Australian Government

BIOREGIONAL ASSESSMENTS

PROVIDING SCIENTIFIC WATER RESOURCE INFORMATION ASSOCIATED WITH COAL SEAM GAS AND LARGE COAL MINES

# Coal and coal seam gas resource assessment for the Sydney Basin bioregion

## Product 1.2 from the Sydney Basin Bioregional Assessment

2018

A scientific collaboration between the Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia

### The Bioregional Assessment Programme

The Bioregional Assessment Programme is a transparent and accessible programme of baseline assessments that increase the available science for decision making associated with coal seam gas and large coal mines. A bioregional assessment is a scientific analysis of the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential impacts of coal seam gas and large coal mining development on water resources. This Programme draws on the best available scientific information and knowledge from many sources, including government, industry and regional communities, to produce bioregional assessments that are independent, scientifically robust, and relevant and meaningful at a regional scale.

The Programme is funded by the Australian Government Department of the Environment and Energy. The Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia are collaborating to undertake bioregional assessments. For more information, visit http://www.bioregionalassessments.gov.au.

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### Cover photograph

Surface infrastructure of the Clarence underground coal mine located approximately 15 km east of Lithgow, adjacent to the Greater Blue Mountains World Heritage Area, showing vegetation recovering from bushfire in October 2013. The hillslope drains into the Wollangambe River

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# Acknowledgements

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- Technical Assurance Reference Group: Chaired by Peter Baker (Principal Science Advisor, Department of the Environment and Energy), this group comprises officials from the NSW, Queensland, South Australian and Victorian governments.

# Introduction

The Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development (IESC) was established to provide advice to the federal Minister for the Environment and Energy on potential water-related impacts of coal seam gas (CSG) and large coal mining developments (IESC, 2015).

Bioregional assessments (BAs) are one of the key mechanisms to assist the IESC in developing this advice so that it is based on best available science and independent expert knowledge. Importantly, technical products from BAs are also expected to be made available to the public, providing the opportunity for all other interested parties, including government regulators, industry, community and the general public, to draw from a single set of accessible information. A BA is a scientific analysis, providing a baseline level of information on the ecology, hydrology, geology and hydrogeology of a bioregion with explicit assessment of the potential impacts of CSG and coal mining development on water resources.

The IESC has been involved in the development of *Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* (the BA methodology; Barrett et al., 2013) and has endorsed it. The BA methodology specifies how BAs should be undertaken. Broadly, a BA comprises five components of activity, as illustrated in Figure 1. Each BA will be different, due in part to regional differences, but also in response to the availability of data, information and fit-for-purpose models. Where differences occur, these are recorded, judgments exercised on what can be achieved, and an explicit record is made of the confidence in the scientific advice produced from the BA.

## The Bioregional Assessment Programme

The Bioregional Assessment Programme is a collaboration between the Department of the Environment and Energy, the Bureau of Meteorology, CSIRO and Geoscience Australia. Other technical expertise, such as from state governments or universities, is also drawn on as required. For example, natural resource management groups and catchment management authorities identify assets that the community values by providing the list of water-dependent assets, a key input.

The Technical Programme, part of the Bioregional Assessment Programme, will undertake BAs for the following bioregions and subregions (see http://www.bioregionalassessments.gov.au/assessments for a map and further information):

- the Galilee, Cooper, Pedirka and Arckaringa subregions, within the Lake Eyre Basin bioregion
- the Maranoa-Balonne-Condamine, Gwydir, Namoi and Central West subregions, within the Northern Inland Catchments bioregion
- the Clarence-Moreton bioregion
- the Hunter and Gloucester subregions, within the Northern Sydney Basin bioregion

- the Sydney Basin bioregion
- the Gippsland Basin bioregion.

Technical products (described in a later section) will progressively be delivered throughout the Programme.

