as can be seen from the information presented in **Table 9.14**, no privately owned bores used for agricultural purposes are located within 2 km of LCO. No privately owned bores will be impacted upon by the Proposed Action.

Potential social and cultural receptors include users of water resources used for recreational purposes and/or social amenity (e.g. water sports, fishing, etc.). The region surrounding LCO is characterised by extensive underground and open-cut coal mining operations and in the vicinity of LCO Bowmans Creek is not recognised for recreational uses or social amenity. In addition, the Aboriginal and Historic Heritage Assessment prepared for the Proposed Action (OzArk, 2013) did not identify any indigenous cultural needs that are dependent on water resources in the area. As such no social and cultural users of water resources potentially impacted by the Proposed Action have been identified.

### 9.2.4 Fauna, flora and species that are dependent on the water resource

Of the key MNES addressed within this document (being the regent honeyeater, swift parrot, spotted-tailed quoll, green and golden bell frog and large-eared pied bat); only the spotted-tailed quoll has been identified occurring along Bowmans Creek.

The spotted-tailed quoll is known to use the Bowmans Creek riparian corridor for movement and social interactions. Breeding has also been recorded near to, albeit outside of this riparian corridor. Due to the usage of the riparian corridor by this species, it is highly likely that it would be using Bowmans Creek as a drinking resource. However, it is not considered likely that the spotted-tailed quoll is completely dependent on this creek as a water resource given that:

- it is not an aquatic species;
- it is a highly mobile species and would readily use other available water resources within its home range, such as farm dams and Bayswater Creek; and
- it is not dependent on aquatic prey species in its diet.

As none of the remaining four MNEs were identified and were considered to have a low potential of occurrence, none were considered to be dependent on the Bowmans Creek water resource for breeding, roosting, refuge or foraging purposes (i.e. any stages within their life cycles). Of these species, only the green and golden bell frog would be considered to be an aquatic–dependent species; however this species relies on primarily stationary waters as opposed to flowing creek resources and has not been recorded in this Creek, despite annual ecological survey and/or monitoring occurring since 2001.

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# 10.0 RELEVANT IMPACTS – WATER RESOURCES

A Groundwater Impact Assessment, including a detailed hydrogeological model, was developed for the Proposed Action by SKM (2014). Information regarding the likely significant impacts on important water resources and water related assets, as detailed in SKM (2014), is provided in the sections below, and the full report is attached in **Appendix C**. The information presented is in accordance with the requirements set out in Section 8 of the "Guidelines for Additional Information – Assessment by Preliminary Documentation" (DOTE), with the relevant requirement in ***italics*** and the information presented below.

## 10.1 Model Results

***An assessment of the likely significant impacts on important water resources and water-related assets should include:***

### 10.1.1 The numerical model

***Incorporating water quality and quantity (including salt) balances for both the project site and broader area of potential impact. The water quality and quantity balances should:***

*(i) assess the changes that occur as a result of the proposed development on the quality and quantity of water within any store, or flow of water and salt between these stores;*

Site water balances based on surface and groundwater modelling have been assessed to determine salinity changes and fluxes through shallow (alluvial) and deeper (hard rock) aquifers.

Model simulations provide no indication that the Proposed Action will alter the hydrogeologic regime in a manner that would adversely affect groundwater quality within the Bowmans Creek alluvium, nor the hard rock aquifers. Predicted post mining equilibrium water levels in the final voids are lower than predicted groundwater heads within the Bowmans Creek alluvial aquifer, indicating leakage from the voids to the alluvial aquifer is unlikely to occur and adversely impact groundwater quality. Leakage may occur from the final voids to the hard rock aquifers, although it is noted that groundwater quality in this aquifer is already brackish, and no users of this aquifer have been identified.

*(ii) identify any water necessary for the project that is not available from within the extraction and treatment loops that must be imported from elsewhere. This water may be from surface, underground, or from another activity external to the system boundary; and*

Glencore have established water sharing arrangements between its neighbouring mines in the Hunter Valley. These arrangements allow water to be transferred between operations depending on the operational needs of the operations. LCO participates in this water sharing scheme, having the infrastructure to both export and import water from neighbouring Glencore mines, such as the Mount Owen Complex, as required.

*(iii) undergo a sensitivity analysis and take into account seasonal and long term climate variations, as well as the development of activity over time;*

Through the use of stochastic calibration, a series of realisations for future water movement has been generated. This provides both a statistical sample of potential recharge impacts (seasonal and climatic variability) as well as a sensitivity analysis of all calibration parameters. That is, the statistical spread of the predictive runs represents both a sensitivity analysis on the modelling and an indication of potential impacts from climatic variability. This variability/sensitivity is represented by the error bars on the potential impact estimates shown in **Figure 10.1**, and **Figures 10.9 – 10.11**.

### 10.1.2 A quantitative prediction of subsidence and effects from dewatering and depressurisation (including lateral effects)

***On surface topography, ground water, surface water and movement of water across the landscape, possible fracturing of confining layers throughout the life of the operation;***

The long history of underground mining in the LCO area has impacted upon Bowmans Creek at various times and in different ways, including leakage induced by depressurisation of the seams at depth, and leakage down connective cracking as a result of subsidence related failures. MER (2001) provided the following summary of events related to reports of loss of flow in Bowmans Creek and underground leakage.

- In December 1979, loss of flow was experienced in the Bowmans Creek in an area near Dams 1 and 4 (near monitoring bores ALV1, LBH and ALV3). Subsidence cracks arising from mining at Hazeldene Colliery were observed in the dry creek bed. Reported loss of flow supports the presence of a connective cracking regime both within the creek bed and in areas beneath the alluvial cover, whilst the widespread presence of transmissive basal gravels within the alluvium would have facilitated localised dewatering of the alluvium. While infilling and closure of cracks undoubtedly occurred at surface, it is not known whether the cracking subsequently closed at depth. At around the same time, local farm bores were reported to go dry.

- In September 1987, an inspection of Hazeldene Colliery by the Department of Mineral Resources (DMR) reported water inflow to the Pikes Gully workings at a rate of 1.5ML/day from a narrow chimney in goaf where convergence of two fault slip planes occurred. Failure is believed to have been induced through mining in the underlying Liddell seams. Leakage was noted to rise sharply following heavy rainfall. It was also noted that conditions for mining were excellent – the roof required minimal support, the coal ribs were stable and the floor comprised strong sandstone. Mining at Liddell Colliery (Coal & Allied) in the Liddell seam at this time reported influx rates of about 2.5ML/day with no increases during high rainfall periods. Operations at Hazeldene ceased in late 1987 and groundwater levels were then allowed to rise and fully submerge the workings in both seams.

- In October 1987, DMR undertook mapping of the creek bed and alluvium (Beckett, 1987) from Hebden Road crossing in the north and immediately east of Mountain Block, to an area near the confluence with Yorks Creek in the south. Visual assessment of flows suggested a loss of 50% for the creek section transgressing Hazeldene Colliery. Further south in the Liddell Colliery area, surface cracking was observed in outcrop on hill slopes adjacent to the alluvial lands. Leakage of creek water was also inferred from gravel structures in the creek bed in an area where longwall panels were extracted. The depth of cover in these areas is greater than 160 metres, however, and observations may have reflected shallow non-connected cracking. Continuing concern for leakage to workings prompted the installation of 14 groundwater monitoring piezometers in May 1988 in the alluvial lands overlying Liddell Colliery longwall panels.

- In June 1990, the Department of Land and Water Conservation (DLWC) completed monitoring of the 14 piezometers installed in the area above longwall panels of the Liddell Colliery and concluded that creek flows had re-established and that no long term loss of flow would result from mining. MER's (2001) review of monitoring data supports this, as significant changes in creek flow or storage within the alluvial lands do not have an observable influence on water levels within the old workings. This does not, however, preclude the possibility that connective cracking is present and is acting as a relatively constant leakage source governed by crack impedance.

To better evaluate the observations and interpretations of these reports, climatic data for the period must also be considered. Data from streamflow gauge 210042 (refer **Figure 10.1**) is useful in this regard as it was operational during the 1980s. Cumulative rainfall data exhibits a series of drying trends through the decade (downward trajectories on **Figure 10.1**). Years 1986 and 1987 were particularly dry, with stream

flow only recorded following moderate events. Increasing rainfall trends in 1984, 1988 and 1989, on the other hand, generated good flows and by 1989, groundwater levels had risen sufficiently that baseflow was a significant proportion of total annual flow for the creek.

Based on this data, conclusions regarding causes for the drying of the creek and local bores cannot be definitively established. Thus, drying may be due to connective cracking and leakage or due to the drier than average climate conditions, or a combination of both.

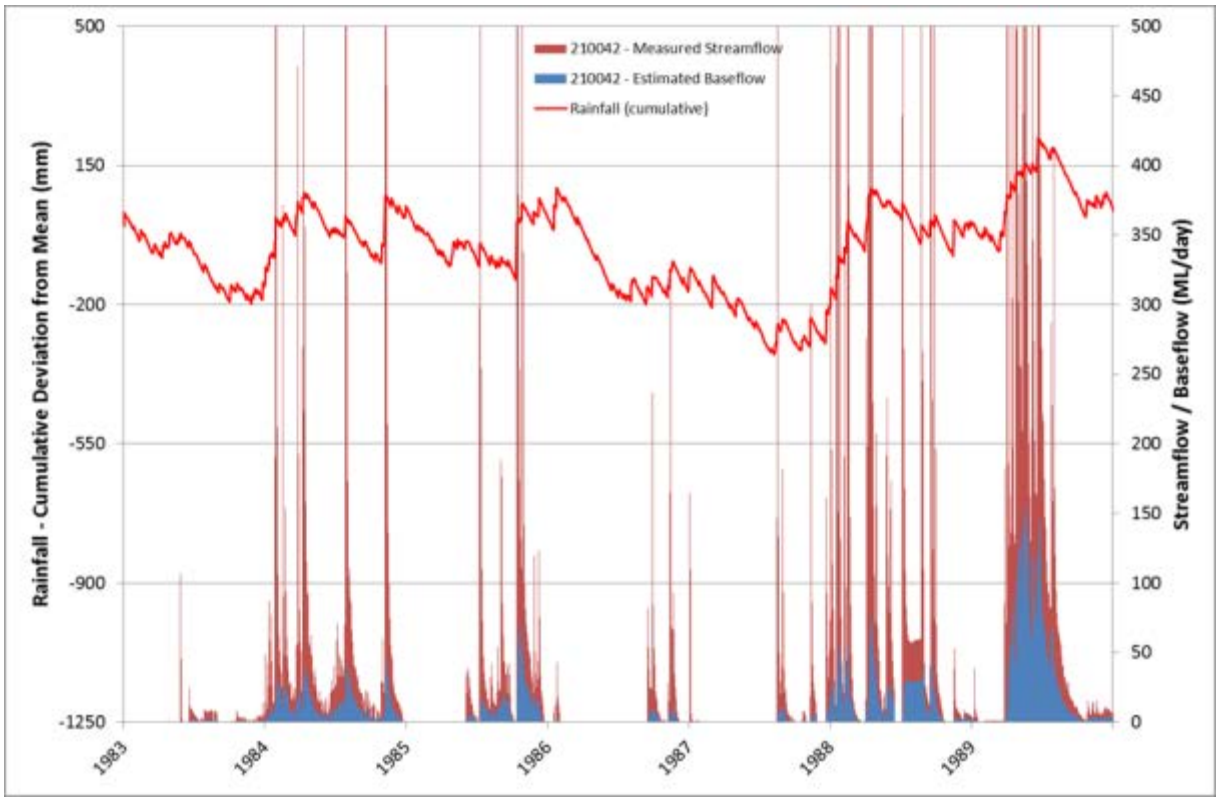



**Figure 10.1 – Streamflow and estimated (modelled) baseflow data at Gauge 210042**

Refer also to **Section 10.1.6** and **10.2**.

### 10.1.3 A quantitative prediction of the extent of the cone of depression and consequential impacts of the cone of depression and void

***on surface topography, ground water, surface water and movement of water across the landscape throughout the life of the mine, post mining, and final site (including void) management. The changed hydrogeology post-mining should be accounted for even if the void is backfilled***

Refer to **Section 10.1.6**, **10.1.8** and **10.2**.

### 10.1.4 Predictions for stressors and toxicants

***Including chemical composition, mass and volumes, utilised and or released to a water resource over the life of the project;***

Historical monitoring data suggest minimal impacts from any stressors or toxicants. The primary stressor is increased salinity and toxicants include dissolved metals, acidity and boron released from the coal measures. Model simulations provide no indication that the Proposed Action will alter the

hydrogeologic regime in a manner that would adversely affect groundwater quality within the Bowmans Creek alluvium. Predicted post mining equilibrium water levels in the final voids are lower than predicted groundwater heads within the Bowmans Creek alluvial aquifer, indicating leakage from the voids to the alluvial aquifer is unlikely to occur and adversely impact groundwater quality.

### 10.1.5 Predicted volumes and quality of water proposed to be used during mining

***Including within the mine itself (for example, coal washing, dust suppression) and for other associated activities (for example, cooling or other industrial processes);***

The predicted volumes of water to be used during the life of the mine are discussed above in **Section 9.1.5.1** Model Inputs and Assumptions.

### 10.1.6 Details of impacts to hydrogeological units

*(i)* ***that will be directly impacted by mining operations, including the hydrogeological units that will be exposed/partially removed or dewatered;***

Mining operations can directly impact groundwater resources through physical disruption of an aquifer, which often occurs during removal of an ore body. Current and historical mining operations at LCO and in the local area have resulted in disruption of the regional hard rock aquifer found within the coal measures. The removal of coal reserves from historical underground mines (such as the Hazeldene and Liddell underground) left subsurface voids, while open cut pits and backfill sequencing can transform confined aquifers into unconfined systems with different hydraulic properties.

A three-stage process was undertaken to incorporate the potential impacts from underground mining on surface waters. The approach entailed:

1. Identification of anecdotal and observed cracking associated with underground workings were identified by Glencore in site records at the time of mining by abnormal increases in inflows to the underground workings and these areas have been incorporated into the groundwater model as columns of increased transmissivity to the surface. These areas were assigned higher hydraulic conductivity values than the surrounding rock; using similar conductivity values as the regolith. This method of replicating the historic cracking was considered conservative because it does not account for resealing of the fractures and does not account for the constrained zone, which typically restricts vertical migration of water from the surface to underground workings.

2. Comparison of modelled to observed impacts on stream flow revealed that during the calibration period (1990-present), this did not provide a good fit to the data. Rather, reduced connectivity was required to explain the observed hydrographs in the alluvium, consistent with sealing of any cracks beneath the alluvium and minimal connectivity between alluvium and hard rocks. The use of site-specific increases to hydraulic conductivity, however, has allowed site-specific calibration of alluvial fluctuations resulting from underground (Hazeldene and M49) dewatering, which was observed via variable fluctuations in the ALV hydrographs and compared to simulated water levels. The ALV series of bores represent a transect of nested sites, with a shallow standpipe sampling the lower alluvium sediments and a deeper bore penetrating the upper hard rock aquifer, following the course of Bowmans Creek from north to south adjacent to the Liddell operations (refer **Figure 9.7**). The calibration to these bores has always been recognised as being good (and endorsed by the peer reviewer) and reflective of the interactions between the surficial and shallow hard rock aquifers. Hence, the interconnectivity between the alluvium and shallow hard rock is an intrinsic component of the groundwater model and does not need specific connectivity inclusion. That is, connectivity is a calibrated response to the hydrographs.

Specifically, interconnectivity between undisturbed aquifers is simulated within MODFLOW-SURFACT by the parameterisation of vertical conductivity. An equivalent vertical conductance is then calculated between the aquifers. Vertical conductivity between aquifers was assigned within the calibration,

sensitivity and uncertainty analyses by assigning constrained ranges in anisotropy. The ranges in anisotropy are based upon site specific measurements as well as published references for hydraulic conductivity values (horizontal and vertical) within the Hunter Coal Seams and Interburdens.

3. Studies undertaken by Aurecon (2012) at the local Integra Underground mine provided comparable data to estimate the actual effect of underground workings on cracking and hence generate an algorithm (based on work by Guo, et al., 2007) describing the change in hydraulic conductivity with height above the underground workings. Using this algorithm, a set of scaling factors was derived that were applied to cells above each underground working following the timed sequence of mining and goaf emplacement. Thus, cracking was scaled to the intrinsic hydraulic parameters at each underground location, rather than applying generic values across the region. This process was applied to all underground workings represented in the model. This methodology was endorsed by the peer reviewer.

The incorporation of underground mining impacts into the groundwater model still gave results that indicated additional impacts to the hard rock aquifer caused by the Proposed Action are predicted to be minimal. Specifically, the proposed expansions to the open cut pits will not extend into the Bowmans Creek alluvium and will not physically disrupt this aquifer system.

*(ii)* ***that will be indirectly impacted due to dewatering in connected hydrogeological units;***

The critically connected units in the region include the alluvium sediments and the underlying hard rock aquifers.

Results from the predictive simulations were analysed to evaluate estimated changes in groundwater flux and corresponding drawdown effects on the Bowmans Creek alluvial aquifer as a result of mining activities at LCO. By subtracting the estimated groundwater flux to the model layer representing the Bowmans Creek alluvium under the No Liddell scenario from the Approved scenario, the cumulative impact of current mining activities at LCO can be isolated. Similarly, the difference between the No Liddell and Proposed case scenarios allows the cumulative contribution of mining activities under the Proposed Action to be quantified.

**Figure 10.2** shows the estimated groundwater flux to the Bowmans Creek alluvium under currently approved mining operations (Approved case) and for the Proposed Action (Proposed case) as well as the case if LCO where not to exist (no Liddell). The lines shown represent the median (50th percentile) of results from the calibrated datasets. Negative values represent flux out of the alluvium to the hard rock beneath.

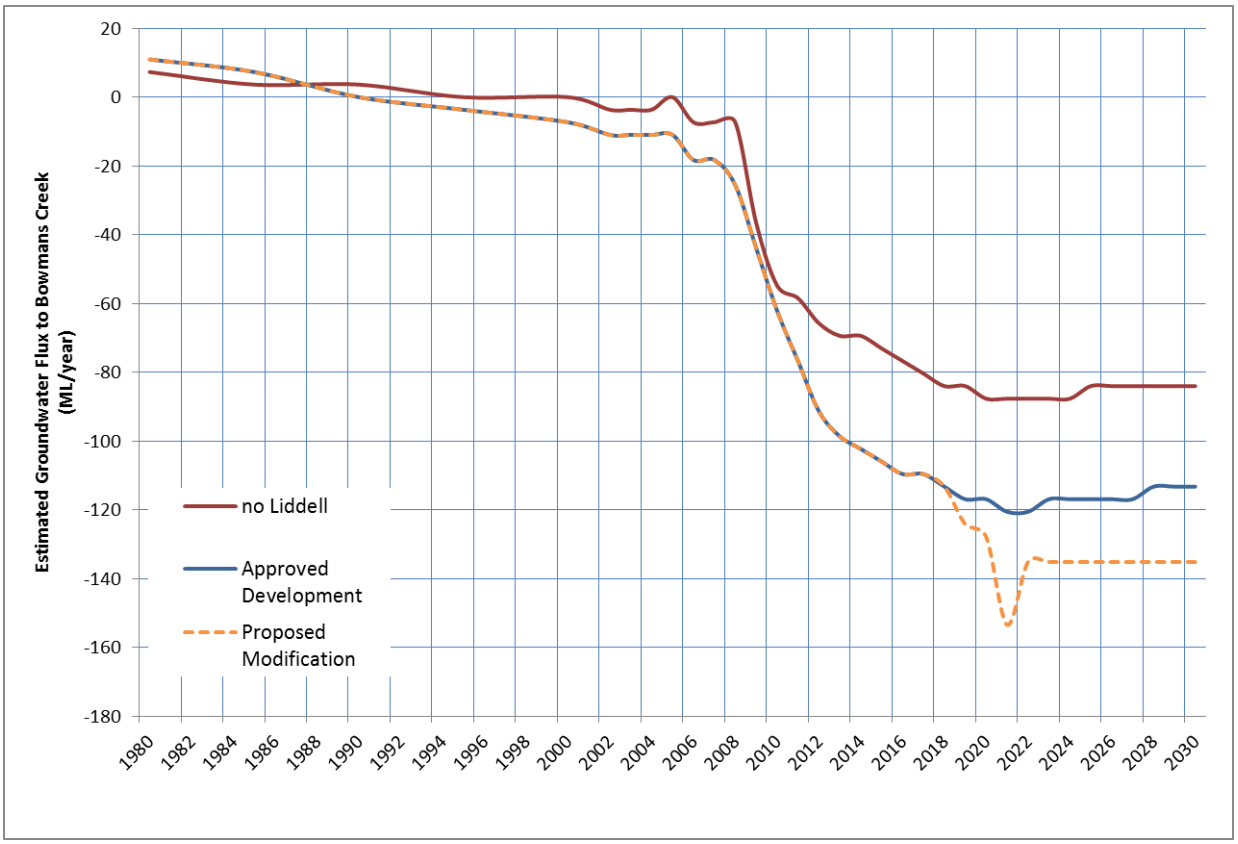



**Figure 10.2 – Estimated Groundwater Flux to Bowmans Creek Alluvium**

The estimates are provided for the duration of the modelling runs from 1982 to 2030 (1980 represents the steady-state, pre-recent development levels). The start of the recovery post mining (2022) can be seen, as well as the significant impact from other operations in the region on Bowmans Creek since 2008.

Analysis of **Figure 10.2** provides an understanding of the influence of current and proposed mining activities on estimated groundwater fluxes to the Bowmans Creek alluvium. In particular, **Figure 10.2** shows:

- Prior to 2019 the estimated leakage from the Bowmans Creek alluvium under the Proposed case scenario is virtually identical to the predicted groundwater fluxes under the Approved case scenario. These model results indicate that up to 2019 the estimated leakage under the proposed modification will be only slightly greater than that occurring under the currently approved mine plans.

- After 2019 the Approved case curve flattens, reflecting the beginning of system recovery following the end of mining under the currently approved mining plans. This recovery corresponds with the cessation of dewatering of former underground workings from the 8 South 2, Middle Liddell, and M49 pumping bores.

- The similarity in leakage estimates for the Approved and Proposed case scenarios prior to 2019 confirms that dewatering of underground workings is primarily responsible for the groundwater losses from the Bowmans Creek alluvium. The progression of the South Pit between 2013 and 2019 in the Proposed case scenario appears to have negligible effect on the predicted leakage rates.

- After 2019 the extension of the Entrance Pit begins to have minor additional impacts on leakage rates from the alluvium through to 2021. Between 2021 and 2022 the predicted losses increase by approximately 30 ML/year. This peak leakage rate corresponds to progression of the Entrance Pit to the south-eastern side of the dyke and Davis Creek Fault and into the M49 underground workings.

Notwithstanding, the model can assess the impact of all mining in the region excluding the impacts of Liddell. That is, if Liddell did not exist. Subtracting this "No Liddell" scenario from the other scenarios (**Figure 10.3**) shows that from the end of 2009 (to correlate with the introduction of the Hunter Unregulated and Alluvial WSP) the approved development may result in about 20-25 ML/year additional leakage from the Bowmans Creek Alluvium into the underlying rocks by about 2015, stabilising after that date.

The Proposed Action may result in a short (1-2 year) period of increased additional leakage (an additional 35 ML/year), reducing to a total leakage potentially attributable to LCO of approximately 50 ML/year in 2023.

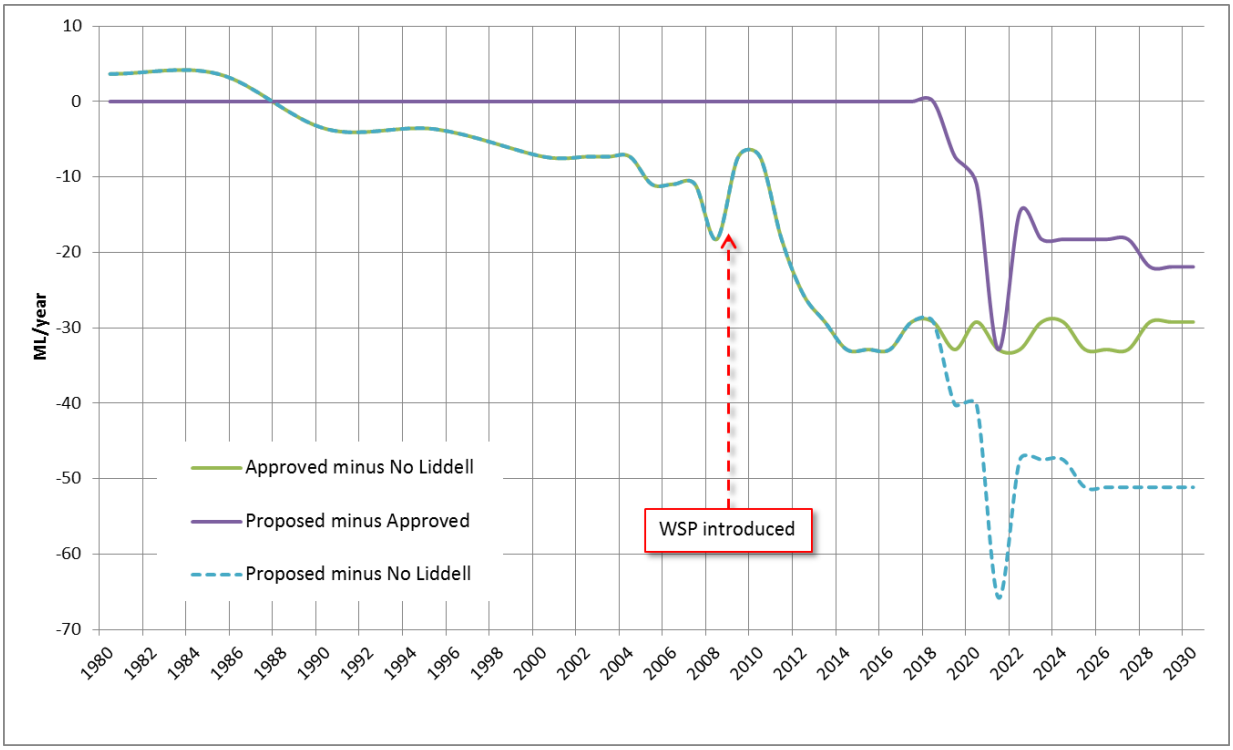



**Figure 10.3 – Estimated Incremental Flux to Bowmans Creek Accountable to the Project**

**Figure 10.4** illustrates the estimated additional drawdown within the Bowmans Creek alluvial model layer under the Proposed case scenario relative to the Approved case (i.e. results of the Proposed case minus the Approved case) for the years 2019 and 2022. Drawdown estimates have been presented in this format to provide an indication of the estimated additional (or incremental) impact of the Proposed Action relative to currently approved mine plans. It should be noted, however, that the incremental drawdown attributable to the Proposed Action also takes into account the predicted recovery of groundwater flows to the alluvium (i.e. reduction in leakage) for the Approved case scenario beginning in 2019.

Drawdown in the alluvium is limited to two small areas along Bowmans Creek over the old Upper Liddell underground workings and do not exceed 2 metres for the worse impacted year (2022). Note that no impact is expected to the alluvium of Bayswater Creek, as can be seen in **Figure 10.4**.

Recent groundwater monitoring data for LCO (see **Section 9.1.4**) indicates groundwater levels in the alluvium have largely been stable, including over the 2010 to 2013 period over which the model is estimating leakage rates up to 120 ML/year. As the model predicts similar leakage rates under both the Approved and Proposed case scenarios in 2019, the resulting incremental drawdown is negligible. Furthermore, with the exception of 2022, the groundwater losses predicted are similar in magnitude to the rates estimated by the model for current (2013) mining operations at LCO.

Considering the monitoring data available, current and peak estimated leakage rates, the conservative assumptions adopted in constructing and calibrating the model, and the predicted recovery in groundwater flows for the Approved case scenario, the incremental drawdown shown for 2022 likely represents a conservative prediction. Additional monitoring data and corresponding revision and validation of the groundwater model under the Proposed Action will refine and provide additional confidence in these estimates.

Interrogation of the model provides insight into the mechanisms and causes of the groundwater losses and corresponding drawdown predicted within the Bowmans Creek alluvial aquifer. As described above, the progression of the South Pit under the Proposed Action appears to have negligible additional impact on groundwater flows and drawdown from the alluvium, while the Entrance Pit progression has minimal impacts up to 2021. The similarity in results for the Approved case and Proposed case scenarios up to 2019, plus the immediate recovery observed in the Approved case scenario after 2019 when dewatering ends, indicates that the predicted losses are primarily due to dewatering of the underground workings (from the 8 South 2, Middle Liddell, and M49 bores). The actual progression of the South Pit, and to a lesser extent the Entrance Pit, under the Proposed case scenario has little effect on the predicted alluvial leakage rates.

After 2021, however, the estimated leakage under the Proposed Action increases significantly to a peak of 65 ML/year. **Figure 10.5** shows that this year corresponds to progression of the Entrance Pit to the south eastern side of the dyke and Davis Creek Fault and into the former Liddell underground workings that are dewatered by the M49 bore. Historical data and reports indicate leakage into the Liddell seam has previously been recorded in this area, attributed to fractures and cracking within the intervening strata between the alluvium and underground workings (MER, 2001; Umwelt, 2006). These reported fracture zones were represented in the model in the form of increased vertical conductivity for model cells within the suspected areas, including the interburden layers which otherwise represent confining model layers. As the extension of the Entrance Pit reaches this area, the depressurisation (de-watering) of the underground Liddell workings, required to accommodate the pit progression, leads to increased vertical leakage and corresponding drawdown within the overlying alluvial aquifer.

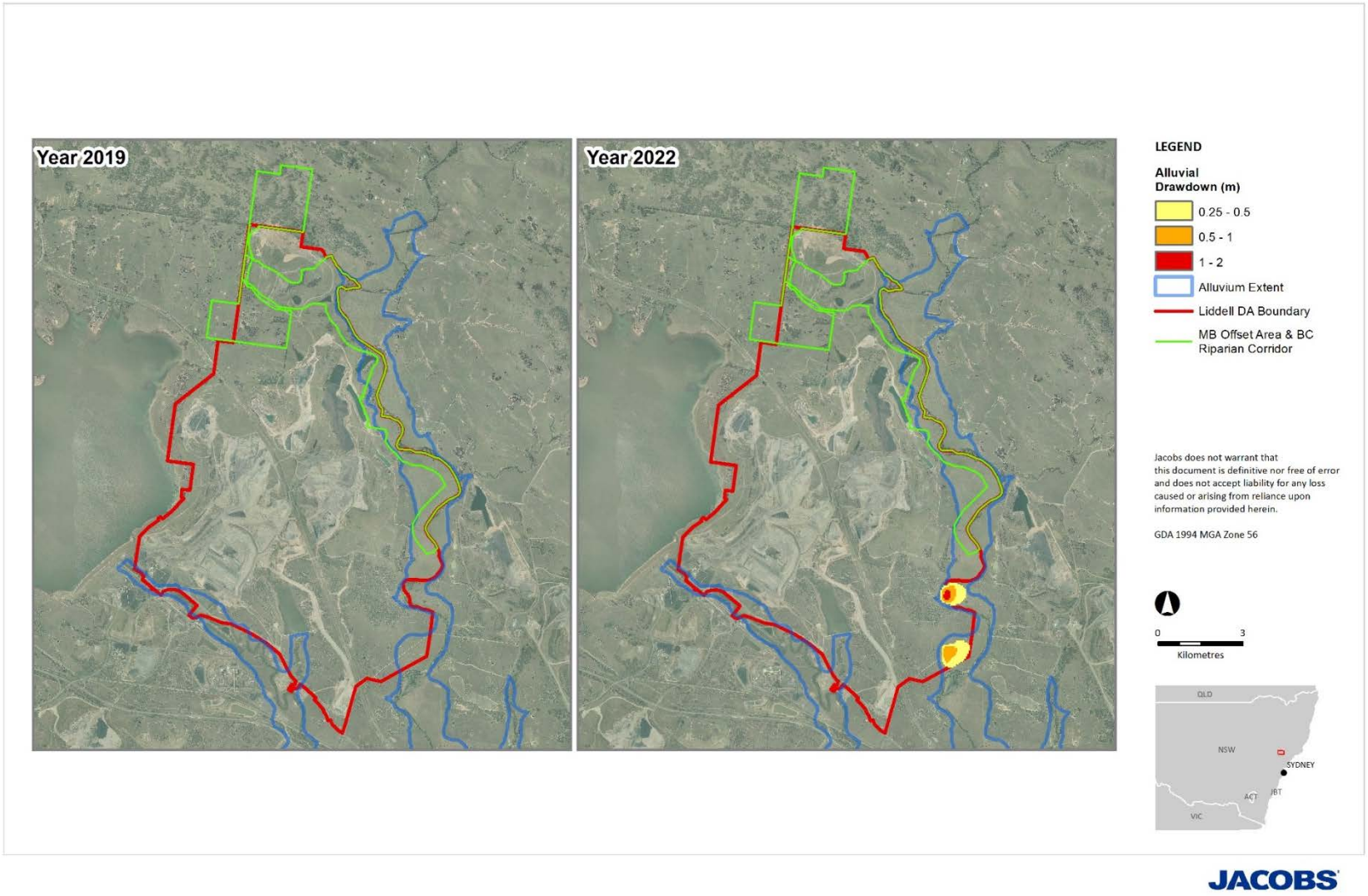



**Figure 10.4 – Median Predicted Drawdown for Bowmans and Bayswater Creek Alluvium Resulting from Proposed Action**

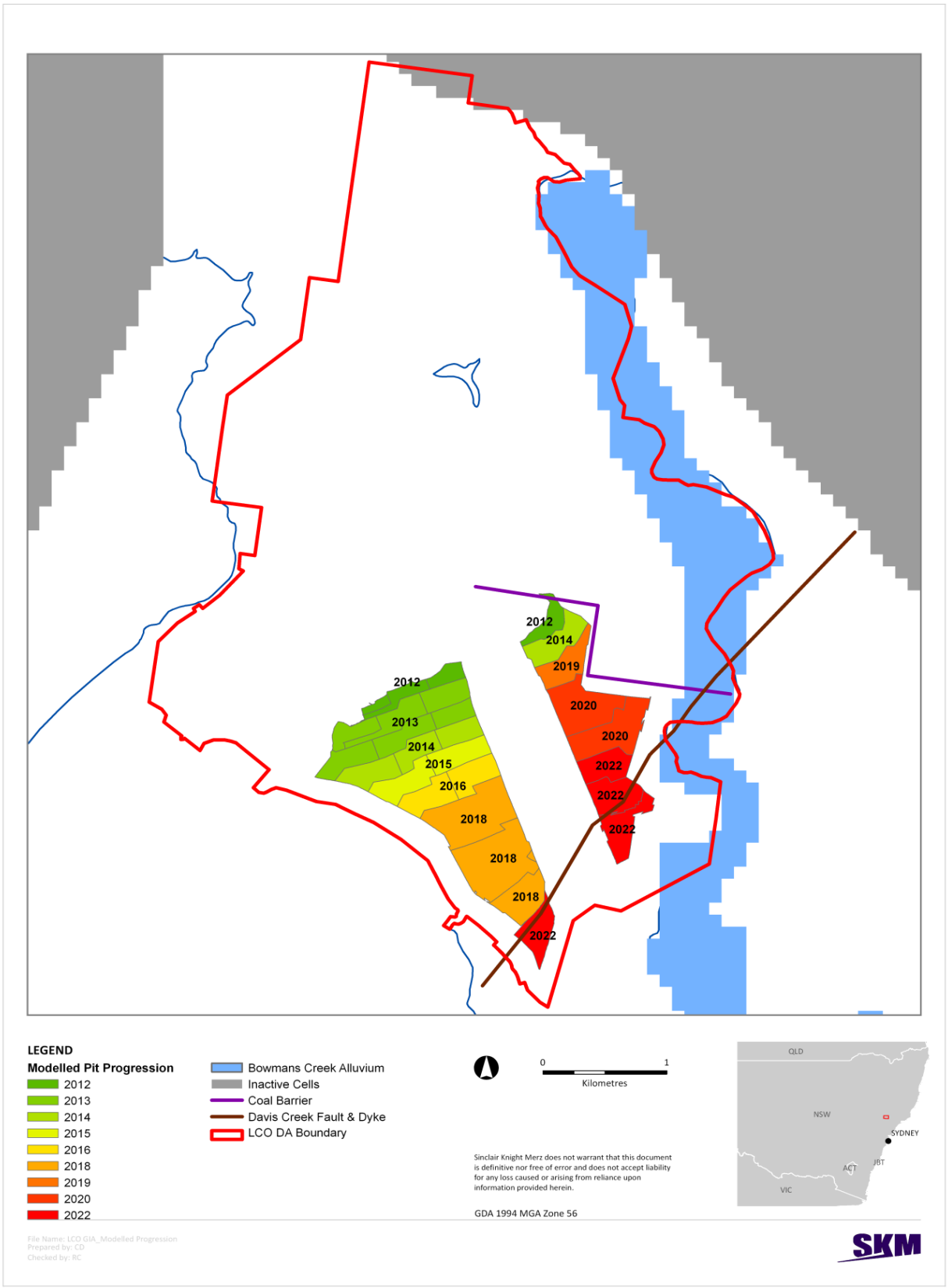



**Figure 10.5 - Modelled Open Pit Progression for Proposed Case Scenario**

Previous environmental assessments have suggested that any cracking created above the former Liddell underground workings has since sealed however these assessments have not been able to be confirmed. Umwelt (2006) previously reported that “several investigations and a review of monitoring data led the [DNR] to conclude that creek flows have re-established and long term loss of flow has resulted from previous mining.” There is a possibility, however, that the surface water and groundwater systems may have achieved a new equilibrium that still includes a constant leakage via higher permeability (i.e. cracking, fracture) areas (MER, 2001).

Given these considerations, SKM adopted a pre-cautionary approach for the representation of these cracking and fracture areas within the regional groundwater model (see **Section 10.1.6 (i)** above). In order to provide a conservative assessment (i.e. worst-case scenario), suspected fracture zones were implemented in the model using increased vertical conductivity values under the assumption that cracking is still present and leakage is still occurring and this would provide a conservative evaluation of potential impacts to the overlying alluvial aquifer. Collection of additional monitoring and lithology data in these areas is on-going and will provide a continuously improved understanding of the presence and extent of any connective cracking.

Predicted additional groundwater drawdown for the Upper Pikes Gully, Liddell A and B, and Barrett coal seams are shown in **Figure 10.6**. Significant drawdown (up to 80 m) is shown for the coal seams due to the dewatering required to undertake mining activities.

Drawdown is centred around the intersection of the workings with the Davis Creek fault and extends to a radius of 3 km at its maximum extent (2022). Upon cessation of mining activities in the Entrance Pit in 2022, de-watering is ceased and groundwater levels begin to return to pre-mining levels.

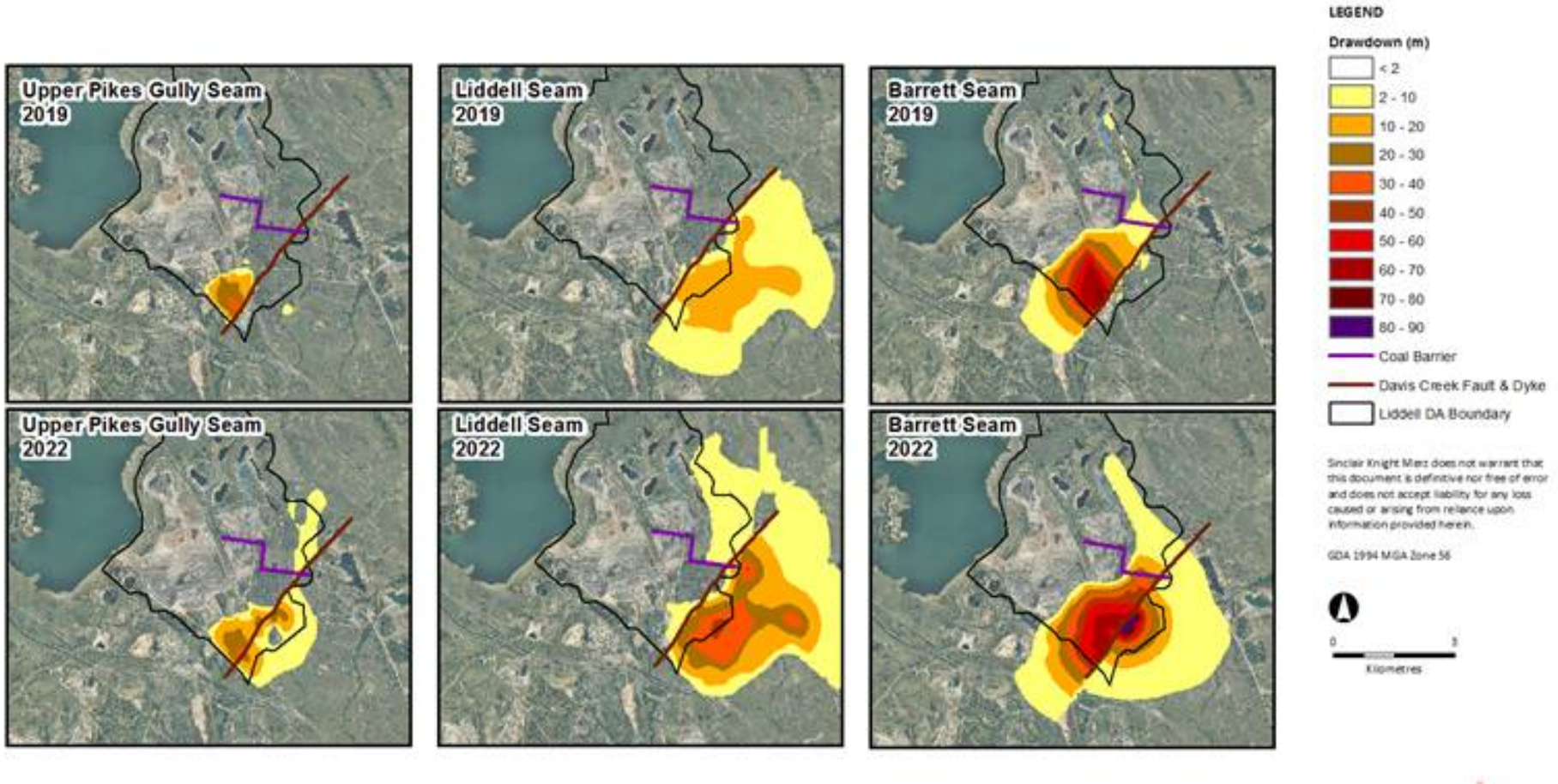



**Figure 10.6 - Predicted Drawdown for Coal Seams Resulting from the Proposed Action**

### 10.1.7 The impacts on hydraulic properties of hydrogeological unit geology

***Including the potential for physical transmission of water within and between formations, effects of depressurisation due to gas and water extraction and estimates of the likelihood of leakage of contaminants from coal beds through geological formations;***

Impacts on the hydrogeological unit geology is summarised in **Table 10.2** – Groundwater Impact Assessment.

### 10.1.8 The impacts associated with surface water extraction, releases and/or diversions

***Including alterations to flow regimes, flood heights, and/or erosion/sedimentation and impacts to habitat;***

No diversions will be constructed as part of the Proposed Action. With regard to surface water extraction, no water will be directly extracted from surface water resources in the region i.e. Bayswater and Bowmans Creeks; however some indirect extraction will occur through the capture of surface runoff within disturbed catchments at LCO. The potential impacts on local and regional water resources of the Proposed Action can be summarised as follows:

- Changes to flows in local creeks due to the extension of mining areas and subsequent capture and use of runoff from mine area catchments;
- Potential for export of contaminants (principally sediments and soluble salts) in runoff from disturbed areas and accidental spills from containment storages (principally sediments, soluble salts, oils and greases), causing degradation of local and regional water courses; and
- Short term increases in salinity during periods of licensed discharge under the HRSTS.

These potential impacts are discussed below.

**Flow Regime in Local Creeks**

The predicted change in catchment area reporting to Bowmans and Bayswater Creeks as a result of the Entrance and South Pit extensions is presented in **Table 10.1** (Gilbert & Associates, 2014).

**Table 10.1 – Changes in Contributing Catchment of Local Creeks**

| | Bowmans Creek | | Bayswater Creek | |
|---|---|---|---|---|
| Catchment Excision (km2) | Maximum Extents | Final Landform | Maximum Extents | Final Landform |
| Increased Catchment Excision (km2)* | 0.95 | 0.98 | 0.78 | 1.0 |
| Proportion Creek Catchment (%)^ | 0.53 | 0.55 | 1.06 | 1.36 |

** Increased catchment excision relative to the approved mining operation*

*^ Creek catchment adjacent to LCO*

As shown in **Table 10.1**, at maximum disturbance the Proposed Action would result in less than a 1 $km^2$ decrease in the catchment area reporting to Bowmans Creek, relative to the approved operation, representing a reduction of only 0.5% of the total catchment. Similarly, an additional 0.78 $km^2$ would be excised from the Bayswater Creek catchment as a result of the Proposed Action at maximum disturbance, and at the end of mining the catchment excision would increase by 1.0 $km^2$ relative to the approved operations at LCO. This represents a reduction in catchment area reporting to Bayswater Creek of 1.06% and 1.36% respectively.

As discussed above in **Section 10.1.6**, the Proposed Action will result in a small loss of baseflow from Bowmans Creek. The peak predicted leakage rate corresponds to the progression of the Entrance Pit to the south-eastern side of the dyke and the Davis Creek fault into the M49 workings, with the predicted groundwater losses increasing by 30 ML/yr. This peak incremental increase is equivalent to between 3 and 5% of estimated baseflow (based on streamflow analysis), or an annual loss to stream flow of less than 1%. As the creeks around LCO are ephemeral in nature, this will not impact the creek flow functionality.

The combined effect of the increased catchment area reduction and predicted maximum reduction in baseflow in Bowmans Creek is therefore predicted to be negligible.

The above estimated changes to average flow rates are unlikely to be discernible from natural variations in the downstream creek flows over extended periods of time. Predicted impacts on downstream water users are therefore considered insignificant and would diminish with distance downstream (Gilbert & Associates, 2013).

**Release of Contaminants in Drainage Off-Site**

No off-site discharges occurred in the water balance model during the 120 climatic realisations simulated. Subject to adherence to established site water management procedures, and other assumptions inherent in the modelling such as the design of all sediment dams in accordance with the guidelines in Landcom (2004) and DECC (2008b), there is a very low risk of spills occurring from the mine water storages over the life of the Proposed Action to either Bowmans or Bayswater Creeks (Gilbert & Associates, 2013).

**Salinity in the Hunter River Due to Controlled Releases**

Off-site discharges of salt to the Hunter River will be controlled by segregation and preferential re-use of the more saline water on site, such as decant water from the tailings storages and re-use of this water in the CHPP. If the proposed water management system is appropriately maintained and management in accordance with current site protocols and as described in the Surface Water Assessment for the Project, there is no foreseeable risk of significant additional contaminants being discharged from site (Gilbert & Associates, 2013).

Under the existing water management rules, any surplus water is stored in the RWTV and may be discharged into Chain of Ponds Creek at a current maximum rate of 100 ML/day in accordance with the Hunter River Salinity Trading Scheme (HRSTS). Discharges can only occur under the rules of the HRSTS in certain flow conditions, ensuring salt loads are managed. Surplus water can also be pumped back into underground workings when discharge opportunities under the HRSTS are unavailable.

**Impacts Relating to the Final Voids and Potential to Spill**

Two voids will be left at the end of mining at LCO, one on the South Pit side, and one on the Entrance Pit side. The results of the site water balance model indicate that neither void is predicted to spill.

Whilst the salt concentration in the Entrance Pit is predicted to stabilise, salinity in the South Pit void is predicted to rise over time, with groundwater outflow from the void to the regional hard rock aquifer (SKM, 2014). The hard rock aquifers in this area contain brackish groundwaters and the additional influx of water from the void will generally be of higher quality than the groundwater in the aquifer. Predicted post mining equilibrium water levels in the final voids are lower than predicted groundwater heads within the Bowmans Creek alluvial aquifer, indicating leakage from the voids to the alluvial aquifer is unlikely to occur and adversely impact groundwater quality in the alluvium.

### 10.1.9 The identification of any landscape modifications that will impact on surface water flow

***This should include consideration of erosion and the fragmentation of habitat of water-dependent species and communities;***

The approach to managing runoff from catchment areas which are undisturbed by surface mining activities is to divert them around surface mining and other disturbance areas and to isolate mine area runoff from undisturbed areas. The objective of this strategy is to reduce the volumes of water that would need to be managed on-site. Over the life of the mine, this would involve the construction of diversion bunds and drains around the open cut mine and overburden emplacement areas. Toe drains and isolation bunds would also be constructed around the perimeter of additional out-of-pit overburden emplacements and other areas disturbed by mining to collect and convey drainage from these areas to containment storages, thereby isolating mine drainage from undisturbed area runoff. Diversions and drains would continue to be constructed with capacities consistent with the Site Water Management Plan.

Due to the progression of the South Pit and Entrance Pit, the main water storage onsite would change throughout the mine life. Until 2014, the main water storage would be the Raw Water Transfer Void (RWTV); however this lies in the planned future extent of the South Pit. From Year 1 (approximately 2014) to Year 7 (approximately 2020), the main water storage would become the Bayswater Void which would be located south of (and within the planned future extent of) the Entrance Pit. From Year 7 onwards, the completed South Pit would become the main water storage. The main water storage would store water removed from the open cut and former underground workings to enable safe and efficient ongoing mining operations.