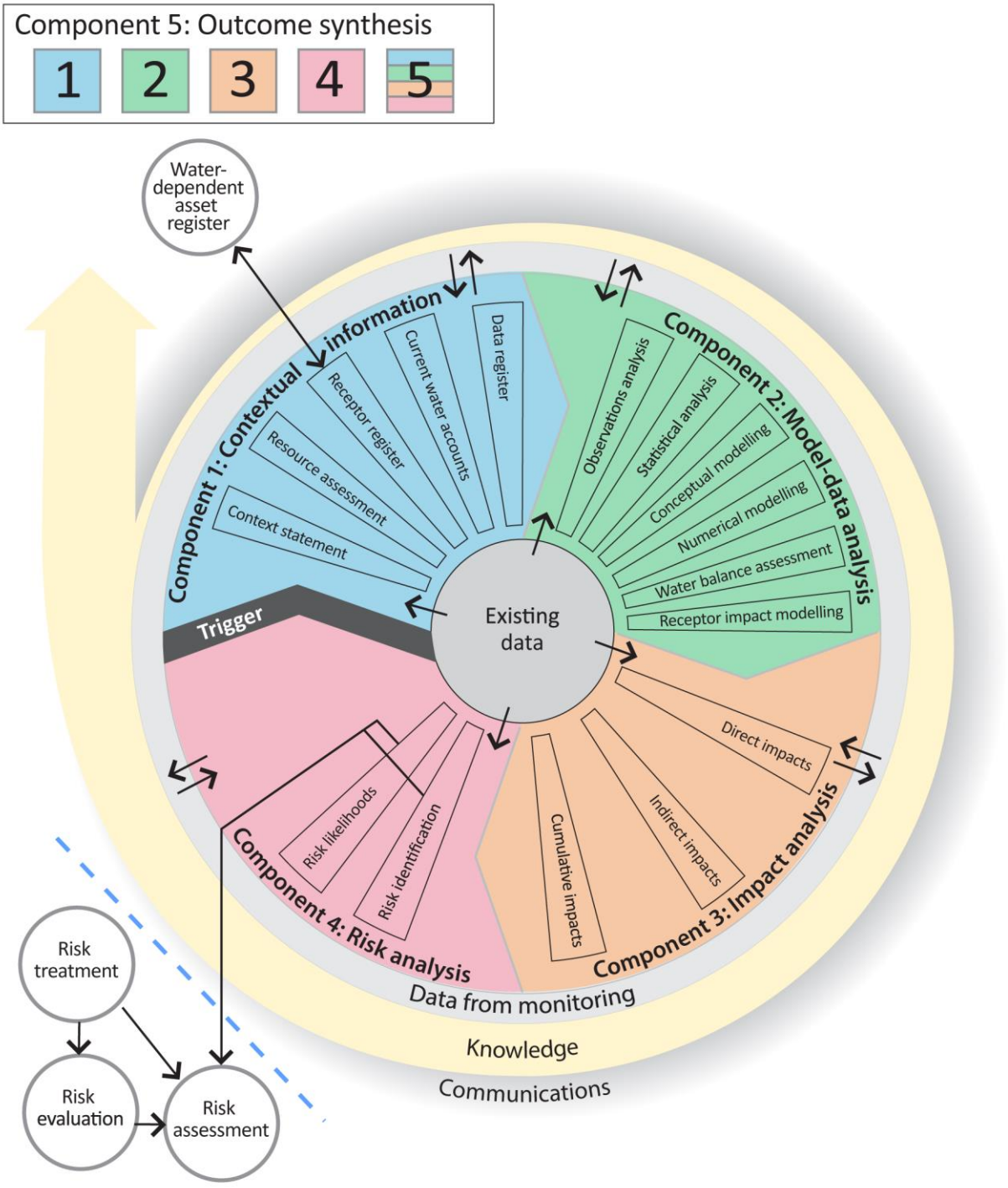


**Figure 1 Schematic diagram of the bioregional assessment methodology**

The methodology comprises five components, each delivering information into the bioregional assessment and building on prior components, thereby contributing to the accumulation of scientific knowledge. The small grey circles indicate activities external to the bioregional assessment. Risk identification and risk likelihoods are conducted within a bioregional assessment (as part of Component 4) and may contribute activities undertaken externally, such as risk evaluation, risk assessment and risk treatment. Source: Figure 1 in Barrett et al. (2013), © Commonwealth of Australia

# Methodologies

The overall scientific and intellectual basis of the BAs is provided in the BA methodology (Barrett et al., 2013). Additional guidance is required, however, about how to apply the BA methodology to a range of subregions and bioregions. To this end, the teams undertaking the BAs have developed and documented detailed scientific submethodologies (Table 1) to, in the first instance, support the consistency of their work across the BAs and, secondly, to open the approach to scrutiny, criticism and improvement through review and publication. In some instances, methodologies applied in a particular BA may differ from what is documented in the submethodologies – in this case an explanation will be supplied in the technical products of that BA. Ultimately the Programme anticipates publishing a consolidated 'operational BA methodology' with fully worked examples based on the experience and lessons learned through applying the methods to 13 bioregions and subregions.