**Figure 10.7** shows the planned mine layout for the final landform. The South Pit and Entrance Pit final landforms will be connected underground via the remnant Middle Underground workings. Drainage from the rehabilitated overburden emplacement areas will be directed off site via a system of swales, berm drains and drop structures. The northern portion of the South Pit overburden emplacement area will eventually drain into Lake Liddell while the remaining area will ultimately drain to Bayswater Creek. The west side of the Entrance Pit overburden emplacement area will be directed to a drain adjacent to the Main Northern Railway line and will drain to the south to Bayswater Creek, while the remainder will ultimately drain directly or via small tributaries to Bowmans Creek.

Across the site, flooding control is designed to return overland flow to the pits and hence represents an operational risk. The site water management system has been designed however to enable water to be pumped to the various water storages around the site where required, as well as between other nearby Glencore operations. As flooding-induced flows are all directed internally, there would be no environmental risks associated with these potential events.

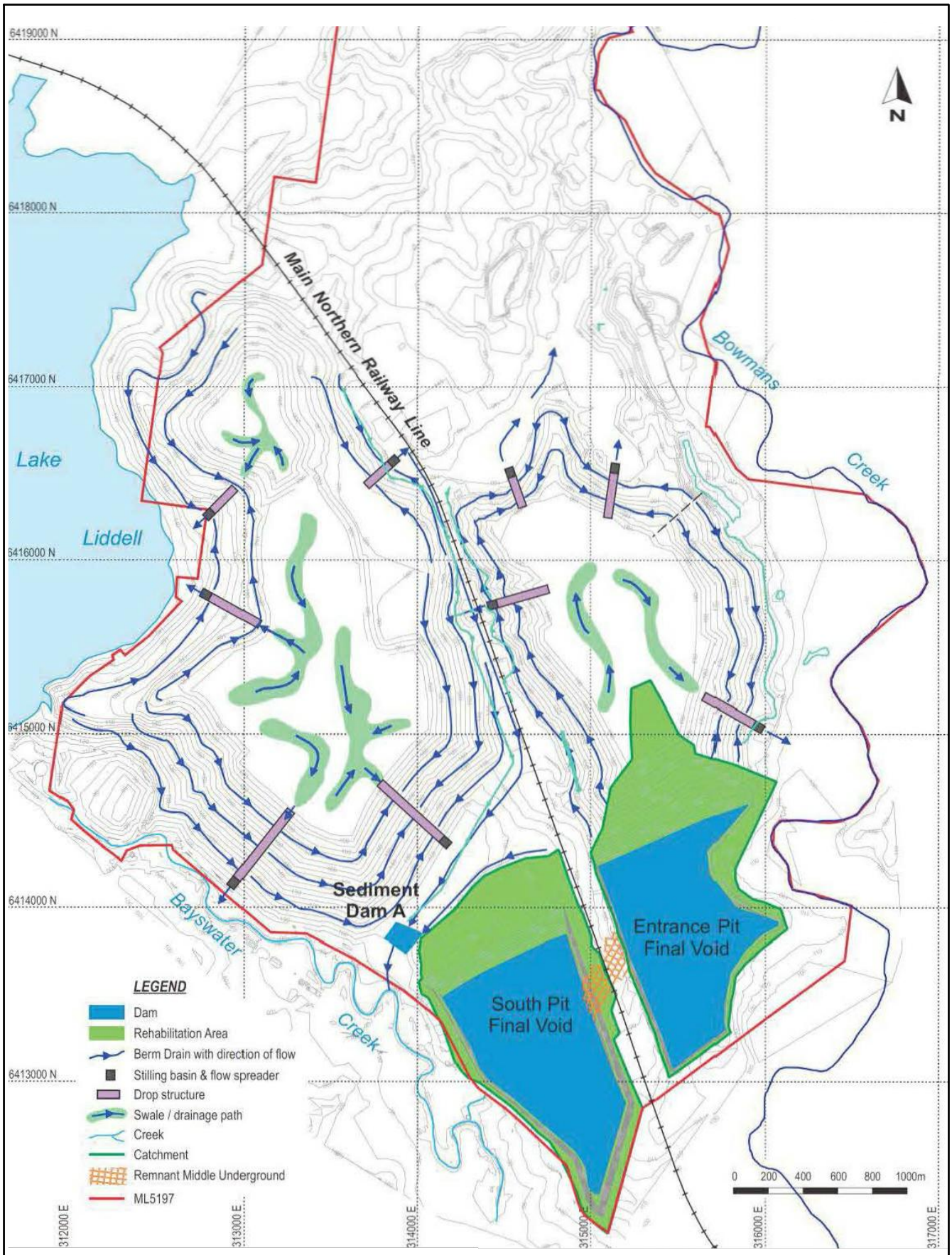
### 10.1.10 An estimate of the quality and quantity of operational discharges of water

***Including potential emergency discharges due to unusual events, discharge of waste water and brine treatment processes and disposal methods, and the likely impacts on water-related assets;***

LCO participates in the HRSTS, allowing it to discharge from a licensed discharge point. These discharges take place during high flow periods in compliance with strict HRSTS regulations. LCO currently holds 66 credits under the scheme. There are no planned changes to the current discharge point and no additional discharge point designated as part of the Proposed Action.

With regard to uncontrolled discharges, the only potential discharges predicted by the site water balance modelling for the Proposed Action are from Sediment Dam A for storm events above design criteria, and only occur when it is receiving water from fully rehabilitated areas. No uncontrolled discharges offsite from any other storage is predicted. All controlled releases that occur throughout the modelled period

are made in accordance with the requirements of the HRSTS, with less than 800 ML released annually on average across all realisations.




*Source: Gilbert & Associates, 2013*

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*To be printed A4*

Conceptual Final Landform Drainage

**FIGURE 10.7**

### 10.1.11 An assessment of the direct and indirect quality and quantity impacts on the water-related assets previously identified

***This includes, but is not limited to, impacts on ground water and surface water aquatic ecosystems, terrestrial ecosystems, drinking water supply and human health, irrigation water supply, surface infrastructure, industry, and regional communities; with reference to the Australian Guidelines for Water Quality Monitoring and Reporting (www.environment.gov.au/water/publications/quality/nwqms-monitoringreporting.html).***

Groundwater Impact Assessment

The potential impacts of mining and related activities on these receptors can be assessed from the results of numerical groundwater models such as that presented in the previous section. Results from predictive model scenarios, combined with other contextual information on LCO, have been used to evaluate the potential impacts to groundwater resulting from the proposed open cut extensions at LCO. Results are summarised in **Table 10.2** and discussed in more detail below in **Section 10.2**.

**Table 10.2 – Groundwater Impact Assessment**

| Potential Receptor | Direct Impact | Discussion |
|---|---|---|
| Bowmans Creek alluvium (including groundwater dependent ecosystems) | Groundwater quantity | • Estimated leakage rates as a result of the Proposed Action are predicted to peak at approximately 65 ML/year at the end of mining. LCO currently holds groundwater licence allocations of 142 ML/year for this water source.<br>• Model simulations predict a peak drawdown within the alluvial aquifer of generally less than two metres as a result of the Proposed Action. This estimated peak drawdown is highly localised and is expected to be limited to one year at the end of mining. This impact falls below the minimal impact criteria (less than two metre drawdown) for aquifer interference activities as specified in the Aquifer Interference Policy (NSW, 2012).<br>• Post mining equilibrium simulations indicate that alluvial groundwater levels will rapidly return to current (2013) levels following the end of mining. |
| | Groundwater quality | • Historical monitoring data suggests minimal impacts on groundwater quality in the Bowmans Creek alluvial aquifer due to current and historical mining operations at LCO.<br>• Model simulations provide no indication that the Proposed Action will alter the hydrogeologic regime in a manner that would adversely affect groundwater quality within the Bowmans Creek alluvium. Predicted post mining equilibrium water levels in the final voids are lower than predicted groundwater heads within the Bowmans Creek alluvial aquifer, indicating leakage from the voids to the alluvial aquifer is unlikely to occur and adversely impact groundwater quality. |
| | Surface Water – Groundwater Interaction | • Estimates of baseflow contributions to Bowmans Creek streamflow suggest the predicted peak annual leakage rate (65 ML/year) caused by the Proposed Action is equivalent to between 1 and 3% of estimated baseflow (based on streamflow analysis), or an annual loss to stream flow of less than 1%. As the creeks around LCO are ephemeral in nature, this will not impact the creek flow functionality.<br>• The estimated peak loss of groundwater flow as a result of the Proposed Action falls well below the range of baseflow contributions estimated from the historical record (365 to 36,500 ML/year).<br>• Recent groundwater monitoring data and predictive model results indicate leakage from the alluvial aquifer induced by current mining activities at LCO are having negligible impact on groundwater levels within the alluvium.<br>• Taking these data into account, the estimated losses in groundwater flow under the Proposed Action is unlikely to have a significant impact on streamflow in Bowmans Creek or on water levels within the associated alluvial aquifer. |
| | Aquifer Impact | • The proposed open cut extensions do not intercept the Bowmans Creek alluvial system. |

With regard to groundwater dependent ecosystems, ELA (2013) identified stygofauna as a GDE in the Bowmans Creek alluvial aquifer. The predicted impact to Bowmans Creek Alluvium will not exceed 2 m in two localised areas (refer **Figure 10.4**) where the depth of alluvium is in excess of 10 m and where water levels are more than 5 m above the base of the formation. Hence, the potential impact would not dry the system and is comparable to seasonal variability. The potential impact would also be short-lived (during the last year of operations) and recovery is expected to be immediate in these highly transmissive systems, and as such no significant impacts on GDEs are expected as a result of the Proposed Action.

In addition, as noted in **Table 10.2** above, estimates of baseflow contributions to Bowmans Creek streamflow suggest the predicted peak annual leakage rate of 65 ML/year caused by the Proposed Action is equivalent to only between 1 and 3% of estimated baseflow (based on streamflow analysis), or an annual loss to stream flow of less than 1%. As the creeks around LCO are ephemeral in nature, this will not impact the creek flow functionality.

In relation to outflows from the final voids, modelling indicates that outflow from the voids will recharge the hard rock aquifers beneath the alluvium and will not rise to a level whereby the alluvium is recharged. Void salinities will rise due to evaporation and are predicted to plateau in South Pit at 4,200 mg/L and continue to rise in the Entrance Pit over many centuries. Recorded salinities in the hard rock aquifers are currently between 3,000 and 7,000 mg/L, hence the outflow from the South Pit will not cause any change in water quality. Acid-generating materials are not significant in the coal measures and the natural levels of bicarbonate act to buffer any potential acid generation.

Water in the Entrance Pit will exceed the salinity of adjacent hard rock aquifers in about 100 years and will provide a saline source to the aquifer. There are no current or projected users of this groundwater as the high intrinsic salinity precludes its use, even for stock water.

## 10.2 Numerical Model – Setup and assumptions

### 10.2.1 The model's conceptualisation of the system

***Including key assumptions and the model's limitations;***

A numerical groundwater model was developed with the multiple aims to:

1. Provide a prediction of the potential impacts of mining on surface water features (specifically the Bowmans Creek and its alluvium);
2. Provide a prediction of expected future mine inflows resulting from the Proposed Action;
3. Provide a prediction of the expected groundwater level drawdown in all aquifers potentially impacted by the Proposed Action.

These aims were determined by:

1. The need to quantify compliance under the water sharing plan;
2. The need to protect groundwater users, including the environment and its ecosystems;
3. The need to provide operations expectations for water balance considerations.

Visual conceptualisation of the groundwater model is presented in **Figure 10.8**. The model constructed was based on the existing numerical groundwater model for the Ravensworth Underground Mine (RUM; MER, 2011b) and extended to the north and east to include LCO and the Mount Owen Complex and Glendell mines. The model was created using the Groundwater Vistas pre-processor with the MODFLOW-SURFACT finite difference code (Hydrogeologic, 2011). The model was peer reviewed by Dr Noel Merrick of HydroAlgorithmics Pty Ltd, and the peer review report is attached in **Appendix D**.

The model domain measures 20.5 km in the north-south direction and 27.4 km in the east-west direction. Grid cells are 100 m by 100 m, resulting in a model grid of 205 rows and 274 columns. The extent of the model domain in relation to LCO and other mines in the area is shown in **Figure 10.9**. Model cells were designated inactive in areas were coal seams belonging to the Vane Subgroup were not present, such as in the northwest and southeast corners of the model domain and north of the Hunter Thrust.

The model includes 20 layers representing stratigraphy from the ground surface down to the Saltwater Creek Formation, with a description of each model layer provided in **Table 10.3**. The extent and depth of the model layer representing the Bowmans Creek alluvium was estimated based on LiDAR data and borehole logs, resulting in the layer shown in **Figure 9.6**.

The conceptualisation ensured incorporation of all relevant processes and activities in the region. Model parameterisation is outlined below. Processes are monitored through the use of cells with defined boundary conditions to represent input and output mass balances within the model domain.

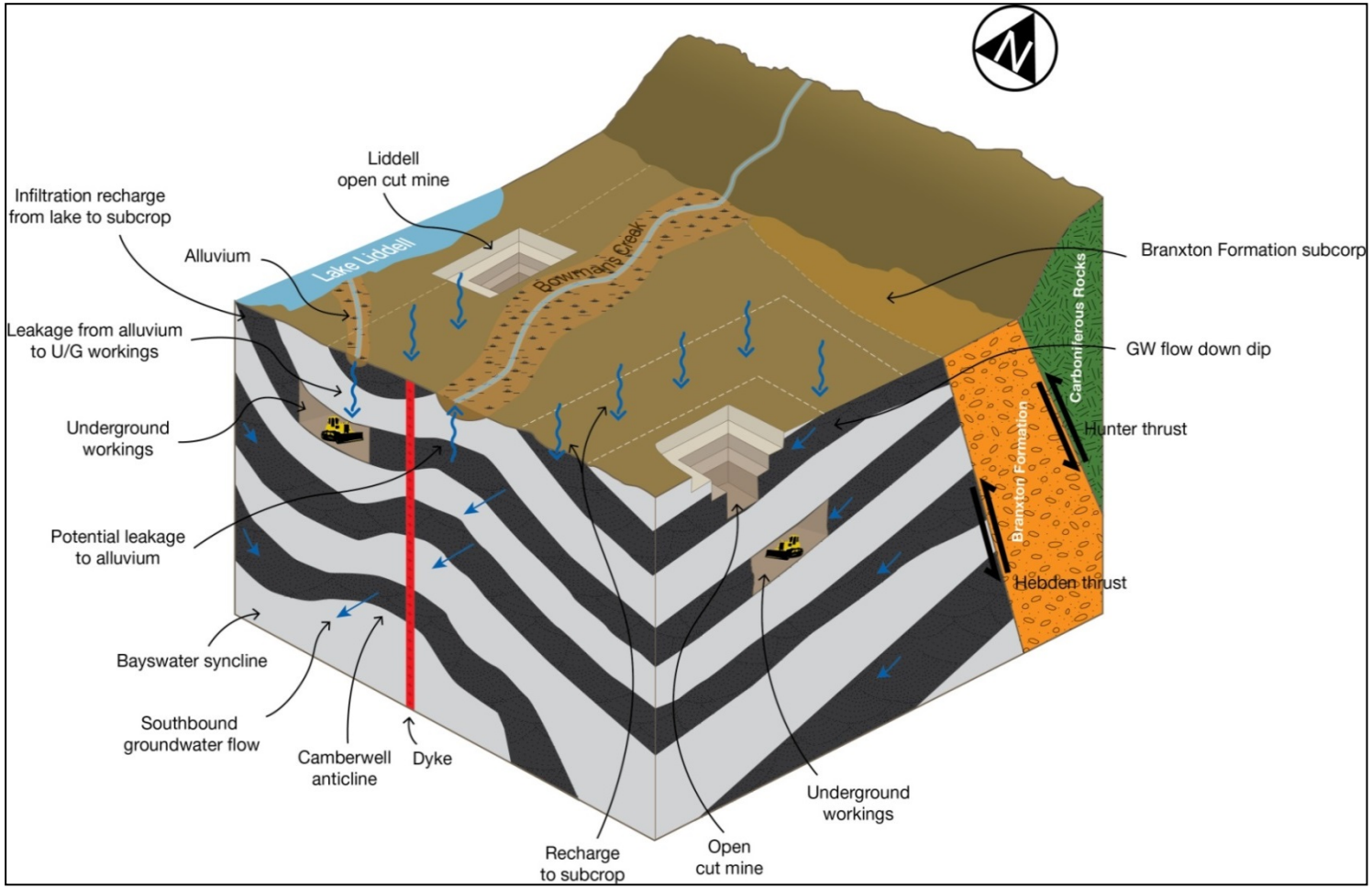



**Figure 10.8 - Conceptual Hydrogeologic Model of LCO Site and Surrounds (not to scale)**

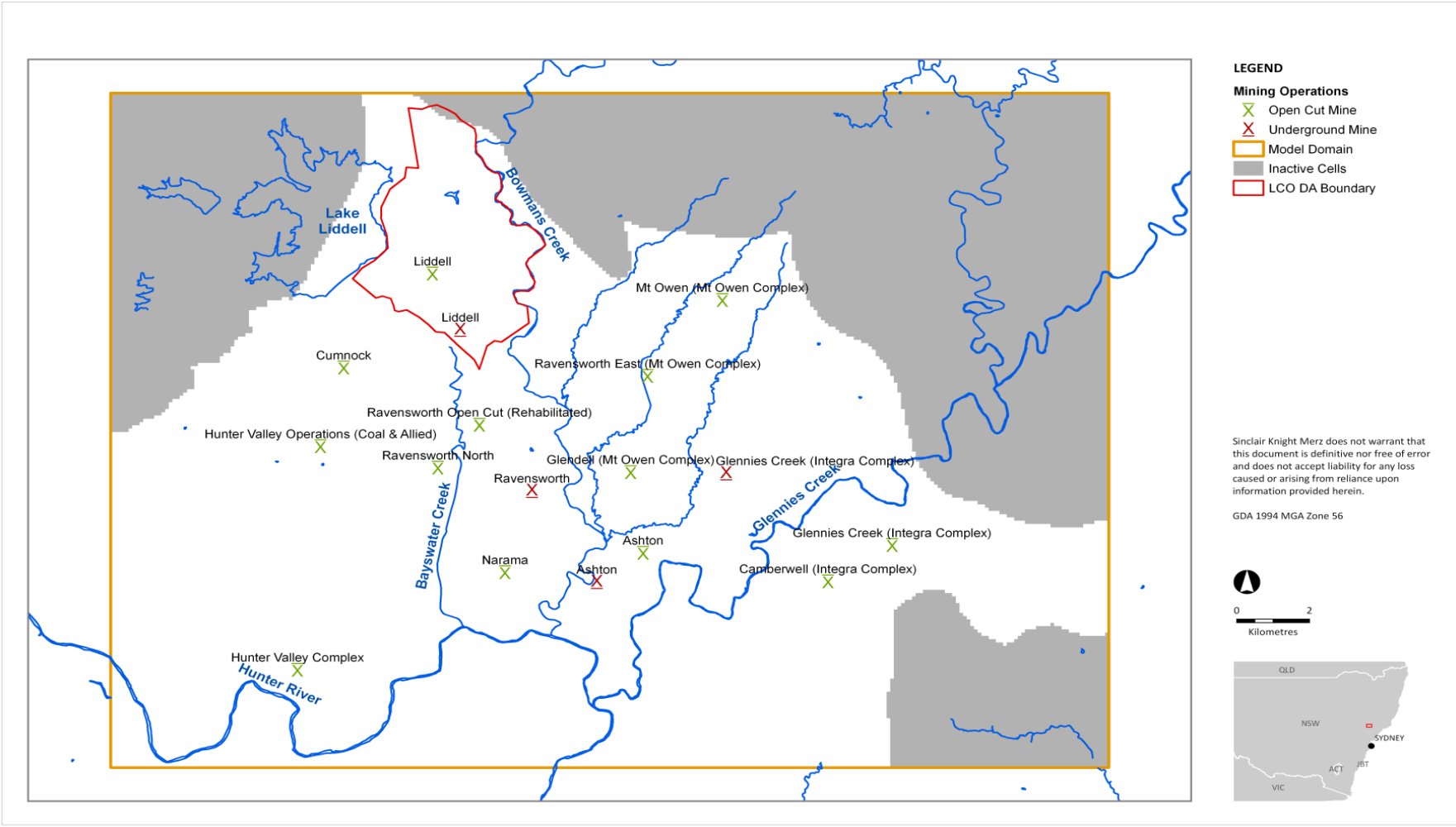



**Figure 10.9 - Model Domain**

**Table 10.3 – Description of model layers**

| Layer | Name | Description |
|---|---|---|
| 1 | Alluvium | Alluvial deposits surrounding the major rivers. |
| 2 | Alluvium/Regolith | Basal Alluvial sediments surrounding the rivers and Regolith (weathered rock) elsewhere. |
| 3 | Overburden | Everything between the base of weathering and the top of the Bayswater Seam, can include seams, but mostly sandstone, claystone and/or siltstone. |
| 4 | Bayswater Seam | All the Bayswater Seams. Includes the upper Bayswater 1, upper Bayswater 2 and Lower Bayswater at Liddell. Also includes interburden between these seams. |
| 5-6 | Interburden | Everything between the base of the Bayswater Seam and the top of the Upper Pikes Gully Seam, includes Lemington Seam. |
| 7 | Upper Pikes Gully Seam | Upper Pikes Gully Seam. |
| 8 | Interburden | Everything between the base of the upper Pikes Gully Seam and the top of the middle Pikes Gully Seam. |
| 9 | Middle and lower Pikes Gully Seam | Everything between the top of the middle Pikes Gully Seam and the base of the lower Pikes Gully Seam, includes interburden between the two seams. |
| 10 | Interburden | Everything between the base of the lower Pikes Gully Seam and the top of the Arties Seam. |
| 11 | Arties Seam | All the Arties Seams. Includes the Arties A, Arties B, Arties L1 and Arties L2 at Liddell. |
| 12 | Interburden | Everything between the base of the lower Pikes Gully Seam and the top of the Arties Seam. |
| 13 | Liddell Seam Sections A & B | All the Liddell Seams in Sections A and B. Includes the Liddell A1, Liddell Parting, Liddell B1, upper Liddell B2 and lower Liddell B2 at Liddell. Also includes interburden between these seams. |
| 14 | Liddell Seam Section C | All the Liddell Seams in Section C. Includes the upper Liddell C1, lower Liddell C1 at Liddell. Also includes interburden between the two seams. |
| 15 | Liddell Seam Section D | All the Liddell Seams in Section D. Includes the upper Liddell D1, lower Liddell D1 at Liddell. Also includes interburden between the two seams. |
| 16 | Interburden | Everything between the base of the Liddell Seam Section D and the top of the Barrett Seam. |
| 17 | Barrett Seam | All the Barrett Seams. Includes the Barrett A, upper Barret B, middle Barrett B, lower Barrett B, Barrett C1, Barret C2 and Barrett D at Liddell. Also includes interburden between these seams. |
| 18 | Interburden | Everything between the base of the Barrett Seam and the top of the Hebden Seam. |
| 19 | Hebden Seam | All the Hebden Seams. Includes upper Hebden and lower Hebden at Liddell. Also includes interburden between the two seams. |
| 20 | Saltwater Creek Formation | This layer represents the basement below the Hebden Seam, its upper part is composed of the Saltwater Creek Formation. |

#### 10.2.1.1 Boundary Conditions

Boundary conditions used throughout the model include general head boundaries, river, drain and wall boundaries, and MODFLOW's stream routing package. General head boundaries were assigned to active cells adjacent to model boundaries where the aquifer is known to extend beyond the limit of the model domain. River boundaries were assigned to replicate surface water – groundwater interaction of the Hunter River and associated alluvium in the southern extents of the model area. The stream routing package was used to define surface water – groundwater interactions for Bowmans Creek as it preserves the mass balance between adjacent stream cells, which is important for replicating ephemeral streams and for simulating potential losses in flow restricted streams such as Bowmans Creek. The dyke and coal barrier that influence groundwater flow in the coal measures at LCO are represented in the model using wall boundary conditions, and non-perennial streams are represented with drain cells.

Recharge was applied to the upper most active hydrogeological unit at a rate consistent with the surface geology characterisation. Areas of alluvium were assigned a recharge rate between 0.1% and 20% average annual rainfall, and other areas were assigned recharge rates between 0.001% and 5% average annual rainfall for calibration and sensitivity assessments. Evapotranspiration rates were set to the corrected pan evaporation rate for LCO (approximately 1,460 mm/yr) with an extinction depth of 2 m.

The model incorporates historical and future approved mining operations as part of its base setup.

Underground mining prior to 1990 is represented in the model by increased hydraulic conductivity (both horizontal and vertical) as well as increased storage properties (specific yield). Post-1990 modelling stress periods incorporate dewatering associated with underground and open cut operations through the use of drain cells. After cessation of dewatering, and to account for backfill sequencing and final voids at the completion of mining, re-saturation and re-equilibrium was accounted for in the model through the use of time varying hydraulic properties, recharge and evapotranspiration rates for relevant cells.

#### 10.2.1.2 Assumptions

Given the extent and complexity of the model and the amount of data available, the following assumptions and simplifications were required to facilitate model construction and development.

In keeping with standard practice, conservative values for model parameters were adopted for which reliable data was either unavailable or unknown. As a result the predictive model results presented are considered conservative estimates of potential impacts.

The Hunter Unregulated and Alluvial WSP commenced in August 2009 and specified sustainable allocations of water from Jerrys Water Source based on agricultural, industrial and stock and domestic use at the time of commencement. No specific estimation or provision for water use by mining operations was made in the allocations. The predictive model results presented here have therefore been assessed against a reference baseline of 2009 to correspond with the introduction of the Hunter Unregulated and Alluvial WSP.

#### 10.2.1.3 Calibration

Calibration of the regional scale model was undertaken using a stochastic calibration methodology designed to meet the following objectives:

- Establish datasets of model parameters that match measured groundwater levels within acceptable error limits. These parameter sets are reported collectively as the 'stochastic datasets'.
- Run the predictive simulations with the stochastic datasets to obtain an envelope of possible outcomes that also collectively represent the uncertainties associated with predictive modelling.

These modelling objectives, as well as the stochastic calibration methodology adopted, were identified and agreed upon through previous discussions with Glencore and NSW Office of Water. The stochastic approach was adopted in preference to a deterministic calibration methodology as it is capable of meeting the agreed upon objectives while offering the additional benefits of providing appropriate uncertainty analysis for predictive model results. This concept is highlighted specifically in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012):

"The approach taken to model calibration must be linked to the questions that all groups of stakeholders (project proponents, regulators and modellers) are trying to answer. It is important at the start of model calibration to understand the purpose of the model, that is, what the model is intended to predict. It is the desire for accuracy in future predictions that must drive the choices that are made during model calibration."

Model calibration using the stochastic approach employed here accounts for the inherent uncertainty associated with complex models based on many inter-related parameters. Each of the 'calibrated' datasets, or realisations that generate model results within the adopted calibration acceptance criteria, is considered equally plausible. The range of model results generated using these stochastic datasets provides a good indication of the uncertainties associated with predictive modelling. Such uncertainty analysis is important in any predictive modelling exercise and is recommended in the Australian Groundwater Modelling Guidelines (Barnett et al., 2012).

The stochastic calibration methodology comprised the following tasks:

- Generation of initial datasets using Monte Carlo analysis within parameter bounds and constraints determined from the conceptual hydrogeological model and relevant data sources;
- Model simulations using each dataset;
- Comparison of model results to calibration targets, including historical groundwater levels and post-mining recovery inflow rates to the Cumnock underground workings;
- Establish the set of calibrated datasets; and
- Run predictive simulations using the calibrated datasets.

The number of stochastic datasets required for recalibration of Model Version 7.2, adopted for this Project, was significantly lower than required for previous model versions. Revisions and outputs from previous model versions have allowed for the continued constraint of parameter ranges allowed within the datasets generated using Monte Carlo analysis. As the model continues to be updated and refined the parameter ranges are expected to be further constrained, reducing the corresponding uncertainty ranges.

The initial datasets were generated automatically using a Monte Carlo simulation program developed by SKM. The program allows for the range of values for each parameter to be:

- Distributed as normal, log normal, random, or log random; and
- Constrained or tied to other parameters. For example, one parameter can be constrained so that it cannot exceed another parameter, or one parameter may be defined as a multiplier of another parameter (as commonly used to define a consistent level of anisotropy in hydraulic conductivity).

The generation of datasets in this method allows for flexibility in how parameters are defined and constrained, and also allows for multiple linking of parameters and constraints. For example, the horizontal conductivity of the regolith was not allowed to exceed that of the alluvium, while at the same time the vertical conductivity of the regolith was not allowed to exceed the horizontal hydraulic conductivity of the regolith, thus indirectly tying it to the horizontal conductivity of the alluvium. These checks and constraints are important in generating datasets to ensure that datasets are not created that violate our conceptual understanding of the system (e.g. vertical conductivities exceeding horizontal conductivities, or the hydraulic conductivity of the interburden exceeding that of the coal seams).

The model parameters used as inputs for the Monte Carlo analysis included hydrogeological parameters properties (horizontal and vertical hydraulic conductivity, specific yield); conductance terms for river, stream, and general head boundary cells, and recharge rates.

**Table 10.4** summarises of the range of values within which the model parameters were permitted to vary. The level of constraint for the parameter bounds was directly related to field-based and reference information available for the parameters. For instance, a comprehensive dataset is available for the range in expected hydraulic conductivity values of the coal seams and interburden material. Therefore the range in hydraulic conductivity values permitted for these layers is relatively small compared to the range permitted for the regolith and alluvium, units for which there was less site specific data available.

The ranges in parameters allowed does not necessarily reflect the expected or final values that will be selected for analysing potential inflows but are simply intended to:

- Allow for a wide range of potential values and thus possibilities to be assessed through the calibration process; and

- Evaluate the sensitivity and uncertainty in the parameterisation and calibration of the model.

**Table 10.4 – Parameter Bounds Assigned for Monte Carlo Analysis**

| | | Parameter Bounds | | | |
|---|---|---|---|---|---|
| **Model Parameter** | **Geologic unit** | **Distribution Type** | **Minimum** | **Maximum** | **Constraints** |
| Sy | Alluvium | Log Random | 1.0E-02 | 2.0E-01 | |
| Sy | Regolith | Log Random | 5.0E-03 | 1.0E-01 | |
| Sy | Interburden | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Bayswater Seams (0-100m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Bayswater Seams (100-200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Bayswater Seams (> 200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Archerfield Sandstone | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Interburden \ Lemington Seam | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Pikes Gully & Liddell Seams (0-100m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Pikes Gully & Liddell Seams (100-200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Pikes Gully & Liddell Seams (> 200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Arties Seams (0-100m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Arties Seams (100-200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Arties Seams (> 200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Barrett Seams (0-100m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Barrett Seams (100-200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Barrett Seams (>200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Underground workings | Log Random | 1.0E-01 | 5.0E-01 | |
| Sy | Hebden Seams (0-100m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Hebden Seams (100-200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Hebden Seams (> 200m)[1] | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Interburden | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Saltwater Creek | Log Random | 5.0E-04 | 5.0E-02 | |
| Sy | Upper Cumnock Workings | Log Random | 2.5E-03 | 7.5E-03 | |
| Sy | Lower Cumnock Workings | Log Random | 2.5E-03 | 8.0E-03 | |

| | | Parameter Bounds | | | |
|---|---|---|---|---|---|
| Model Parameter | Geologic unit | Distribution Type | Minimum | Maximum | Constraints |
| | | | | | |
| Ss | All confined units | Fixed | 5.0E-06 | 5.0E-06 | |
| | | | | | |
| Kx (m/d) | Alluvium | Log Random | 1.0E-01 | 3.0E+02 | |
| Kx (m/d) | Regolith | Log Random | 1.0E-03 | 1.0E+01 | |
| Kx (m/d) | Interburden | Log Normal | 3.3E-06 | 1.7E-02 | |
| Kx (m/d) | Bayswater Seams (0-100m)[1] | Log Normal | 2.3E-04 | 1.3E-02 | |
| Kx (m/d) | Bayswater Seams (100-200m)[1] | Log Normal | 6.7E-05 | 1.7E-03 | |
| Kx (m/d) | Bayswater Seams (> 200m)[1] | Log Normal | 2.0E-05 | 1.7E-03 | |
| Kx (m/d) | Archerfield Sandstone | Log Normal | 3.2E-08 | 2.3E-03 | |
| Kx (m/d) | Interburden \ Lemington Seam | Log Normal | 9.5E-08 | 2.2E-01 | |
| Kx (m/d) | Pikes Gully & Liddell Seams (0-100m)[1] | Log Normal | 1.7E-03 | 8.7E-01 | |
| Kx (m/d) | Pikes Gully & Liddell Seams (100-200m)[1] | Log Normal | 6.5E-04 | 1.9E-01 | |
| Kx (m/d) | Pikes Gully & Liddell Seams (> 200m)[1] | Log Normal | 3.3E-04 | 4.1E-02 | |
| Kx (m/d) | Arties Seams (0-100m)[1] | Log Normal | 6.9E-03 | 2.1E-01 | |
| Kx (m/d) | Arties Seams (100-200m)[1] | Log Normal | 1.4E-03 | 6.9E-02 | |
| Kx (m/d) | Arties Seams (> 200m)[1] | Log Normal | 1.1E-03 | 8.5E-03 | |
| Kx (m/d) | Barrett Seams (0-100m)[1] | Log Normal | 2.1E-03 | 8.5E-02 | |
| Kx (m/d) | Barrett Seams (100-200m)[1] | Log Normal | 7.8E-04 | 2.0E-02 | |
| Kx (m/d) | Barrett Seams (>200m)[1] | Log Normal | 1.0E-03 | 8.4E-03 | |
| Kx (m/d) | Underground workings | Log Random | 1.0E+01 | 1.0E+03 | |
| Kx (m/d) | Hebden Seams (0-100m)[1] | Log Normal | 6.4E-04 | 1.6E+00 | |
| Kx (m/d) | Hebden Seams (100-200m)[1] | Log Normal | 5.3E-04 | 4.1E-01 | |
| Kx (m/d) | Hebden Seams (> 200m)[1] | Log Normal | 5.1E-05 | 1.2E-01 | |
| Kx (m/d) | Interburden | Log Normal | 3.1E-07 | 1.0E-04 | |
| Kx (m/d) | Saltwater Creek | Log Normal | 4.9E-08 | 7.8E-02 | |
| Kz (Kx/Kz) | Alluvium | Log Random | 2 | 100 | Could not exceed Kx |
| Kz (Kx/Kz) | Regolith | Log Random | 2 | 100 | Could not exceed Kx |
| Kz (Kx/Kz) | Interburden | Log Normal | 5 | 50 | Could not exceed Kx |
| Kz (Kx/Kz) | Bayswater Seams (0-100m)[1] | Log Normal | 10 | 200 | Could not exceed Kx |
| Kz (Kx/Kz) | Bayswater Seams (100-200m)[1] | Log Normal | 10 | 100 | Could not exceed Kx |
| Kz (Kx/Kz) | Bayswater Seams (> 200m)[1] | Log Normal | 10 | 20 | Could not exceed Kx |
| Kz (Kx/Kz) | Archerfield Sandstone | Log Normal | 2 | 10 | Could not exceed Kx |
| Kz (Kx/Kz) | Interburden \ Lemington Seam | Log Normal | 10 | 100 | Could not exceed Kx |
| Kz (Kx/Kz) | Pikes Gully & Liddell Seams (0-100m)[1] | Log Normal | 10 | 8000 | Could not exceed Kx |
| Kz (Kx/Kz) | Pikes Gully & Liddell Seams (100-200m)[1] | Log Normal | 10 | 2000 | Could not exceed Kx |
| Kz (Kx/Kz) | Pikes Gully & Liddell Seams (> 200m)[1] | Log Normal | 10 | 600 | Could not exceed Kx |
| Kz (Kx/Kz) | Arties Seams (0-100m)[1] | Log Normal | 10 | 8000 | Could not exceed Kx |
| Kz (Kx/Kz) | Arties Seams (100-200m)[1] | Log Normal | 10 | 2000 | Could not exceed Kx |
| Kz (Kx/Kz) | Arties Seams (> 200m)[1] | Log Normal | 10 | 600 | Could not exceed Kx |
| Kz (Kx/Kz) | Barrett Seams (0-100m)[1] | Log Normal | 10 | 3000 | Could not exceed Kx |

| | | Parameter Bounds | | | |
|---|---|---|---|---|---|
| **Model Parameter** | **Geologic unit** | **Distribution Type** | **Minimum** | **Maximum** | **Constraints** |
| Kz (Kx/Kz) | Barrett Seams (100-200m)[1] | Log Normal | 10 | 600 | Could not exceed Kx |
| Kz (Kx/Kz) | Barrett Seams (>200m)[1] | Log Normal | 10 | 600 | Could not exceed Kx |
| Kz (Kx/Kz) | Underground workings | Log Random | 1 | 1 | |
| Kz (Kx/Kz) | Hebden Seams (0-100m)[1] | Log Normal | 10 | 8000 | Could not exceed Kx |
| Kz (Kx/Kz) | Hebden Seams (100-200m)[1] | Log Normal | 10 | 2000 | Could not exceed Kx |
| Kz (Kx/Kz) | Hebden Seams (> 200m)[1] | Log Normal | 10 | 700 | Could not exceed Kx |
| Kz (Kx/Kz) | Interburden | Log Normal | 5 | 100 | Could not exceed Kx |
| Kz (Kx/Kz) | Saltwater Creek | Log Normal | 5 | 100 | Could not exceed Kx |
| | | | | | |
| Conductance ($m^2/d$) | Hunter River (River cells) | Log Random | 5.0E-05 | 5.0E+05 | |
| Conductance ($m^2/d$) | Glennies Creek (River cells) | Log Random | 5.0E-05 | 5.0E+05 | |
| Conductance ($m^2/d$) | Bowmans Creek (Stream cells) | Log Random | 1.0E+00 | 1.0E+03 | |
| Conductance ($m^2/d$) | General Head Boundary cells | Log Random | 1.0E+01 | 5.0E+05 | |
| | | | | | |
| Recharge[2] | Alluvium | Log Random | 1% | 20% | |
| Recharge[2] | All other coal seam and interburden zones | Log Random | 0.001% | 2% | |
| Recharge[2] | Backfill | Log Random | 1% | 5% | |

The transient calibration model simulated the period from 1 January 1980 to 31 December 2012 in 17 stress periods, the first of which was steady state. The steady state stress period was aimed at providing stable initial heads for the subsequent transient calibration runs. No drain cell boundary conditions representing mining operations are included in the steady-state model. Steady-state does, however, include artefacts of the historical underground workings at Liddell as enhanced conductivity zones representing the impacts of previous underground mining of the Pikes Gully and Liddell Seams.

Early (first four) transient stress periods are represented by blocks of 5 years (1826 days), followed by a single stress period covering 2000-2002 (731 days). All stress periods from 2002 through to 2030 are represented by annual time-steps (365 days).

#### 10.2.1.4 Calibration Targets

Four distinct datasets were identified as appropriate calibration targets to determine which sets of model parameters represented calibrated datasets:

- The first calibration target was the matching of historical water levels recorded for alluvial bores associated with Bowmans Creek (including bores ALV1L through ALV8L adjacent LCO and the BC_SP series bores adjacent Mount Owen Complex) and Glennies Creek (GCP series bores). These bores were chosen as initial calibration targets as potential impacts on these alluvial aquifers were specifically identified as a key concern in the DGRs and by NSW Office of Water. A calibration target criteria of a 5% scaled residual mean squared (SRMS) was used for the alluvial bores.

- The second calibration target was the matching of historic water levels in shallow hard rock bores located in the vicinity of the Project area. A calibration target criteria of a 5% SRMS was used for the hard rock bores.

- The third calibration target dataset comprised the comparison of post-mining inflow estimates to the former Cumnock underground workings. This target dataset was adopted following model simulations conducted by SKM for Glencore's Ravensworth Surface Operations mine.

- The fourth calibration target was set by estimated observed pit inflows to the North Pit of the Mount Owen Complex. Based on estimated pumping rates and mine-site mass balance modelling (Gilberts, 2014), an estimated pit inflow of no more than 1.4 ML/day was determined. Two approaches to this final calibration were undertaken:

    - Take each realisation of the dataset that satisfied the first three calibration targets and perform a PEST optimisation on the storage parameters (which determine the pit inflow levels) to generate a revised set of calibration parameters that satisfy the North Pit inflow criteria. Run these as a prediction dataset.

    - If any realisation achieved all four targets, take the storage parameters from that realisation and transpose into the other 5 realisations that satisfied the first three targets and run these six realisations for an additional prediction dataset.

#### 10.2.1.5 Calibration Results

The calibration simulations resulted in 540 realisations, or sets of model parameters, that were able to achieve a stable solution (i.e. converged). 65 of these realisations simulated groundwater levels at the alluvial calibration bores within the target calibration criteria of 5% SRMS (the first calibration target). Of these, 42 also simulated groundwater levels across all alluvial bore (for the entire model domain) to within 5% SRMS and 16 of these realisations achieved the target calibration criteria of <5% SRMS for the hard rock calibration bores (the second calibration target). Amongst these 16 realisations, six of the datasets simulated inflows to the former Cumnock underground workings within the range of inflow estimates used for calibration (the third calibration target). These six realisations, or sets of model parameters, were optimised for storage parameters using the PEST optimisation methodology. In addition, a single realisation satisfied all of the calibration targets. The storage parameters from this realisation were therefore transposed into the other 5 realisations that satisfied the other three targets. This resulted in a total of 12 parameters sets that are considered the calibrated datasets available for predictive simulations. **Table 10.5** summarises the range of values for model parameters within the calibrated datasets, and Appendix C compares the simulated hydrographs from the calibrated realisations with observed data from the calibration bores.

**Table 10.5 – Range of Model Parameter Values for Calibrated Datasets**

| Model Parameter | Geologic unit | Minimum | Maximum |
|---|---|---|---|
| Sy | Alluvium | 1.2E-2 | 8.2E-2 |
| Sy | Regolith | 5.5E-3 | 3.2E-2 |
| Sy | Interburden | 6.9E-4 | 2.2E-2 |
| Sy | Bayswater Seams (0-100m)[1] | 2.5E-3 | 3.3E-2 |
| Sy | Bayswater Seams (100-200m)[1] | 2.3E-3 | 2.0E-2 |
| Sy | Bayswater Seams (> 200m)[1] | 4.6E-3 | 3.4E-2 |
| Sy | Archerfield Sandstone | 5.5E-4 | 7.1E-3 |
| Sy | Interburden \ Lemington Seam | 5.6E-4 | 5.9E-3 |
| Sy | Pikes Gully & Liddell Seams (0-100m)[1] | 9.6E-4 | 5.0E-2 |
| Sy | Pikes Gully & Liddell Seams (100-200m)[1] | 6.5E-4 | 3.4E-2 |
| Sy | Pikes Gully & Liddell Seams (> 200m)[1] | 6.4E-4 | 4.3E-2 |
| Sy | Arties Seams (0-100m)[1] | 6.1E-4 | 3.7E-2 |
| Sy | Arties Seams (100-200m)[1] | 5.2E-4 | 2.2E-2 |

| Model Parameter | Geologic unit | Minimum | Maximum |
|---|---|---|---|
| Sy | Arties Seams (> 200m)[1] | 5.9E-4 | 8.2E-3 |
| Sy | Barrett Seams (0-100m)[1] | 7.3E-4 | 1.5E-2 |
| Sy | Barrett Seams (100-200m)[1] | 5.6E-4 | 7.2E-3 |
| Sy | Barrett Seams (>200m)[1] | 6.6E-4 | 2.6E-2 |
| Sy | Underground workings | 1.8E-1 | 5.0E-1 |
| Sy | Hebden Seams (0-100m)[1] | 7.5E-4 | 9.0E-3 |
| Sy | Hebden Seams (100-200m)[1] | 6.4E-4 | 3.3E-2 |
| Sy | Hebden Seams (> 200m)[1] | 6.2E-4 | 2.3E-2 |
| Sy | Interburden | 6.7E-4 | 4.4E-2 |
| Sy | Saltwater Creek | 5.6E-4 | 3.0E-2 |
| Sy | Upper Cumnock Workings | 3.4E-3 | 6.8E-3 |
| Sy | Lower Cumnock Workings | 4.7E-3 | 7.9E-3 |
| | | | |
| Ss | All confined units | 5.0E-6 | 5.0E-6 |
| | | | |
| Kx (m/d) | Alluvium | 6.5E-1 | 3.6E+0 |
| Kx (m/d) | Regolith | 2.3E-3 | 9.9E-3 |
| Kx (m/d) | Interburden | 5.5E-5 | 8.7E-4 |
| Kx (m/d) | Bayswater Seams (0-100m)[1] | 7.1E-4 | 2.4E-3 |
| Kx (m/d) | Bayswater Seams (100-200m)[1] | 1.7E-4 | 6.5E-4 |
| Kx (m/d) | Bayswater Seams (> 200m)[1] | 7.0E-5 | 1.4E-4 |
| Kx (m/d) | Archerfield Sandstone | 9.1E-7 | 8.1E-5 |
| Kx (m/d) | Interburden \ Lemington Seam | 7.1E-6 | 5.8E-4 |
| Kx (m/d) | Pikes Gully & Liddell Seams (0-100m)[1] | 5.8E-3 | 2.4E-2 |
| Kx (m/d) | Pikes Gully & Liddell Seams (100-200m)[1] | 3.2E-3 | 1.6E-2 |
| Kx (m/d) | Pikes Gully & Liddell Seams (> 200m)[1] | 1.1E-3 | 4.6E-3 |
| Kx (m/d) | Arties Seams (0-100m)[1] | 2.0E-2 | 8.8E-2 |
| Kx (m/d) | Arties Seams (100-200m)[1] | 7.3E-3 | 1.4E-2 |
| Kx (m/d) | Arties Seams (> 200m)[1] | 2.2E-3 | 4.2E-3 |
| Kx (m/d) | Barrett Seams (0-100m)[1] | 6.4E-3 | 2.5E-2 |
| Kx (m/d) | Barrett Seams (100-200m)[1] | 1.6E-3 | 4.4E-3 |
| Kx (m/d) | Barrett Seams (>200m)[1] | 2.8E-3 | 4.5E-3 |
| Kx (m/d) | Underground workings | 1.9E+1 | 9.3E+2 |
| Kx (m/d) | Hebden Seams (0-100m)[1] | 6.4E-3 | 2.0E-1 |
| Kx (m/d) | Hebden Seams (100-200m)[1] | 1.5E-3 | 1.9E-2 |
| Kx (m/d) | Hebden Seams (> 200m)[1] | 2.0E-4 | 3.2E-2 |
| Kx (m/d) | Interburden | 1.9E-6 | 9.4E-6 |
| Kx (m/d) | Saltwater Creek | 1.1E-6 | 2.1E-4 |
| Kz (m/d) | Alluvium | 4.5E-02 | 4.2E-01 |
| Kz (m/d) | Regolith | 1.0E-04 | 5.8E-04 |
| Kz (m/d) | Interburden | 1.8E-06 | 3.9E-05 |
| Kz (m/d) | Bayswater Seams (0-100m)[1] | 2.1E-05 | 9.9E-05 |
| Kz (m/d) | Bayswater Seams (100-200m)[1] | 4.6E-06 | 5.6E-05 |
| Kz (m/d) | Bayswater Seams (> 200m)[1] | 4.3E-06 | 1.3E-05 |

| Model Parameter | Geologic unit | Minimum | Maximum |
|---|---|---|---|
| Kz (m/d) | Archerfield Sandstone | 3.4E-07 | 3.2E-05 |
| Kz (m/d) | Interburden \ Lemington Seam | 2.3E-07 | 4.3E-05 |
| Kz (m/d) | Pikes Gully & Liddell Seams (0-100m)[1] | 3.5E-06 | 8.6E-04 |
| Kz (m/d) | Pikes Gully & Liddell Seams (100-200m)[1] | 3.6E-06 | 2.8E-04 |
| Kz (m/d) | Pikes Gully & Liddell Seams (> 200m)[1] | 5.1E-06 | 2.3E-04 |
| Kz (m/d) | Arties Seams (0-100m)[1] | 9.5E-05 | 3.9E-03 |
| Kz (m/d) | Arties Seams (100-200m)[1] | 7.0E-06 | 7.4E-04 |
| Kz (m/d) | Arties Seams (> 200m)[1] | 6.3E-06 | 1.5E-04 |
| Kz (m/d) | Barrett Seams (0-100m)[1] | 2.4E-06 | 1.9E-03 |
| Kz (m/d) | Barrett Seams (100-200m)[1] | 7.8E-06 | 2.8E-04 |
| Kz (m/d) | Barrett Seams (>200m)[1] | 7.6E-06 | 3.2E-04 |
| Kz (m/d) | Underground workings | 1.9E+01 | 9.3E+02 |
| Kz (m/d) | Hebden Seams (0-100m)[1] | 3.0E-05 | 8.8E-03 |
| Kz (m/d) | Hebden Seams (100-200m)[1] | 8.7E-06 | 6.3E-04 |
| Kz (m/d) | Hebden Seams (> 200m)[1] | 2.0E-06 | 2.1E-03 |
| Kz (m/d) | Interburden | 4.6E-08 | 4.3E-07 |
| Kz (m/d) | Saltwater Creek | 2.5E-08 | 1.0E-05 |
| | | | |
| Conductance ($m^2$/d) | Hunter River (River cells) | 7.6E+0 | 9.9E+4 |
| Conductance ($m^2$/d) | Glennies Creek (River cells) | 1.3E-1 | 1.6E+4 |
| Conductance ($m^2$/d) | Bowmans Creek (Stream cells) | 3.9E+0 | 7.4E+2 |
| Conductance ($m^2$/d) | General Head Boundary cells | 8.5E+1 | 9.9E+4 |
| | | | |
| Recharge[2] | Alluvium | 3% | 9% |
| Recharge[2] | All other coal seam and interburden zones | 0.002% | 2% |
| Recharge[2] | Backfill | 3% | 5% |

[1] Following the convention of Mackie, 2009

[2] Percent of annual rainfall (Station # 61086) equal to 645 mm/yr (www.bom.gov.au)

**Table 10.6** provides a summary of statistical measures used to compare results from model simulations using the calibrated datasets with observed data used as calibration targets (measured groundwater levels at alluvial and hard rock bores). Plots of observed and all equivalent realisation-simulated groundwater levels for the alluvial and hard rock calibration bores are presented in **Figure 10.10** and **Figure 10.11**, respectively.

**Table 10.6 – Summary of Calibration Statistics**

| | Statistical Range | | |
|---|---|---|---|
| Statistical Measure | All Alluvial Bores (unweighted) | Project Bedrock Observations (unweighted) | All Bedrock Bore Observations (weighted*) |
| Residual Mean (m) | -0.4 – 0.7 | -0.2 – 2.2 | -3.9 – 1.7 |
| Absolute Residual Mean (m) | 0.8 – 1.0 | 2.4 – 3.0 | 9.6 – 11.8 |
| Residual Standard Deviation (m) | 1.5 – 2.3 | 3.8 – 4.4 | 13.7 – 16.2 |
| Sum of Squares (m) | 1,400 – 3,000 | 1,000 – 1,700 | 990,000 – 1,400,000 |
| RMS Error (m) | 1.5 – 2.3 | 3.9 – 4.9 | 13.8 – 16.5 |

| | Statistical Range | | |
|---|---|---|---|
| **Statistical Measure** | **All Alluvial Bores (unweighted)** | **Project Bedrock Observations (unweighted)** | **All Bedrock Bore Observations (weighted*)** |
| Minimum Residual (m) | -31.3 – -16.6 | -21.2 - -8.9 | -66.7 – -56.7 |
| Maximum Residual (m) | 3.0 – 4.8 | 20.3 – 32.2 | 42.6 – 45.3 |
| Number of Observations | 588 | 724 | 5247 |
| Range in Observations (m) | 46.1 | 168.9 | 168.9 |
| Scaled Standard Deviation | 3% – 5% | 2% - 3% | 8% – 10% |
| Scaled Absolute Mean | 2% | 1% – 2% | 6% – 7% |
| Scaled RMS | 3% – 5% | 2% - 3% | 8% – 10% |

* All alluvial and Project Bores are given a weight of 1 to calculate residuals. For all other bores a weight of 0.4 was applied.

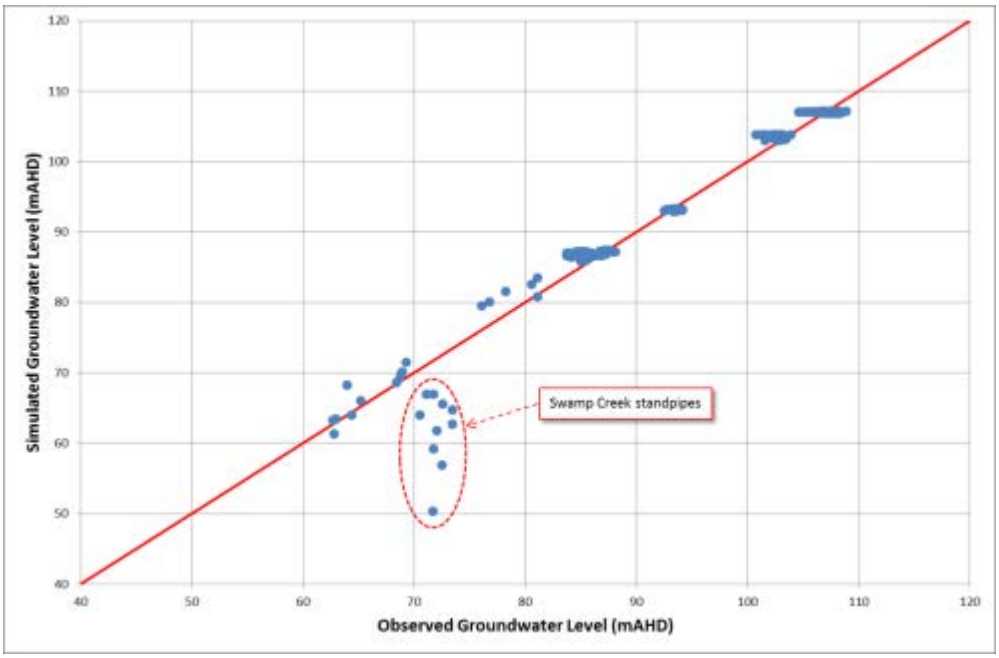



**Figure 10.10 – Observed vs. Simulated Groundwater Levels for all Alluvial Bores**

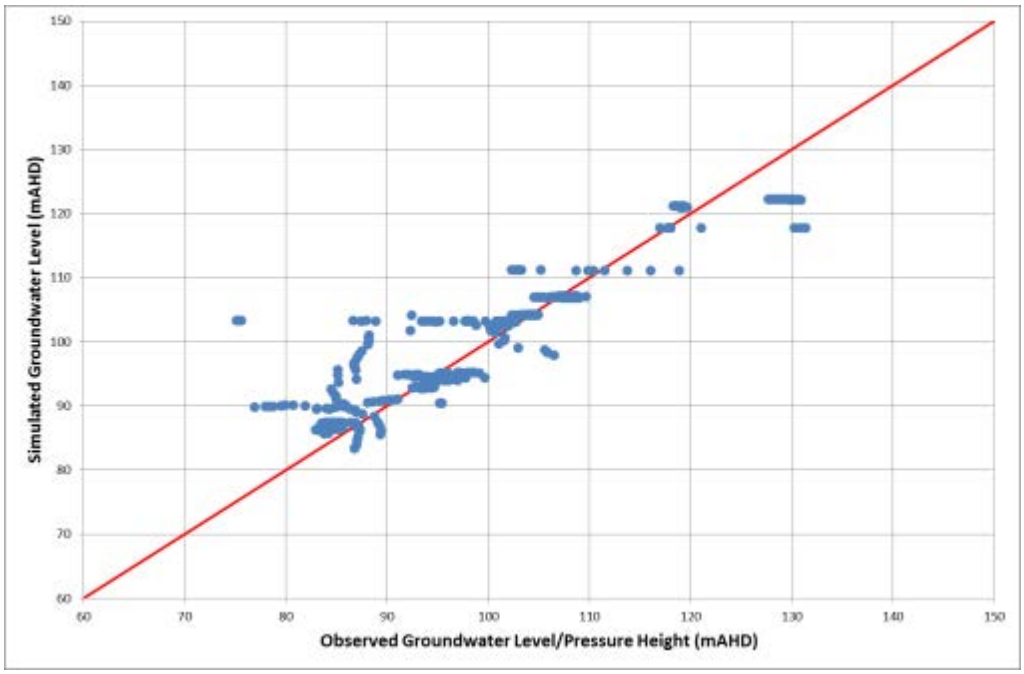



**Figure 10.11 – Observed vs. Simulated Groundwater Levels for Hard Rock Calibration Bores**

In the area along Swamp Creek, the regional model is underestimating alluvial water levels (**Figure 10.10**) which could indicate that the model is overestimating impacts from the Glendell Mine. These bores are beyond the maximum potential impacts determined attributable to Liddell. Simulated levels with greater than 3 m difference from observed levels account for less than 10% of comparisons (588 observations).

Horizontal trends in **Figure 10.11** generally represent sub-stress period changes in observed pressures most likely reflecting inter-annual changes in mining operations affecting these bores. Again, the impacted bores are not within the potentially impacted region of Liddell operations. Simulated levels with greater than 10 m difference from observed levels account for less than 8% of comparisons (724 observations).

The calibration statistics and hydrographs indicate the numerical model accurately replicates the observed data.

#### 10.2.1.6 Sensitivity Analysis

**7** summarises the range of values for model parameters within the calibrated datasets along with the percentage of the input parameter range. The calibrated parameter ranges in relation to the input parameter ranges are presented graphically in **Figure 10.12** through **Figure 10.16**. These figures and the percentage of the stochastic range provide an indication of the model's sensitivity to changes in the parameter values while also providing an indication of the parameter value's uncertainty. For the calibrated datasets model parameters with values that represent a lower percentage of the stochastic range indicate those parameters that will have a larger effect on the model predicted responses (i.e. the model is more sensitive to these parameters).

**Table 10.7 – Range of Model Parameter for Calibrated Datasets**

| Model Parameter | Geologic unit | Minimum | Maximum | Percent of Stochastic Range |
|---|---|---|---|---|
| Sy | Alluvium | 1.2E-2 | 8.2E-2 | 37% |
| Sy | Regolith | 5.5E-3 | 3.2E-2 | 28% |
| Sy | Interburden | 6.9E-4 | 2.2E-2 | 43% |
| Sy | Bayswater Seams (0-100m)[1] | 2.5E-3 | 3.3E-2 | 62% |
| Sy | Bayswater Seams (100-200m)[1] | 2.3E-3 | 2.0E-2 | 35% |
| Sy | Bayswater Seams (> 200m)[1] | 4.6E-3 | 3.4E-2 | 60% |
| Sy | Archerfield Sandstone | 5.5E-4 | 7.1E-3 | 13% |
| Sy | Interburden \ Lemington Seam | 5.6E-4 | 5.9E-3 | 11% |
| Sy | Pikes Gully & Liddell Seams (0-100m)[1] | 9.6E-4 | 5.0E-2 | 99% |
| Sy | Pikes Gully & Liddell Seams (100-200m)[1] | 6.5E-4 | 3.4E-2 | 67% |
| Sy | Pikes Gully & Liddell Seams (> 200m)[1] | 6.4E-4 | 4.3E-2 | 86% |
| Sy | Arties Seams (0-100m)[1] | 6.1E-4 | 3.7E-2 | 73% |
| Sy | Arties Seams (100-200m)[1] | 5.2E-4 | 2.2E-2 | 43% |
| Sy | Arties Seams (> 200m)[1] | 5.9E-4 | 8.2E-3 | 15% |
| Sy | Barrett Seams (0-100m)[1] | 7.3E-4 | 1.5E-2 | 29% |
| Sy | Barrett Seams (100-200m)[1] | 5.6E-4 | 7.2E-3 | 14% |
| Sy | Barrett Seams (>200m)[1] | 6.6E-4 | 2.6E-2 | 52% |
| Sy | Underground workings | 1.8E-1 | 5.0E-1 | 83% |
| Sy | Hebden Seams (0-100m)[1] | 7.5E-4 | 9.0E-3 | 17% |
| Sy | Hebden Seams (100-200m)[1] | 6.4E-4 | 3.3E-2 | 65% |
| Sy | Hebden Seams (> 200m)[1] | 6.2E-4 | 2.3E-2 | 44% |
| Sy | Interburden | 6.7E-4 | 4.4E-2 | 88% |
| Sy | Saltwater Creek | 5.6E-4 | 3.0E-2 | 59% |
| Sy | Upper Cumnock Workings | 3.4E-3 | 6.8E-3 | 66% |
| Sy | Lower Cumnock Workings | 4.7E-3 | 7.9E-3 | 57% |
| | | | | |
| Ss | All confined units | 5.0E-6 | 5.0E-6 | 100 |
| | | | | |
| Kx (m/d) | Alluvium | 6.5E-1 | 3.6E+0 | 1% |
| Kx (m/d) | Regolith | 2.3E-3 | 9.9E-3 | < 1% |
| Kx (m/d) | Interburden | 5.5E-5 | 8.7E-4 | 5% |
| Kx (m/d) | Bayswater Seams (0-100m)[1] | 7.1E-4 | 2.4E-3 | 13% |
| Kx (m/d) | Bayswater Seams (100-200m)[1] | 1.7E-4 | 6.5E-4 | 29% |
| Kx (m/d) | Bayswater Seams (> 200m)[1] | 7.0E-5 | 1.4E-4 | 4% |
| Kx (m/d) | Archerfield Sandstone | 9.1E-7 | 8.1E-5 | 3% |
| Kx (m/d) | Interburden \ Lemington Seam | 7.1E-6 | 5.8E-4 | < 1% |
| Kx (m/d) | Pikes Gully & Liddell Seams (0-100m)[1] | 5.8E-3 | 2.4E-2 | 2% |
| Kx (m/d) | Pikes Gully & Liddell Seams (100-200m)[1] | 3.2E-3 | 1.6E-2 | 7% |
| Kx (m/d) | Pikes Gully & Liddell Seams (> 200m)[1] | 1.1E-3 | 4.6E-3 | 8% |
| Kx (m/d) | Arties Seams (0-100m)[1] | 2.0E-2 | 8.8E-2 | 33% |
| Kx (m/d) | Arties Seams (100-200m)[1] | 7.3E-3 | 1.4E-2 | 10% |
| Kx (m/d) | Arties Seams (> 200m)[1] | 2.2E-3 | 4.2E-3 | 27% |

| Model Parameter | Geologic unit | Minimum | Maximum | Percent of Stochastic Range |
|---|---|---|---|---|
| Kx (m/d) | Barrett Seams (0-100m)[1] | 6.4E-3 | 2.5E-2 | 22% |
| Kx (m/d) | Barrett Seams (100-200m)[1] | 1.6E-3 | 4.4E-3 | 15% |
| Kx (m/d) | Barrett Seams (>200m)[1] | 2.8E-3 | 4.5E-3 | 23% |
| Kx (m/d) | Underground workings | 1.9E+1 | 9.3E+2 | 92% |
| Kx (m/d) | Hebden Seams (0-100m)[1] | 6.4E-3 | 2.0E-1 | 12% |
| Kx (m/d) | Hebden Seams (100-200m)[1] | 1.5E-3 | 1.9E-2 | 4% |
| Kx (m/d) | Hebden Seams (> 200m)[1] | 2.0E-4 | 3.2E-2 | 26% |
| Kx (m/d) | Interburden | 1.9E-6 | 9.4E-6 | 7% |
| Kx (m/d) | Saltwater Creek | 1.1E-6 | 2.1E-4 | < 1% |
| Kz (m/d) | Alluvium | 4.5E-02 | 4.2E-01 | < 1% |
| Kz (m/d) | Regolith | 1.0E-04 | 5.8E-04 | < 1% |
| Kz (m/d) | Interburden | 1.8E-06 | 3.9E-05 | 6% |
| Kz (m/d) | Bayswater Seams (0-100m)[1] | 2.1E-05 | 9.9E-05 | 29% |
| Kz (m/d) | Bayswater Seams (100-200m)[1] | 4.6E-06 | 5.6E-05 | 45% |
| Kz (m/d) | Bayswater Seams (> 200m)[1] | 4.3E-06 | 1.3E-05 | 6% |
| Kz (m/d) | Archerfield Sandstone | 3.4E-07 | 3.2E-05 | 4% |
| Kz (m/d) | Interburden \ Lemington Seam | 2.3E-07 | 4.3E-05 | < 1% |
| Kz (m/d) | Pikes Gully & Liddell Seams (0-100m)[1] | 3.5E-06 | 8.6E-04 | 2% |
| Kz (m/d) | Pikes Gully & Liddell Seams (100-200m)[1] | 3.6E-06 | 2.8E-04 | 3% |
| Kz (m/d) | Pikes Gully & Liddell Seams (> 200m)[1] | 5.1E-06 | 2.3E-04 | 13% |
| Kz (m/d) | Arties Seams (0-100m)[1] | 9.5E-05 | 3.9E-03 | 29% |
| Kz (m/d) | Arties Seams (100-200m)[1] | 7.0E-06 | 7.4E-04 | 19% |
| Kz (m/d) | Arties Seams (> 200m)[1] | 6.3E-06 | 1.5E-04 | 23% |
| Kz (m/d) | Barrett Seams (0-100m)[1] | 2.4E-06 | 1.9E-03 | 34% |
| Kz (m/d) | Barrett Seams (100-200m)[1] | 7.8E-06 | 2.8E-04 | 19% |
| Kz (m/d) | Barrett Seams (>200m)[1] | 7.6E-06 | 3.2E-04 | 39% |
| Kz (m/d) | Underground workings | 1.9E+01 | 9.3E+02 | 92% |
| Kz (m/d) | Hebden Seams (0-100m)[1] | 3.0E-05 | 8.8E-03 | 17% |
| Kz (m/d) | Hebden Seams (100-200m)[1] | 8.7E-06 | 6.3E-04 | 6% |
| Kz (m/d) | Hebden Seams (> 200m)[1] | 2.0E-06 | 2.1E-03 | 39% |
| Kz (m/d) | Interburden | 4.6E-08 | 4.3E-07 | 3% |
| Kz (m/d) | Saltwater Creek | 2.5E-08 | 1.0E-05 | < 1% |
| | | | | |
| Conductance ($m^2$/d) | Hunter River (River cells) | 7.6E+0 | 9.9E+4 | 20% |
| Conductance ($m^2$/d) | Glennies Creek (River cells) | 1.3E-1 | 1.6E+4 | 3% |
| Conductance ($m^2$/d) | Bowmans Creek (Stream cells) | 3.9E+0 | 7.4E+2 | 74% |
| Conductance ($m^2$/d) | General Head Boundary cells | 8.5E+1 | 9.9E+4 | 20% |
| | | | | |
| Recharge[2] | Alluvium | 3% | 9% | 32% |
| Recharge[2] | All other coal seam and interburden zones | 0.002% | 2% | 99% |
| Recharge[2] | Backfill | 3% | 5% | 57% |

[1] Following the convention of Mackie, 2009

[2] Percent of annual rainfall (Station # 61086) equal to 645 mm/yr (www.bom.gov.au)

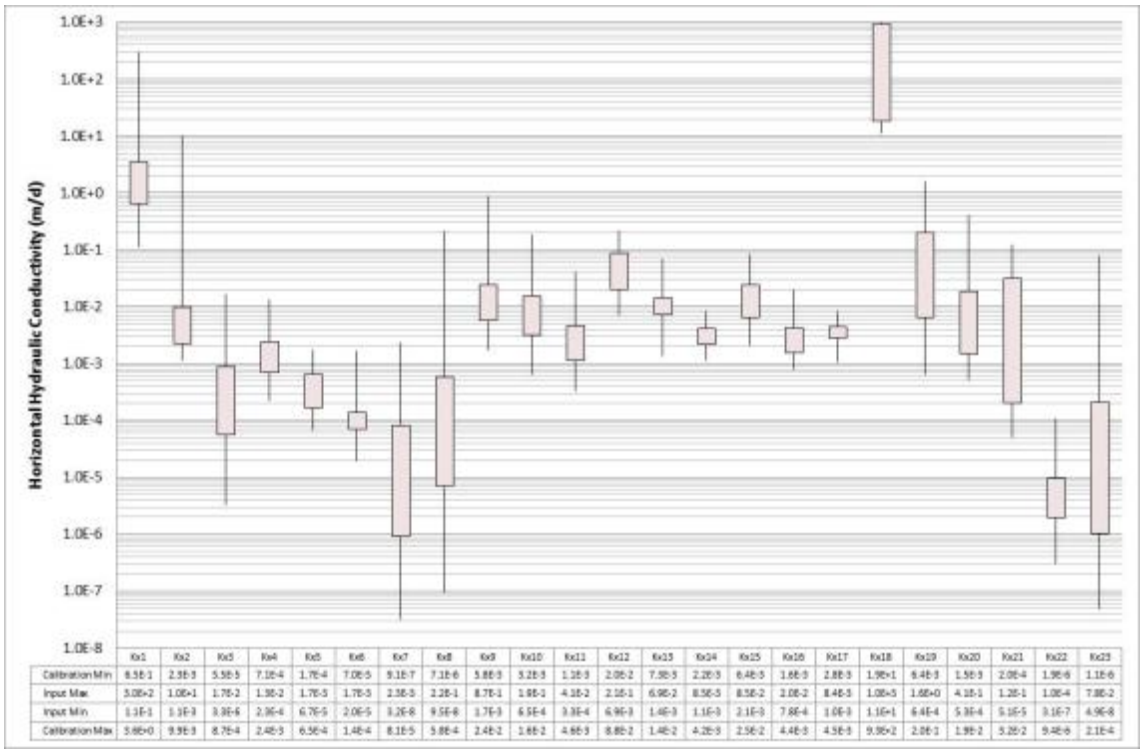



**Figure 10.12 – Model Parameter Sensitivity: Horizontal Hydraulic Conductivity**

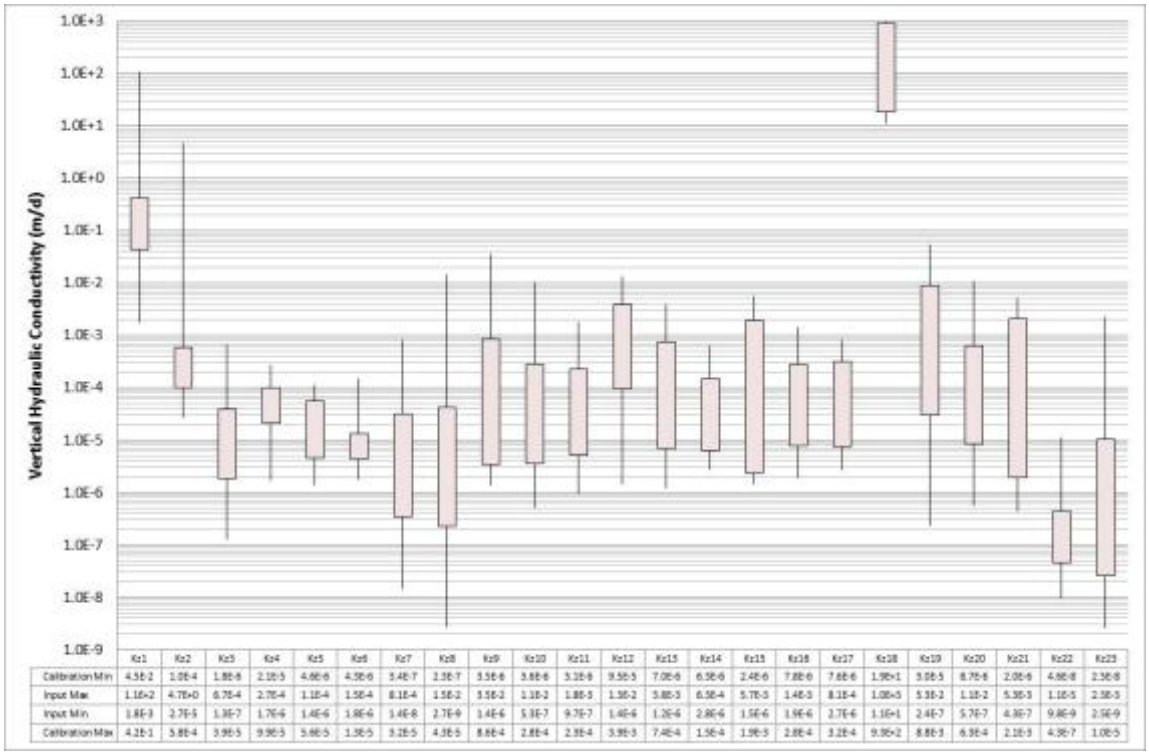



**Figure 10.13 – Model Parameter Sensitivity: Vertical Hydraulic Conductivity**

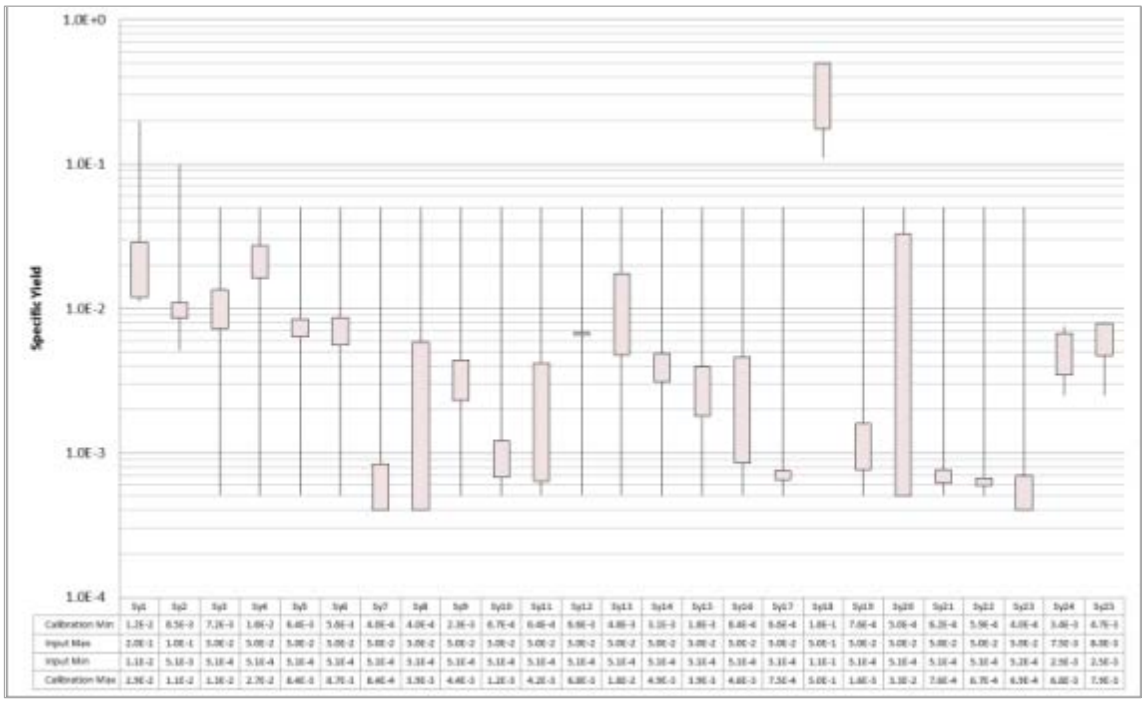
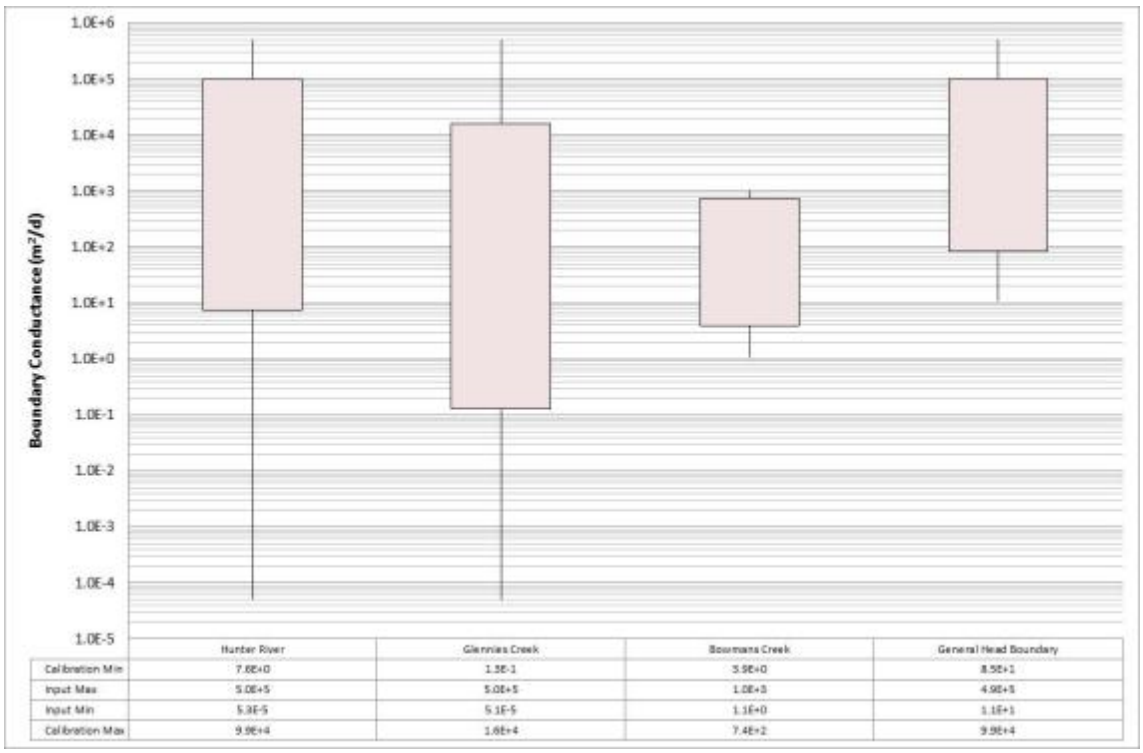



**Figure 10.14 – Model Parameter Sensitivity: Specific Yield**




| | Hunter River | Glennies Creek | Bowmans Creek | General Head Boundary |
|---|---|---|---|---|
| Calibration Min | 7.6E+0 | 1.3E-1 | 5.9E+0 | 8.5E+1 |
| Input Max | 5.0E+5 | 5.0E+5 | 1.0E+3 | 4.9E+3 |
| Input Min | 5.3E-5 | 5.1E-5 | 1.1E+0 | 1.1E+1 |
| Calibration Max | 9.9E+4 | 1.6E+4 | 7.4E+2 | 9.9E+4 |

**Figure 10.15 – Model Parameter Sensitivity: Boundary Conductance**

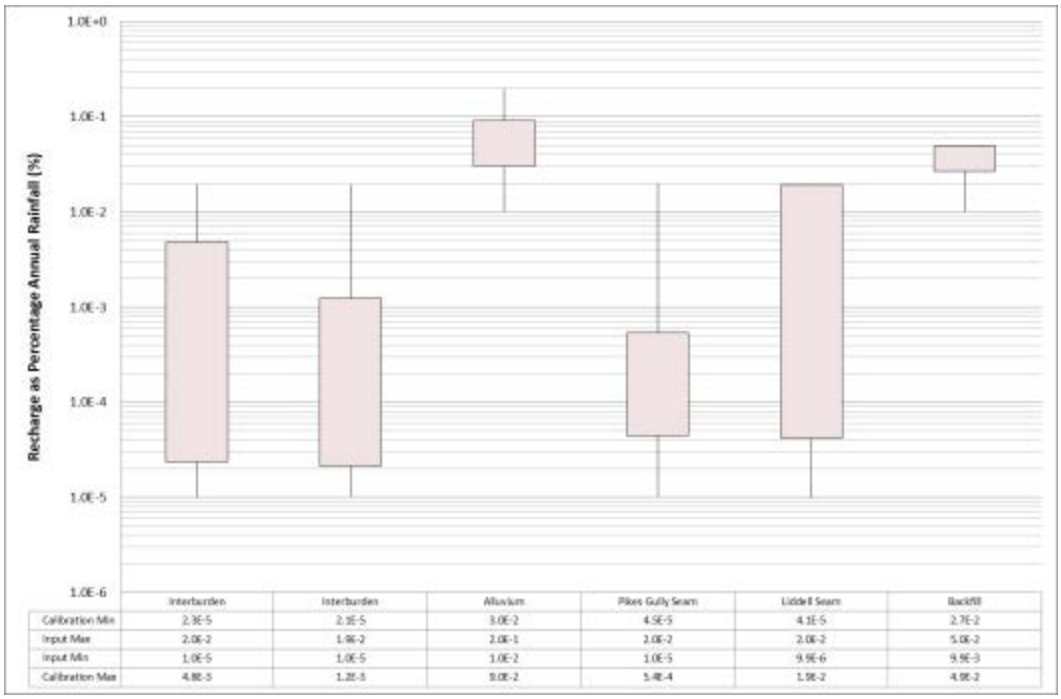



**Figure 10.16 – Model Parameter Sensitivity: Recharge**

### 10.2.1.7 Baseflow estimations

Loss of streamflow flow to Bowmans Creek due to reduced groundwater input was estimated from reduction in flow to stream cells along Bowmans Creek (refer **Figure 9.1** for gauge locations), and this was compared to baseflow estimations from analysis of streamflow data at the gauges along this creek (refer **Table 10.8**). Whilst the model provides output data at an annual time step, there is good agreement between the model and long-term median values at the gauges (**Figure 10.17**).

**Table 10.8 – Calculated baseflow component to streamflow at gauges along Bowmans Creek**

| Stream gauge[1] | Median baseflow[2] (ML/day) | Period of assessment |
|---|---|---|
| 210113 | 1.0 | 1980-1985 |
| 210115 | 3.9 | 1981-1985 |
| 210116 | 3.4 | 1982-1985 |
| 210042 | 0.4 | 1980-1999 |
| 210130 | 2.1 | 1993-2009 |
| [1] Gauge run north to south | | |
| [2] Calculated using Basejumper® software | | |

Thus, analysis of the “slow flow” component of the streamflow suggests this component may average between 0.4 to 4 ML/day. Equivalent long-term stream discharge calculated from the 12 calibrated realisations (shown below) range between 0.9 and 1.5 ML/day. The spread in values from the realisation results gives an indication of baseflow variability under dry to wet conditions, though this does not represent a true climatic variability assessment as recharge and evapotranspiration inputs and outputs have not been fixed to constrain different climatic conditions.

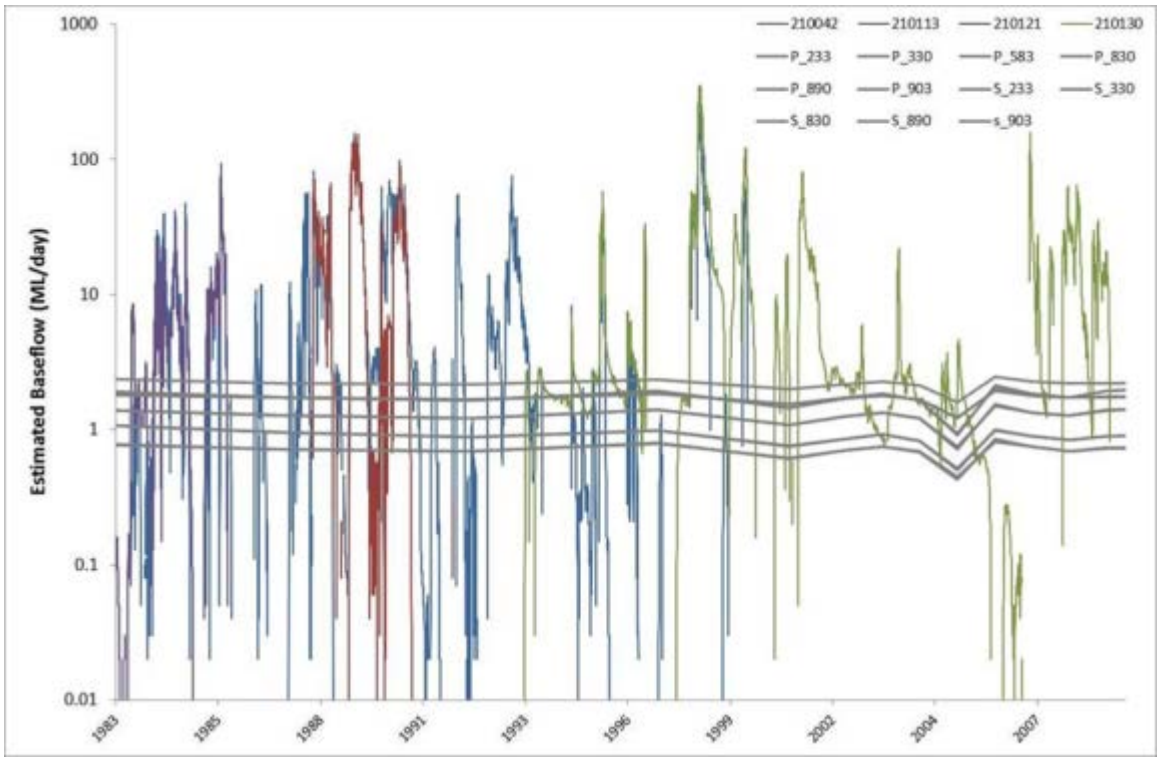



**Figure 10.17 – Modelled baseflow from the eleven calibrated realisations compared to estimated baseflow from streamflow data from gauges along Bowmans Creek**

The scale of model cells (100m x 100m) and temporal resolution (annual steps) precludes detailed and fully quantitative comparison, though the approximations can be used to assess comparable values. Results suggest an order of magnitude similarity as shown in **Figure 10.17**, but these results are not deemed of adequate quality to be reported in the Groundwater Impact Assessment.

#### 10.2.1.8 Mass balance considerations

Site water balance results and predictions are provided by Gilberts & Associates (2014). The groundwater inputs to the GoldSIM model used to estimate site water balance constituted lumped volumes for inflows to the open pits and losses from the alluvium. These lumped values were derived from a detailed groundwater balance for each year of the model. An example of the water balance values through time from the median realisation (#S890) is illustrated in **Figure 10.18**.

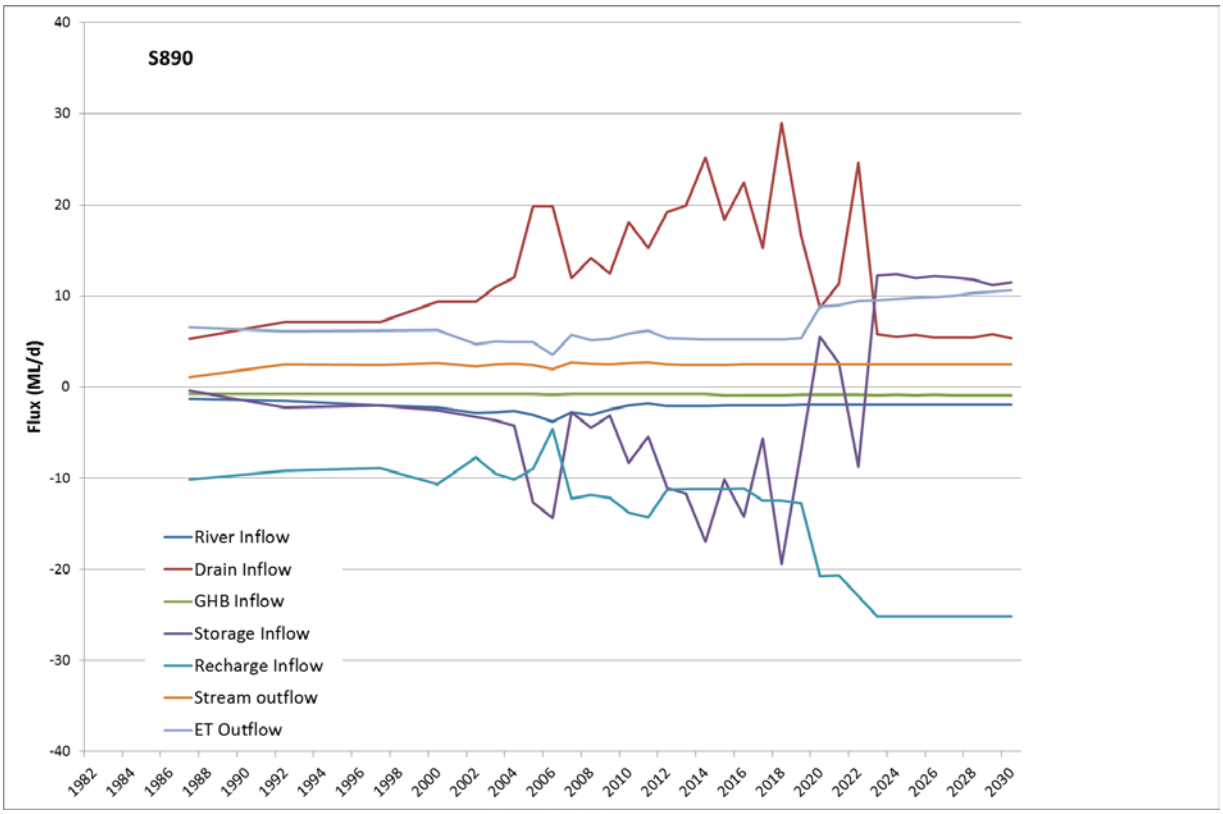
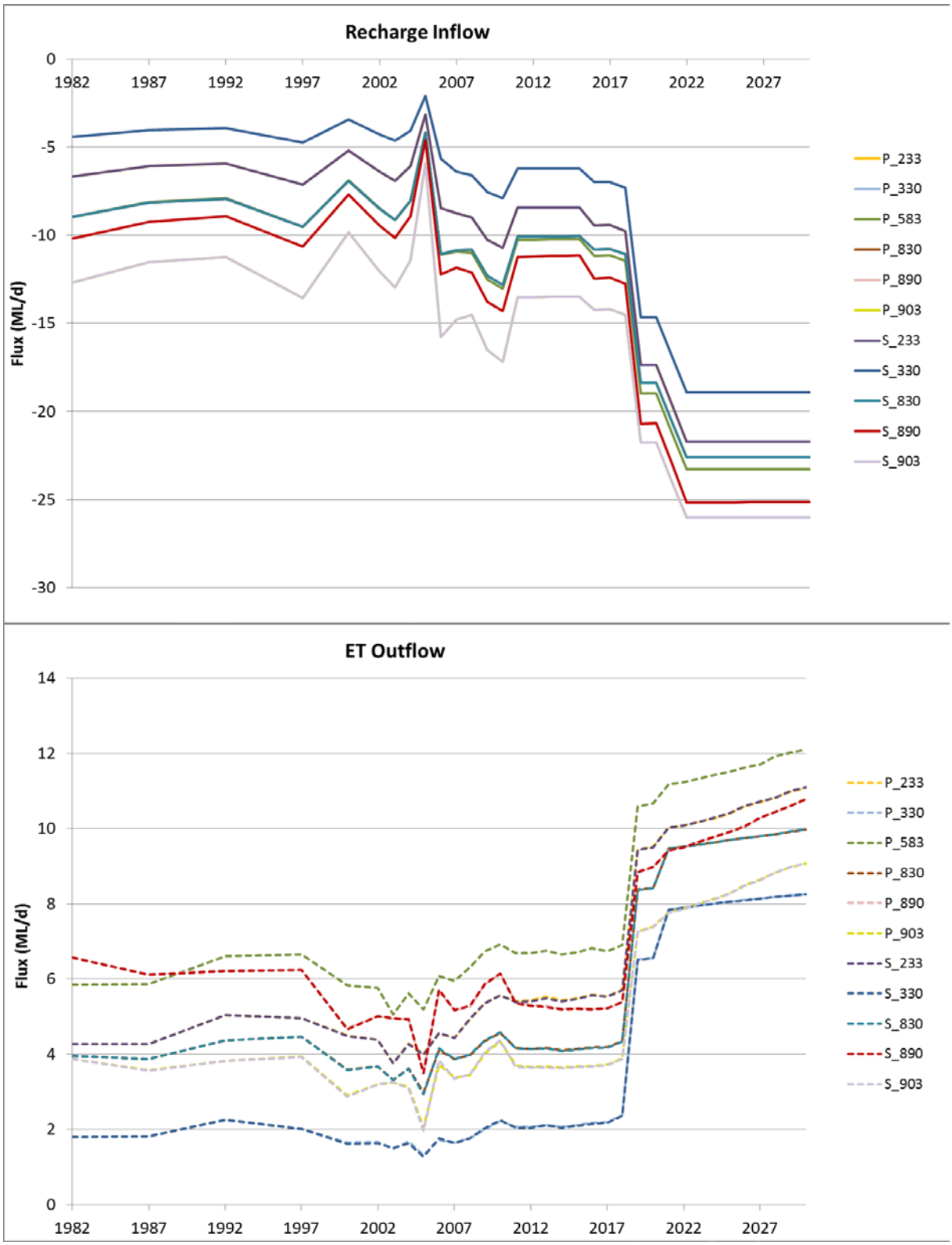
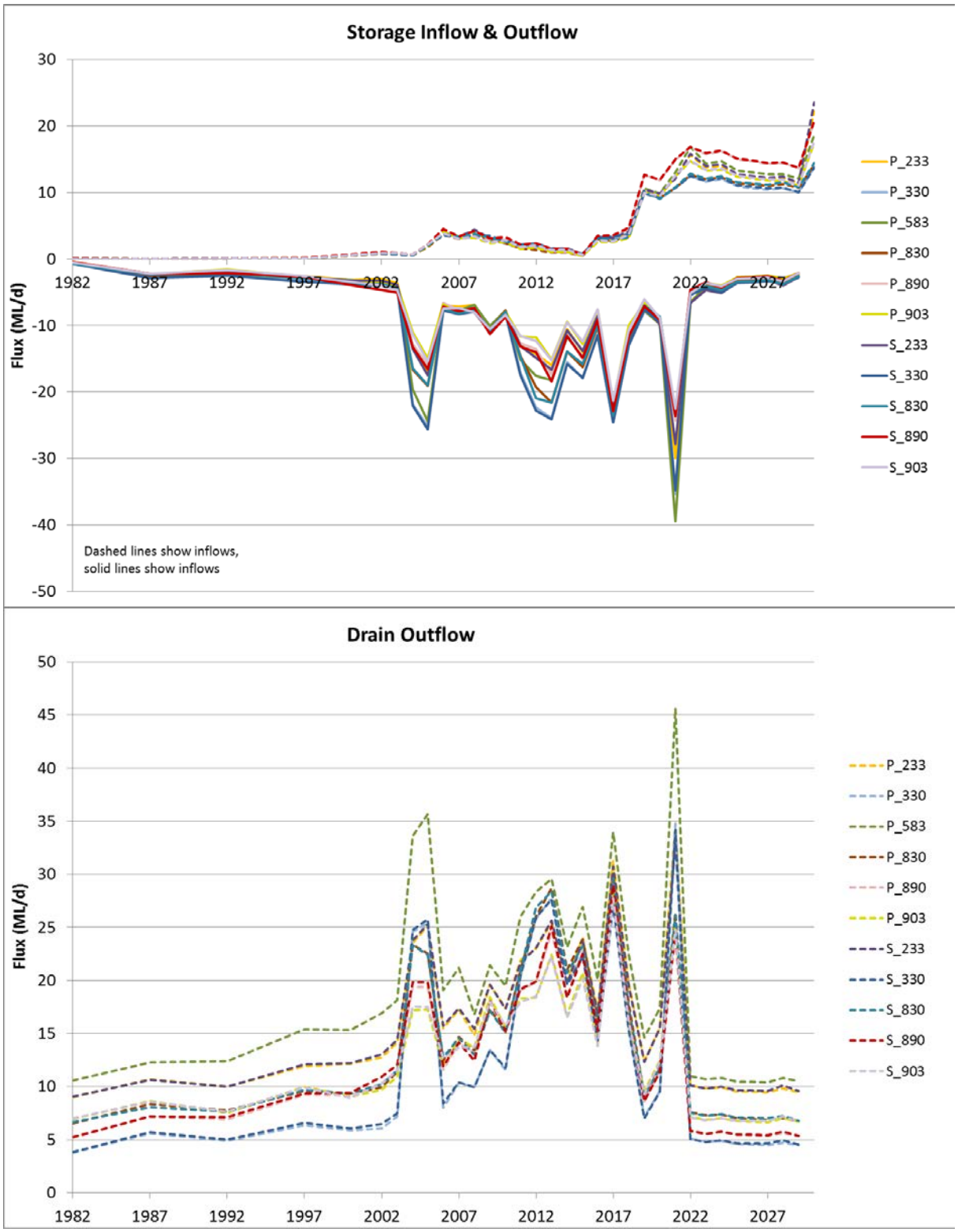


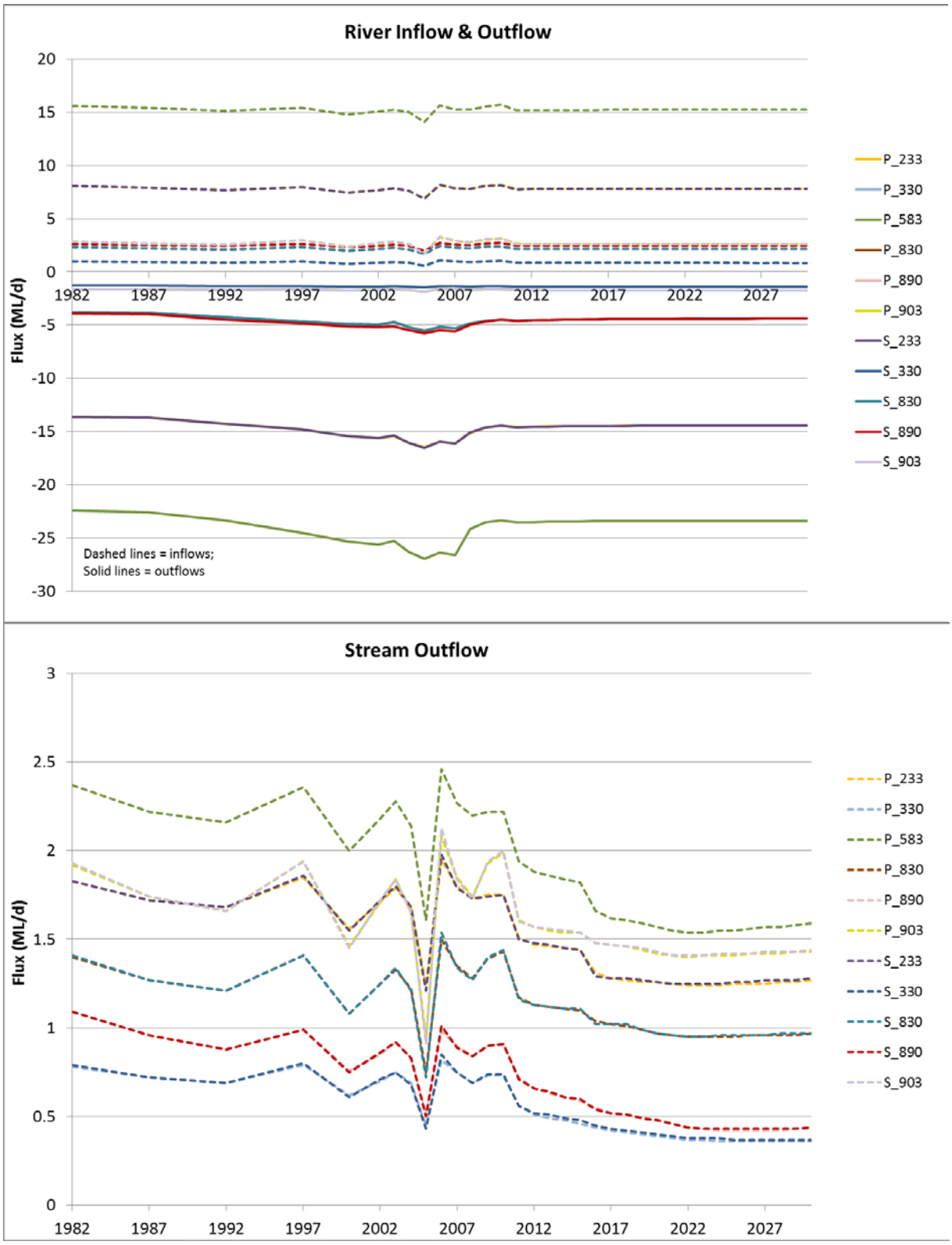

**Figure 10.18 – Temporal changes in water balance for the median calibrated realisation (S890)**

Realisation S890 represents the median water balance result from 11 realisations that satisfied all calibration criteria. The ranges of mass balance components across these realisations are illustrated in Figure 10.19. It should be re-iterated that while there is significant spread in some of the parameters, all realisations satisfied all calibration criteria, hence all are equally valid modelled results for the region. The wide spread in input parameter ranges (recharge, ET) provides a good surrogate for a sensitivity analysis while the tight spread of output parameters (inflows, drains) provides good confidence in the results and predictive results. The relatively flat river profiles indicate minimal impacts from the project, though the ephemeral stream outflows show greater variability but significantly lower total fluxes.

**Figure 10.19 – Mass balance parameter spreads across the 11 calibrated realisations**




Storage Inflow & Outflow
Flux (ML/d)
30
20
10
0
-10
-20
-30
-40
-50
1982
1987
1992
1997
2002
2007
2012
2017
2022
2027
Dashed lines show inflows,
solid lines show inflows
P_233
P_330
P_583
P_830
P_890
P_903
S_233
S_330
S_830
S_890
S_903
Drain Outflow
Flux (ML/d)
50
45
40
35
30
25
20
15
10
5
0
1982
1987
1992
1997
2002
2007
2012
2017
2022
2027
P_233
P_330
P_583
P_830
P_890
P_903
S_233
S_330
S_830
S_890
S_903




Of note from these time series, recharge and ET show a sympathetic response to mining and particularly reflect the impact of recovery following the end of mining in 2022 and rising water levels of the mine voids. Similarly, storage and drain inflows and outflows can be directly related to periods of mining activity and expansion phases of the project. The limited impact on rivers is indicated by the subdued temporal response in the river inflows and outflows.

### 10.2.2 Represent each water resource, storage and flow characteristics of each, linkages, if any between water resources, and the existing flow regime

***Including recharge and discharge pathways of the hydrogeological units, and any changes that are predicted to occur upon commencement of the development activities.***

The water balance schematic in **Figure 9.13a** and **Figure 9.13b** shows the linkages between each water source while the system conceptualisation in **Figure 10.8** illustrates the linkages and pathways.

LCO is an established open-cut coal mining operation and represents the current phase of coal extraction following earlier extensive underground and open-cut coal enterprises, which have altered the area's physical features and setting, including the regions surface water and groundwater systems.

### 10.2.3 Predictions of water flow rates and water level/pressure changes in each hydrogeological unit for the life of the project and beyond

Following model calibration, the stochastic datasets were used to run predictive simulations to investigate the potential impacts of mining activities on local aquifer systems. The objectives of the predictive simulations were to estimate:

- Potential reductions in groundwater flow to Bowmans Creek and its alluvial aquifer as a result of the proposed mine extensions;
- Drawdown in the bedrock and Bowmans Creek alluvium as a result of the Proposed Action;
- The cumulative impacts of the Proposed Action within the context of regional mining operations;
- Pit inflows and dewatering requirements; and
- Post mining equilibrium and the time period to reach equilibrium.

Predictive simulations were undertaken using three different scenarios in order to better quantify the potential impacts of the proposed mine extensions at LCO on groundwater resources:

- No Liddell case: including other mining operations in the area but excluding all historical, current and future mining activities at LCO;
- Approved case: simulates all historical, current and approved future mining operations at LCO; and
- Proposed case: includes all historical, current and approved future mining operations at LCO including the Proposed Action that is the focus of this assessment.

Model results for the No Liddell and Approved case simulations provide an estimation of the cumulative impacts to local groundwater resources that can be attributed to historical and currently approved mining operations at LCO. Results for the Proposed and Approved case simulations provide estimates of the additional impacts (if any) that can be attributed to the proposed extensions to open cut pits.

The annual progression of the South Pit and Entrance Pits simulated for the Proposed case scenario is shown in **Figure 10.5**. Drain cells within the boundary of the pit shells were progressively switched on for the years shown in **Figure 10.5** to simulate the extension of the pits under the Proposed Action. For modelling purposes progression of the South Pit beneath the MIA was simulated for the 2022 timestep. Initial predictive simulations including progression through the MIA in the 2023 timestep, as is planned, showed this extension has minimal impact on leakage rates and groundwater extraction requirements.

In addition to estimates of reductions in groundwater flow to alluvial systems and groundwater drawdown, the predictive simulations also provide estimates of pit inflows and dewatering requirements needed to accommodate the proposed extensions to open cut pits. **Figures 10.20** and **10.21** show estimated rates of pit inflows into the Entrance Pit and South Pit, respectively, for the duration of mining under the Proposed Action.

**Figure 10.22** shows the total estimated groundwater extraction required to accommodate the Proposed Action. The total extraction requirements are the sum of the pit inflows and dewatering rates predicted in the model simulations, with the rates determined in ML/year to allow comparison with groundwater extraction licenses held by LCO.

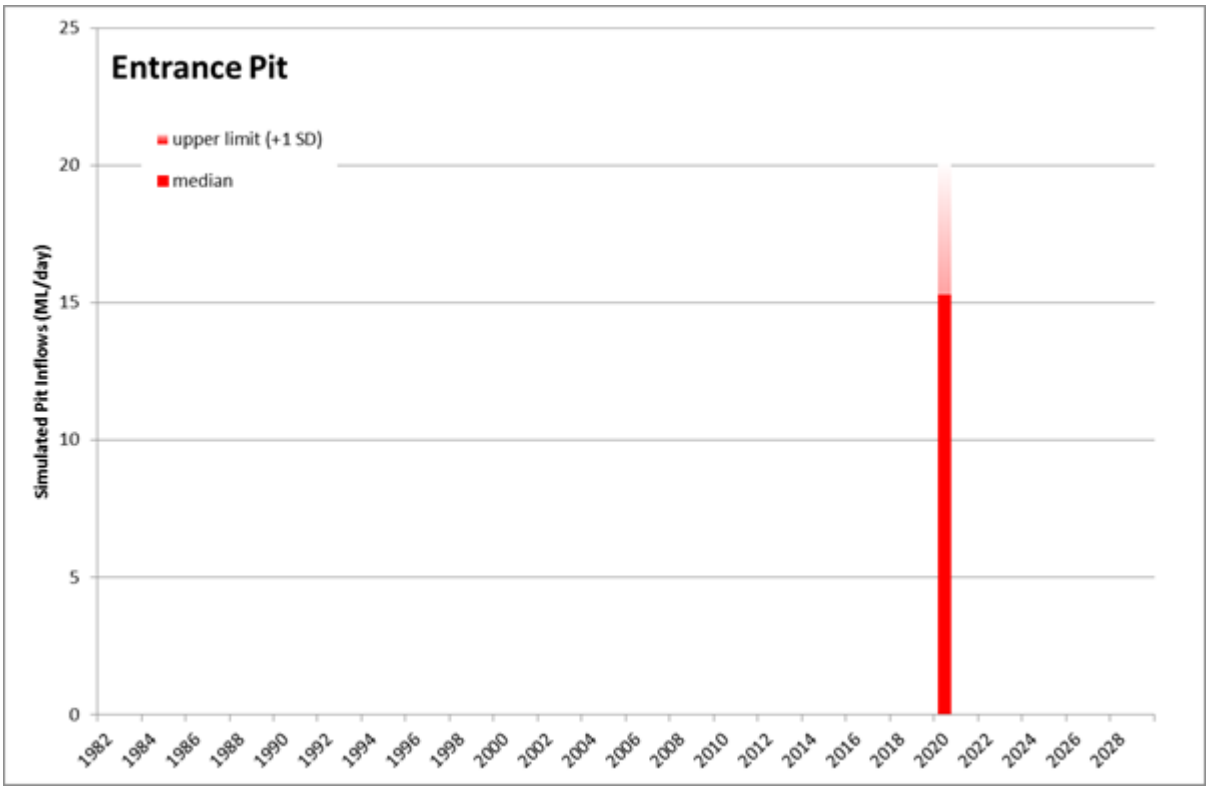



**Figure 10.20 - Estimated Pit Inflows to the Entrance Pit**

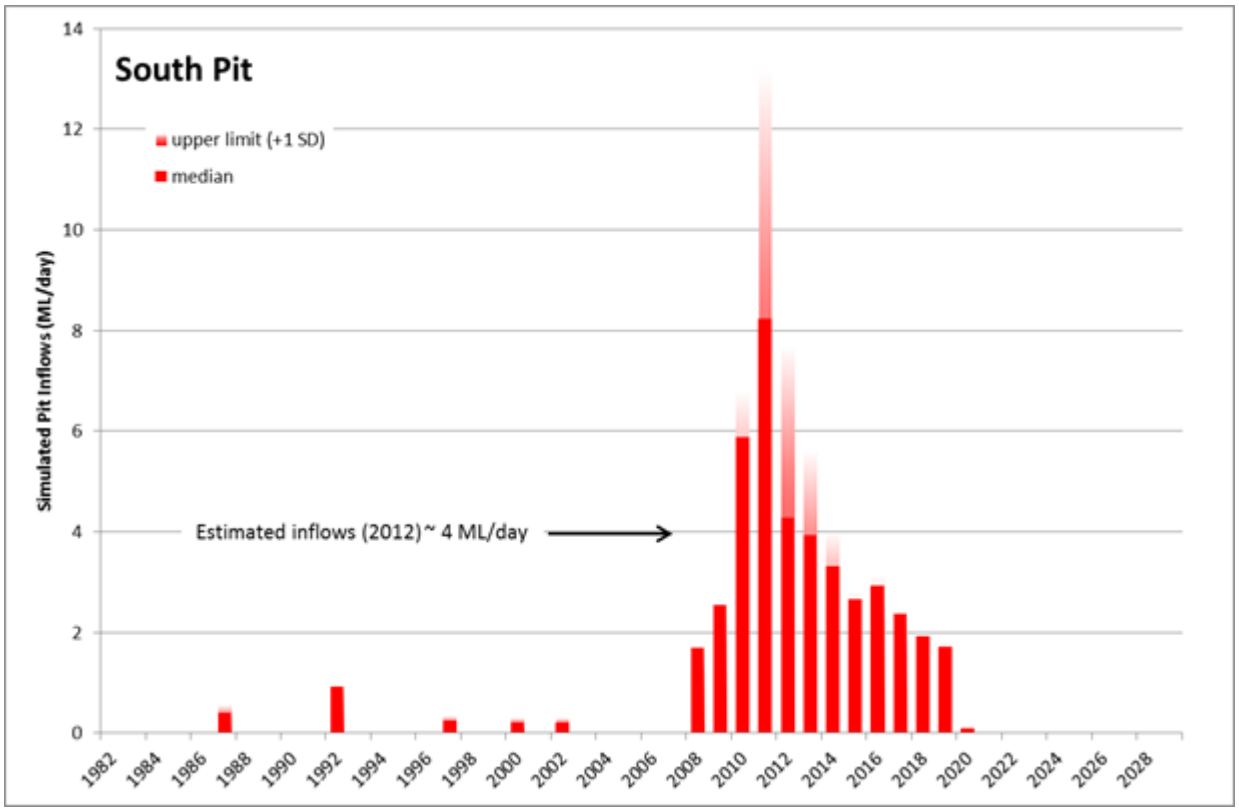



**Figure 10.21 - Estimated Pit Inflows to the South Pit**

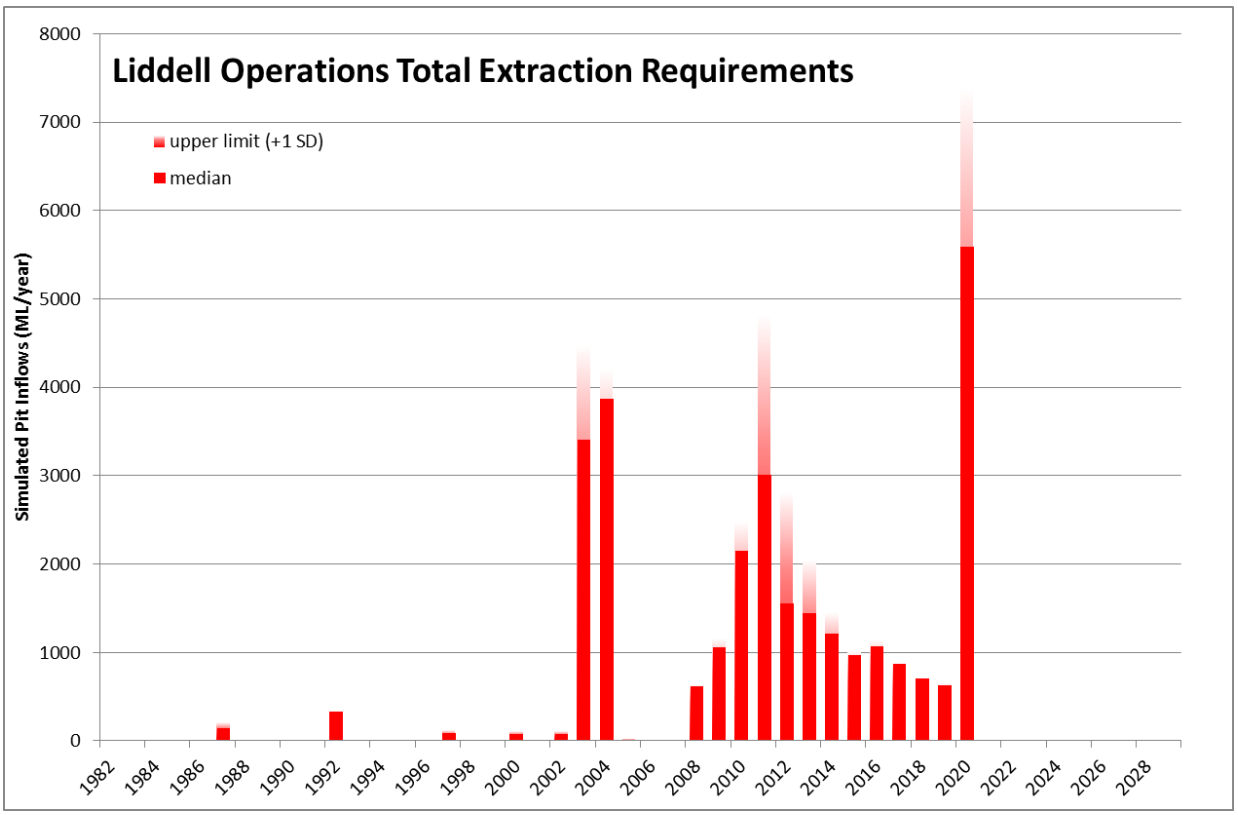



**Figure 10.22 - Total Estimated Groundwater Extraction Requirements**

### 10.2.4 Progress of development

***Including timing to maximum impact of water resources, including time to maximum drawdown and time for drawdown equilibrium to be reached, and timing for return to predevelopment conditions.***

Refer to information presented in **Section 10.2.6** below.

### 10.2.5 Identify the volumes of water predicted to be used on an annual basis

Water demands at LCO are described above in **Section 9.1.5.1** Model Inputs and Assumptions.

### 10.2.6 Potential recovery rates and timeframes in each water resource for the life of the project and until predevelopment conditions are expected to be achieved

**Post Mining Equilibrium**

Steady state post mining equilibrium simulations were conducted using final void water level information calculated by Gilbert & Associates (2014) in their water balance assessment for the Proposed Action. Water levels in the final voids of the South Pit and Entrance Pit determined by Gilbert & Associates (2013) were used as boundary conditions in the post mining equilibrium simulations. Results of the assessment and the post mining equilibrium simulations provided the following conclusions:

- Groundwater levels within the final voids of the South Pit and Entrance Pit are predicted to recover and stabilise to approximately 67 m AHD within 50 years following the end of mining.

- Peak estimated inflow rates to the Entrance Pit and South Pit final voids are predicted to be approximately 43 ML/day and 14 ML/day, respectively.

- Steady state simulations using the predicted final void equilibrium water levels indicate the Entrance Pit final void will act as a sink for groundwater flow from the surrounding hard rock aquifer (i.e. groundwater heads in the surrounding aquifer will be greater than the final void water level), and the South Pit final void will act as a source of groundwater flow to the hard rock aquifer when water levels are above approximately 65 m AHD.

- As parts of the final voids will not be backfilled, evaporation is predicted to cause salinity in the South Pit to increase continuously over time. Salinity levels in the Entrance Pit are predicted to stabilise at approximately 4,200 mg/L, as illustrated in **Figure 10.23** due to groundwater inflows and water transfer to the South Pit via the remnant Middle Liddell underground workings.

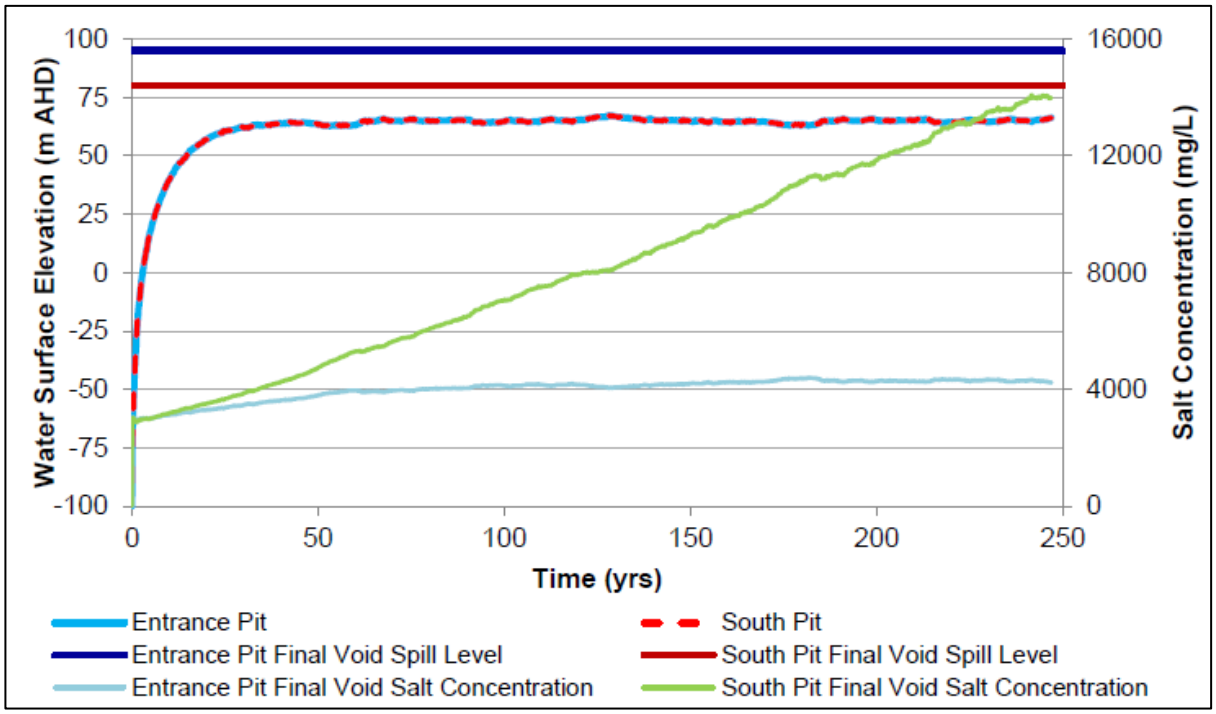



**Figure 10.23 - Predicted final void water levels and salt concentrations for the mined pits (Gilbert & Associates, 2014)**

- Steady state post mining equilibrium simulations indicate groundwater heads within the Bowmans Creek alluvial aquifer will recover to levels equal to or above the estimated and observed levels at the introduction of the Hunter Unregulated and Alluvial WSP 2009, and above water levels in the Entrance Pit and South Pit final voids. No leakage will therefore occur from the final voids to the alluvial aquifer.

Potential long term impacts to groundwater in the hard rock aquifer may result from leakage of increasingly saline water from the South Pit final void when water levels in the void rise above approximately 65 m AHD. However, the groundwater in this aquifer is already brackish, and no users of this aquifer have been identified.

### 10.2.7 Model Review and Update

The numerical groundwater model has been peer-reviewed by Dr Noel Merrick (HydroAlgorithmics).

Review of the groundwater model based on the on-going collection of monitoring data is discussed in **Section 11**, and specifically in **Table 11.1**.

## 10.3 Cumulative and Indirect Impacts

### 10.3.1 Estimates of sediments as total suspended solids and salts (including metals, metalloids and organic salts) being discharged from the proposal

***This should also include estimates from overflow events from mine and sediment dams. These figures should be compared to background load levels, and with the estimated loads from current and likely future developments, both upstream and downstream***

As described above in **Section 10.1.10**, the only offsite discharges predicted by the site water balance for the Proposed Action are from Sediment Dam A, and this only occurs when it is receiving water from fully rehabilitated areas. No uncontrolled discharges offsite from any other storage is predicted. All controlled releases that occur throughout the modelled period are made in accordance with the water quality and volume requirements of the HRSTS, with less than 800 ML released annually on average across all realisations.

### 10.3.2 Mapping of existing and proposed mining and exploration activities within the catchment and region

**Figure 10.24** illustrates the mines in the region. Refer also to **Figure 1.2** (Proposed Action) and **Figure 9.7** (existing underground workings at LCO).

### 10.3.3 Total existing and planned licensed and actual take of water for consumptive, industrial and agricultural purposes in the surface catchment and ground water basin within which the proposed action is based

LCO currently holds several different licenses to extract groundwater from water sources in the area to accommodate mining operations. These licenses include allocations to extract groundwater from Jerrys Water Source, which is regulated under the Hunter Unregulated and Alluvial WSP (2009), as well as allocations to extract water from deeper regional hardrock aquifers where the targeted coal measures are found. **Table 10.9** provides a summary of the current extraction licenses held by LCO. Current licensing allocations permit LCO to extract a total of 142 ML/year from Jerrys Water Source, which includes Bowmans Creek and its associated alluvial aquifer system, and up to 27,000 ML/year (27 GL/year) from the regional hard rock aquifer.

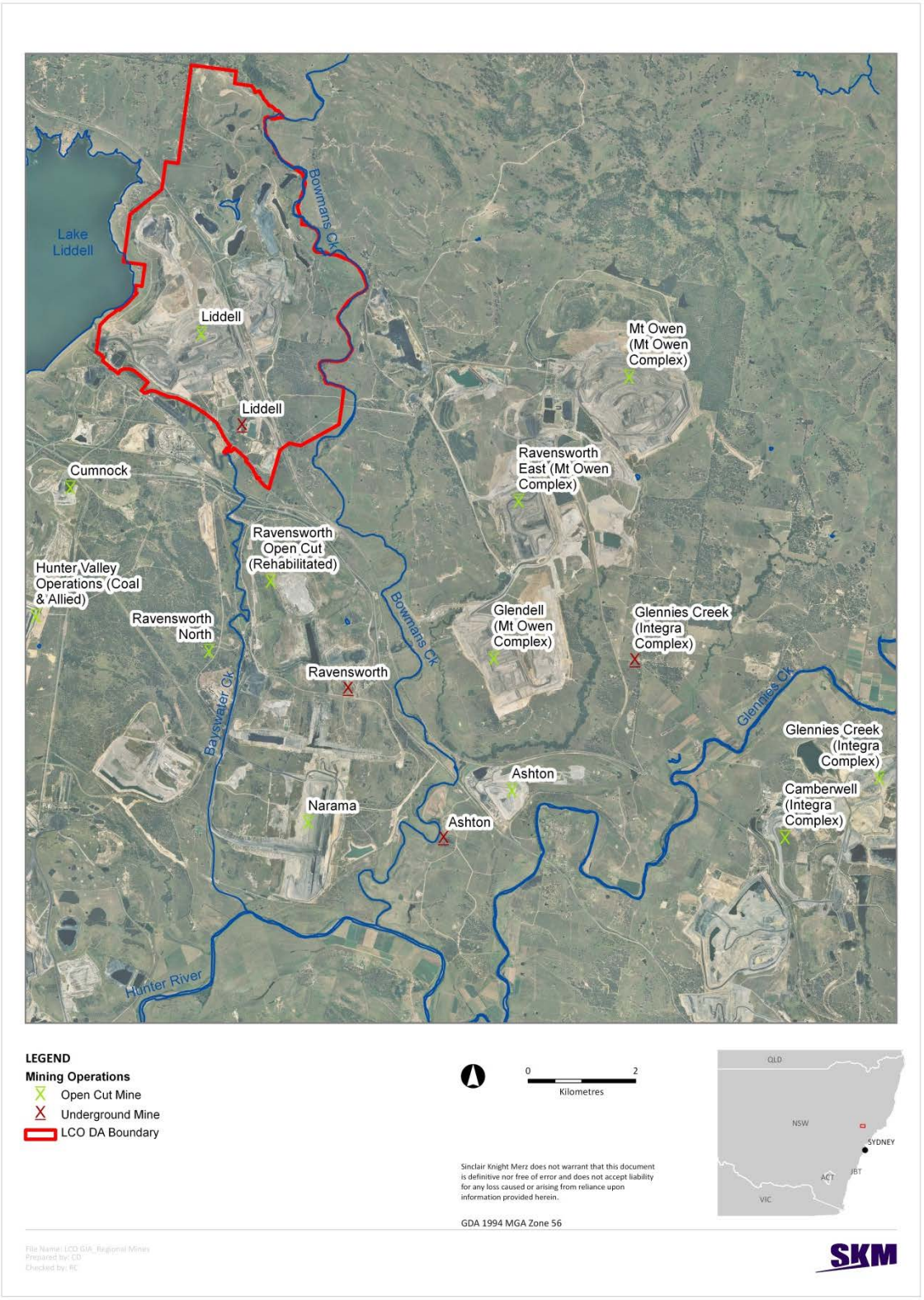



**Figure 10.24 – Mining Operations in the Region**

**Table 10.9 – Summary of Groundwater Extraction Licences held by LCO**

| Name / Licence No. | Licence Holder | Water Source | Type / Use | Allocation | Status / Notes |
|---|---|---|---|---|---|
| Surface water licences | | | | | |
| WAL18304 | Enex Foydell P/L | Jerrys Water Source | Irrigation | 32 | On Glendell land |
| WAL18318 | Enex Foydell P/L | Jerrys Water Source | Irrigation | 55 | |
| WAL18320 | Enex Foydell P/L | Jerrys Water Source | Irrigation | 50 | Mt Owen Complex 50 unit share - responsible |
| Groundwater licences | | | | | |
| WAL18302 | Liddell Southern Tenements P/L | Jerrys Water Source | Irrigation | 5 | |
| Haz 2 / 20BL168060 | Liddell Tenements P/L | Hardrock (Coal Measures) | Industrial | 5500 | Dewatering into Hazeldene workings |
| Durham 2 & 4 | Liddell Tenements P/L | Hardrock (Coal Measures) | Industrial | 1000 | |
| 8 South 3 & 4 | Liddell Tenements P/L | Hardrock (Coal Measures) | Industrial | 6000 | Dewatering into Hazeldene workings east of Barrier Pit |
| Durham 1 | Liddell Tenements P/L | Hardrock (Coal Measures) | Industrial | 6000 | Dewatering into Liddell workings |
| M49 | Liddell Southern Tenements P/L | Hardrock (Coal Measures) | Dewatering | 2500 | |
| Middle Liddell | Liddell Coal Operations P/L | Hardrock (Coal Measures) | Dewatering | 6000 | |

### 10.3.4 Total existing and planned discharges of waste water

***And injections of water into hydrogeological units from other mining and industrial purposes in the surface catchment and ground water basin within which the proposed action is based;***

No water is re-injected into hydrogeological units at LCO, nor through any other mining operations in the region. Rather, water is pumped from the former underground workings at LCO to surface water storages, primarily the RWTV. This is done to prevent inflow to the open cut pits (from the former underground workings) from disrupting the open cut operations. Occasionally during high storm events, some surface water in surface water storages is pumped into the underground workings for temporary storage, rather than allowing discharge to local creeks.

Mine water supply is drawn from these former underground workings, which act as sinks and storage areas for regional groundwater (SKM, 2014). The RWTV is also used to store water transferred to site from Coal & Allied operations (via agreement). Current water uses on-site comprise make-up to the CHPP, control of spontaneous combustion, and haul road dust suppression. In addition, water may be sent off-site to Coal & Allied operations at a rate of 1820 ML per year (by agreement) and to the Mount Owen Complex at a rate of approximately 5 ML/d.

LCO hold 66 credits under the HRSTS. Pumping infrastructure currently limits the discharge rate from the RWTV to Chain of Ponds Creek to approximately 45 ML/d. LCO may increase this rate in the future subject to the limitations of EPL2094.

### 10.3.5 Existing water quality guidelines, targets, environmental flow objectives and requirements

***for the ecosystems of the surface catchment and ground water basin within which the project is based;***

The NSW Aquifer Interference Policy clarifies water licence requirements and details how these potential interference activities will be assessed under relevant planning and approvals processes. The policy provides 'minimal impact considerations' to evaluate potential impacts on groundwater levels, pressures, and quality for different categories of groundwater sources. The policy also includes provisions for water take from a source following the cessation of the aquifer interference activity.

### 10.3.6 The proportional increase in water resource use and impacts as a consequence of the proposed action

Estimates of total groundwater extraction rates (i.e. dewatering rates plus pit inflows) required to accommodate the Proposed Action peak at approximately 5,500 ML/year. LCO currently holds sufficient licenses (27,000 ML/year) to extract groundwater from the regional hard rock aquifer to accommodate these flows.

With the exception of the final year of mining in the Entrance Pit, total extractions will decrease during the period of the mine progression. Following the end of mining, groundwater will recover to pre-mining levels. There will be no additional impact as a result of the Proposed Action.

### 10.3.7 The overall level of risk to water-related assets that combine probability of occurrence with severity of impact of current or potential multiple actions.

The overall risk to water-related assets in the region is considered to be negligible in consideration of prior impacts from earlier mining operations. Thus, the region operates under a revised equilibrium and all current water-related assets have either adapted to this new regime, or will not be impacted.

The long history of underground mining in the LCO area has impacted upon Bowmans Creek at various times and in different ways, including leakage induced by depressurisation of the seams at depth, and leakage down connective cracking as a result of subsidence related failures. In all cases of recorded surface water disruption thought to be due to cracking, a return to normal flow conditions has been observed, indicating that the alluvium system has capacity to re-seal within a short time-frame (within 1-3 years (MER, 2001). Further details are reported in SKM (2014).

# 11.0 PROPOSED SAFEGUARDS AND MITIGATION MEASURES

A precautionary approach has been applied to the development of the regional groundwater model by SKM for predicting the potential groundwater related impacts of the Proposed Action. The model results are therefore considered conservative, and predict that until the final year of mining in the Entrance Pit, there will be minimal impact (as defined in the NSW Aquifer Interference Policy, 2012) in the magnitude of alluvial losses from Bowmans Creek compared to that associated with current approved operations. Peak modelled alluvial losses are not anticipated to occur until the last stage of mining in the Entrance Pit, and even at its peak, alluvial losses are not predicted to result in a significant impact on Bowmans Creek and its alluvial aquifer.

LCO will therefore adopt an adaptive management approach to the monitoring and mitigation (if necessary) of any impacts beyond those predicted to the Bowmans Creek alluvial system, particularly as open cut mining activities progress across the dyke and Davis Creek Fault in the Entrance Pit. The key commitments of this approach are described in the sections below.

## 11.1 Water quality and quantity trigger values

Refer to **Section 9.1.4**.

## 11.2 Water Monitoring Program

Details of the baseline monitoring program are provided in **Section 9.1**, and additional information on proposed monitoring, particularly in relation to adaptive management, is provided below.

### 11.2.1 Regional Monitoring

LCO currently undertakes a comprehensive groundwater monitoring program (Umwelt, 2013e), with results reported in Annual Environmental Management Reports. The current groundwater monitoring network is shown in **Figure 9.7** and includes piezometers in the Bowmans Creek alluvium and shallow bedrock (overburden) and bores in the target coal measures. The piezometers are measured monthly for groundwater level and every two months for water quality. Eleven of the piezometers are also sampled biannually, and groundwater samples are analysed for a range of parameters (anions, cations, metals, inorganics, physico-chemical) (Umwelt, 2013e).

Currently, monitoring is focussed along Bowmans Creek (and tributaries) on the eastern side of LCO. The western side of operations coincides with the artificial Lake Liddell and the highly regulated Bayswater Creek and monitoring of these areas would not provide useful baseline or modelling calibration data.

Model simulations of the Proposed Action predict drawdown to occur within the Bowmans Creek alluvial aquifer to the southeast of the Liddell DA boundary. Drawdown in the alluvium is predicted to peak at the end of mining, though the incremental drawdown resulting from the Proposed Action is predicted to be less than one metre. Taking into account the extent of the current monitoring network, additional sites from the recently established Mt Owen Complex Groundwater Investigation Program (SKM, 2012) should be added to the monitoring program in order to better evaluate the potential impacts of the proposed mine expansion on the Bowmans Creek alluvial system. These bores include shallow alluvial standpipes as well as multiple depth vibrating wire piezometers (VWPs) along Bowmans Creek to the southeast of LCO.

### 11.2.2 Water Quality

The water management plan (Umwelt, 2013d) and groundwater monitoring program (Umwelt, 2013e) currently in place at LCO references the trigger values provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000) as default criteria. The 80th percentile trigger values provided in the ANZECC (2000) guidelines have been adopted due to the highly disturbed nature of the site (Umwelt, 2008). The data indicates that analyte concentrations in groundwater samples at LCO generally fall below the adopted criteria. Exceedances of the default criteria are observed for heavy metals copper and zinc and to a lesser extent aluminium, lead and nickel. No major trends are apparent for these species during the monitoring period however, indicating minimal impact on groundwater quality as a result of mining activities.

Continued monitoring under this plan will continue. In addition, a series of new standpipes and piezometers have recently been installed on Bowmans Creek, to the south of LCO, and these will be incorporated in the monitoring program of LCO.

Where monitoring indicates an exceedance of water quality trigger values, the response protocol documented in the LCO Surface and Groundwater Response Plan will be followed. This response protocol states that where surface or groundwater quality monitoring results exceed the trigger values an investigation into the exceedance will be undertaken as follows:

- confirm the timing and general location of the exceedance(s);
- confirm the meteorological conditions at the time of the exceedance(s) (where relevant);
- identify any potential contributing factors;
- assess the monitoring results against background trends to identify any anomalies or causes;
- develop appropriate mitigation and management strategies;
- implement the mitigation and management strategies;
- implementation and review of additional monitoring to measure the effectiveness of the strategies undertaken; and
- report the exceedance where applicable to the relevant authorities.

## 11.3 Bowmans Creek Alluvial Aquifer

Model simulations predict that leakage from the Bowmans Creek alluvium into the underlying strata occurs as a result of current operations at LCO and will continue under the Proposed Action. The additional leakage, however, is not expected to have a significant additional impact on groundwater levels within the alluvium as a result of the Proposed Action. Cumulative impacts from LCO and surrounding operations are not predicted to significantly alter the current flow regime of Bowmans Creek. LCO will continue monitoring of the alluvial system to ensure this is the case. Such monitoring and management is especially applicable towards the end of the Proposed Action when the predicted leakage rates increase.

Based upon the impact assessment and predictive model results, an adaptive management strategy is proposed for the monitoring and (if necessary) mitigation of any potential unacceptable impacts to the Bowmans Creek alluvial system. Key aspects and justification for this approach are presented in **Table 11.1**.

**Table 11.1 - Adaptive Management Approach for Groundwater Management**

| Management Approach | Discussion |
|---|---|
| Continue monitoring the alluvial and shallow bedrock groundwater systems in accordance with the current Groundwater Monitoring Program for LCO | • Site monitoring data suggests current operations are having negligible impacts on the alluvial system, and model results predict that leakage rates will not significantly increase over and above those estimated for current operations. The progression of the South Pit, which with the exception of the MIA, finishes in approximately Year 5 (2019), therefore appears to have negligible impact on the alluvial system compared to current mine operations. |
| Supplement the existing monitoring program with additional monitoring locations for the alluvial system, focusing on those areas predicted by the model to have drawdown as a result of the proposed modification | • Site monitoring data suggests current operations are having negligible impacts on the alluvial system, and model results predict that drawdown may occur in the alluvial aquifer to the southeast of the LCO DA boundary. Including the shallow alluvial standpipes and VWPs installed as part of the Mount Owen Complex Groundwater Investigation Program (SKM, 2012) would provide suitable additional locations to monitor and track these predicted impacts. |
| Continued refinement and re-validation of the groundwater model with additional data collected to provide more confidence in the predictive results | • As with any model representations of real systems, additional site data will allow alteration and refinement of the model and will provide added confidence in the results. The groundwater model was constructed using a pre-cautionary approach, with results considered to represent conservative estimations of potential impacts. The results of monitoring programs and additional studies can be used to determine the frequency of refinement for the model. |
| If necessary, pursuit of additional licenses for the Jerrys Water Source to cover the predicted losses from the Bowmans Creek alluvial system | • Based on the predictive modelling results, LCO currently holds sufficient water licence allocations for the Jerry Water Source to account for the estimated losses from the Bowmans Creek alluvium for the life of the Proposed Action. |
| If and where necessary, adjustment of mining and/or dewatering plans to mitigate unacceptable actual or predicted impacts on the alluvial system | • Given the predicted impacts to the alluvial system do not significantly increase over and above those estimated for current operations (and all impacts are currently deemed to be of minimal impact), on-going data collection will be used to verify model predictions and determine whether corrective action is required. |

## 11.4 Dewatering and Inflow Management

The current water management system at LCO has been designed to address four main areas:

- Surface water runoff to existing pits and operation areas;
- Groundwater seepage in open cut and old underground workings;
- Mine operation water for the coal handling and processing plant and dust suppression; and
- Off-site discharges and water sharing arrangements.

The water management system includes a system of surface water structures designed to separate and capture surface runoff and seepage water from open cut pits and collect groundwater extracted from dewatering bores. Under current operating conditions the site water balance results in LCO being a net water producer, with surplus water being exported to surrounding mines.

Groundwater modelling undertaken for this assessment has provided estimates of dewatering rates and pit inflows for the Proposed Action (**Figure 9.13**). The current Water Management Plan (Umwelt, 2013d) will be reviewed and updated to ensure the management system can accommodate these estimated loads. The update will include a review of the site water balance, erosion and sediment control plan, and surface water and groundwater response plan to account for the estimated extraction loads and expansion of open cut pits. Given the Proposed Action falls entirely within the approved LCO DA boundary and extends current open cut operations, significant amendments to the water management strategy and site water balance are not expected to be required.

## 11.5 Review and Reporting

As mentioned above, the existing Water Management Plan and Groundwater Monitoring Program for LCO will be updated to include the above management and monitoring recommendations. In line with current practice, the water management system, site water balance, and monitoring results will be subject to an annual review by an experienced hydrogeologist and reported in LCO's Annual Environmental Management Report. Should any review or monitoring data indicate significant variance with model predictions, existing monitoring data, or otherwise suggest substantial and/or unexpected impacts to surface water or groundwater systems, the implications and potential risks will be assessed and appropriate response actions undertaken in accordance with the Surface Water and Groundwater Response Plan contained in the Water Management Plan.

In addition, after commencement of the Proposed Action, the groundwater model should continue to be updated and refined as additional data are collected to evaluate model predictions with respect to site monitoring data. When necessary, model re-calibration and predictive scenarios will be undertaken to reduce model uncertainty and provide confirmatory predictions.

# 12.0 CONCLUSION

LCO seeks to modify to DA 305-11-01 under section 75W of the NSW EP&A Act to allow for the extension of open cut mining operations beyond the currently approved mining footprint, so as to maximise coal recovery and maintain continuity of coal production. The Proposed Action relates to areas of proposed additional disturbance associated with an extension of the existing Entrance and South Pits to the south east within DA 305-11-01.

In a letter dated 21 October 2013, LCO were advised by DoE that the Minister's delegate determined the Proposed Action to be a controlled action. In the DoE's Decision of Referral Letter, the controlling provisions listed were listed threatened species and communities (sections 18 & 18A), listed migratory species (sections 20 & 20A) and a water resource (sections 24D & 24E). The MNES specifically mentioned by the DoE were the Large-eared Pied Bat (*Chalinolobulus dwyeri*), Swift Parrot (*Lathamus discolor*), Regent Honeyeater (*Acanthochaera Phrygia*) Spotted-tailed Quoll (*Dasyurus maculatus maculatus*) and the Green and Golden Bell Frog (*Litoria aurea*).

None of the MNES mentioned have been recorded in the Referral Area. Based on the lack of local records of the identified MNES, with the exception of the spotted-tailed quoll, and the loss of a small area of moderate/poor quality habitat, it is not likely that the potential impacts of the Proposed Action will threaten the persistence of these species in the local area or region.

With regard to the spotted-tailed quoll, whilst no records of this species have been obtained within the Referral Area, there are a number of records of this species in the general locality, in the land to the east and north-east of Lake Liddell and to the north of the New England Highway. The Proposed Action will remove 180 ha of potential foraging habitat for this local population. However, most of the habitat is likely to be of moderate habitat quality at best, and the habitat loss will be staged so that the resulting impact to potential habitat for this species will occur over a number of years. Although the loss of 180 ha of potential foraging habitat is important in the local context, at the scale of the regional population defined for this assessment it constitutes only 0.11 per cent of habitat which is potentially available for the spotted-tailed quoll. Based on the application of the precautionary principle it was concluded however that as a result of this indirect impact of loss of potential habitat, the Proposed Action has the potential to result in a significant impact on this species.

A comprehensive biodiversity offset strategy has therefore been developed to offset the residual impacts of the Proposed Action on ecological values, including on MNES. This strategy includes the Mountain Block Offset Area, a 166 ha property located immediately north-west of LCO. In addition, as part of the offset strategy habitat enhancement works will be undertaken along the Bowmans Creek riparian corridor, totalling 183 ha, within the LCO DA boundary, with the specific purpose of enhancing existing habitat, and in particular providing additional habitat for the spotted-tailed quoll.

In relation to water resources, the Referral Area is located within two sub-catchments of the Hunter River catchment. Lake Liddell bounds LCO to the west and is an artificial lake constructed to supply water to several coal-fired power stations in the area. The lake was created by damming Bayswater Creek, which bounds LCO to the south west. Bayswater Creek is a highly modified system, designed in its upper reaches to take flow from Lake Liddell and the HRSTS, with its lower reaches realigned to allow mining at Ravensworth South and Narama mines. Bowmans Creek bounds LCO to the east and drains a catchment area of approximately 250 square km. LCO's proposed extension to the open cut Entrance Pit is in close proximity to Bowmans Creek and its associated alluvial deposits.

A numerical groundwater model was developed for the Proposed Action, which has been peer reviewed and subsequently deemed 'fit for purpose'. Groundwater drawdown will occur as a result of the Proposed Action, with model simulations predicting a peak drawdown within the Bowmans Creek alluvial aquifer of less than two metres. This estimated peak drawdown is highly localised and short term, expected to be limited to just one year at the end of mining. This impact falls below the minimal impact

criteria (less than two metre drawdown) for aquifer interference activities as specified in the NSW Aquifer Interference Policy (NSW, 2012). This drawdown does not extend into the Bowmans Creek Riparian Corridor, discussed above as part of the Offset Strategy. No impact is expected to the alluvium of Bayswater Creek.

Estimated leakage rates from the Bowmans Creek Alluvial aquifer are predicted to peak at approximately 65 ML/year at the end of mining. LCO currently holds sufficient groundwater licences to account for this intake, with an allocation of 142 ML/year for this water source. This peak leakage rate is equivalent to between 1 and 3% of estimated baseflow (based on streamflow analysis), or an annual loss to streamflow of less than 1%. As the creeks around LCO are ephemeral in nature, this will not impact the creek flow functionality, or any GDEs in the area.

Post mining equilibrium simulations indicate that alluvial groundwater levels will rapidly return to current levels following the end of mining. Predicted post mining equilibrium water levels in the final voids are lower than predicted groundwater heads within the Bowmans Creek alluvial aquifer, indicating leakage from the voids to the alluvial aquifer is unlikely to occur. Potential long term impacts to groundwater in the hard rock aquifer may result from leakage of increasingly saline water from the South Pit final void when water levels in the void rise above approximately 65 m AHD. However, the groundwater in this aquifer is already brackish, and no users of this aquifer have been identified.

There is a long history of mining at the LCO site. The current open cut operations have been in operation since 1990, and since this time LCO has gained an extensive understanding of the environment in which it operates and the potential for impacts as a result of the mining activities. LCO has a comprehensive Environmental Management System in place and an extensive environmental monitoring network.

The Project is not anticipated to result in any significant changes to the landscape beyond existing and that currently approved. The net impact of the Project to the local, regional and NSW communities, and to the National economy, will be positive, with a net production benefit to Australia of $316M. The environmental, cultural and social impacts are estimated at less than $1M, which is significantly less than the net production benefit. The Project will enable the continuation of employment at LCO and the associated flow-on benefits, as well as broader benefits to the State in the form of royalty revenues and taxes associated with the continuation of coal production at LCO.

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# 14.0 ABBREVIATIONS

| | |
|---|---|
| % | percent |
| AEMR | Annual Environmental Management Report |
| AHD | Australian Height Datum |
| AIP | Aquifer Interference Policy |
| AIS | Agricultural Impact Statement |
| AMZ | Agricultural Management Zone |
| ANZECC | Australian and New Zealand Environment and Conservation Council |
| ANZMEC | Australia and New Zealand Minerals and Energy Council |
| ARD | Acid Rock Drainage |
| BCA | Benefit Cost Analysis |
| BoM | Bureau of Meteorology |
| BSAL | Biophysical Strategic Agricultural Land |
| CCC | Community Consultative Committee |
| CEEC | Critically Endangered Ecological Community |
| CHPP | Coal Handling and Preparation Plant |
| CMA | Catchment Management Authority |
| DA | Development Application |
| DNG | Derived Native Grassland |
| DECCW | Former NSW Department of Environment Climate Change and Water |
| DGRs | Director General's Requirements |
| DoS | Degree of Saturation |
| DP | Deposited Plan |
| DPI | NSW Department of Primary Industries |
| DP&I | Former NSW Department of Planning and Infrastructure |
| DPE | NSW Department of Planning and Environment |
| DSC | Dam Safety Committee |
| DSEWPaC | Commonwealth Department of Sustainability, Environment, Water, Population and Communities (Now Department of the Environment) |
| DTEA | Durham Tailings Emplacement Area |
| DTIRIS | NSW Department of Trade and Investment, Regional Infrastructure and Services |
| EA | Environmental Assessment |
| EC | Electrical Conductivity |
| EEC | Endangered Ecological Community |
| EIS | Environmental Impact Statement |
| ELA | Eco Logical Australia |
| EMS | Environmental Management System |

| | |
|---|---|
| EPA | NSW Environmental Protection Authority |
| EP&A Act | *Environmental Planning and Assessment Act 1979* |
| EPBC Act | *Environment Protection and Biodiversity Conservation Act 1999* |
| EPI | Environmental Planning Instrument |
| EPL | Environmental Protection Licence |
| ESD | Ecologically Sustainable Development |
| FM Act | *Fisheries Management Act 1994* |
| GDE | Groundwater Dependent Ecosystem |
| GERI | Great Eastern Ranges Initiative |
| GHG | Greenhouse Gas |
| Glencore | Glencore Coal Pty Ltd |
| GRIT | Generation of Input-Output Tables |
| ha | Hectare |
| HRSTS | Hunter River Salinity Trading Scheme |
| LCO | Liddell Coal Operations Pty Ltd |
| LDP | Licensed Discharge Point |
| LEP | Local Environment Plan |
| LGA | Local Government Area |
| km | kilometres |
| m | metres |
| MIA | Mine Infrastructure Area |
| ML | Mining Lease |
| MOP | Mining Operations Plan |
| Mt | Million tonnes |
| Mtpa | Million tonnes per annum |
| NES | National Environmental Significance |
| NGA | National Greenhouse Factors |
| NGER Act | *National Greenhouse and Energy Reporting Act 2007* |
| NPW Act | *National Parks and Wildlife Act 1974* |
| NSW | New South Wales |
| OEH | NSW Office of Environment and Heritage |
| POEO Act | *Protection of Environmental Operations Act 1997* |
| RCE | Riparian Channel and Environmental |
| RCT | Ravensworth Coal Terminal |
| RCCP | Ravensworth Central Coal Processing Facility |
| RMS | NSW Roads and Maritime Services |
| ROM | Run of Mine |

| | |
|---|---|
| RWTV | Raw Water Transfer Void |
| SAL | Sensitive Archaeological Landscape |
| SEPP | State Environmental Planning Policy |
| SoHI | Statement of Heritage Impact |
| SKM | Sinclair Knight Merz Pty Ltd |
| SIP | Social Involvement Plan |
| SRLUP | Upper Hunter Strategic Regional Land Use Plan 2012 |
| SSD | State Significant Development |
| SSI | State Significant Infrastructure |
| TDS | Total Dissolved Solids |
| TEC | Threatened Ecological Community |
| TEOM | Tapered Element Oscillating Microbalance |
| TSC Act | *Threatened Species Conservation Act 1995* |
| TSP | Total Suspended Particulate |
| TSS | Total Suspended Solids |
| Umwelt | Umwelt (Australia) Pty Ltd |
| VPA | Voluntary Planning Agreement |
| WM Act | *Water Management Act 2000* |
| WSP | Water Sharing Plans |