The relationship of the submethodologies to BA components and technical products is illustrated in Figure 2. While much scientific attention is given to assembling and transforming information, particularly through the development of the numerical, conceptual and receptor impact models, integration of the overall assessment is critical to achieving the aim of the BAs. To this end, each submethodology explains how it is related to other submethodologies and what inputs and outputs are required. They also define the technical products and provide guidance on the content to be included. When this full suite of submethodologies is implemented, a BA will result in a substantial body of collated and integrated information for a subregion or bioregion, including new information about the potential impacts of coal resource development on water and water-dependent assets.

**Table 1 Methodologies**

Each submethodology is available online at http://data.bioregionalassessments.gov.au/submethodology/XXX, where 'XXX' is replaced by the code in the first column. For example, the BA methodology is available at http://data.bioregionalassessments.gov.au/submethodology/bioregional-assessment-methodology and submethodology M02 is available at http://data.bioregionalassessments.gov.au/submethodology/M02. Submethodologies might be added in the future.

| Code | Proposed title | Summary of content |
|---|---|---|
| bioregional-assessment-methodology | *Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* | A high-level description of the scientific and intellectual basis for a consistent approach to all bioregional assessments |
| M02 | *Compiling water-dependent assets* | Describes the approach for determining water-dependent assets |
| M03 | *Assigning receptors to water-dependent assets* | Describes the approach for determining receptors associated with water-dependent assets |
| M04 | *Developing a coal resource development pathway* | Specifies the information that needs to be collected and reported about known coal and coal seam gas resources as well as current and potential resource developments |
| M05 | *Developing the conceptual model of causal pathways* | Describes the development of the conceptual model of causal pathways, which summarises how the 'system' operates and articulates the potential links between coal resource development and changes to surface water or groundwater |
| M06 | *Surface water modelling* | Describes the approach taken for surface water modelling |
| M07 | *Groundwater modelling* | Describes the approach taken for groundwater modelling |
| M08 | *Receptor impact modelling* | Describes how to develop receptor impact models for assessing potential impact to assets due to hydrological changes that might arise from coal resource development |
| M09 | *Propagating uncertainty through models* | Describes the approach to sensitivity analysis and quantification of uncertainty in the modelled hydrological changes that might occur in response to coal resource development |
| M10 | *Impacts and risks* | Describes the logical basis for analysing impact and risk |
| M11 | *Systematic analysis of water-related hazards associated with coal resource development* | Describes the process to identify potential water-related hazards from coal resource development |

## Technical products

The outputs of the BAs include a suite of technical products presenting information about the ecology, hydrology, hydrogeology and geology of a bioregion and the potential impacts of CSG and coal mining developments on water resources, both above and below ground. Importantly, these technical products are available to the public, providing the opportunity for all interested parties, including community, industry and government regulators, to draw from a single set of accessible information when considering CSG and large coal mining developments in a particular area.

The information included in the technical products is specified in the BA methodology. Figure 2 shows the relationship of the technical products to BA components and submethodologies. Table 2 lists the content provided in the technical products, with cross-references to the part of the BA methodology that specifies it. The red outlines in both Figure 2 and Table 2 indicate the information included in this technical product.

Technical products are delivered as reports (PDFs). Additional material is also provided, as specified by the BA methodology:

- unencumbered data syntheses and databases
- unencumbered tools, model code, procedures, routines and algorithms
- unencumbered forcing, boundary condition, parameter and initial condition datasets
- lineage of datasets (the origin of datasets and how they are changed as the BA progresses)
- gaps in data and modelling capability.

In this context, unencumbered material is material that can be published according to conditions in the licences or any applicable legislation. All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence.

Technical products, and the additional material, are available online at http://www.bioregionalassessments.gov.au.

The Bureau of Meteorology archives a copy of all datasets used in the BAs. This archive includes datasets that are too large to be stored online and datasets that are encumbered. The community can request a copy of these archived data at http://www.bioregionalassessments.gov.au.

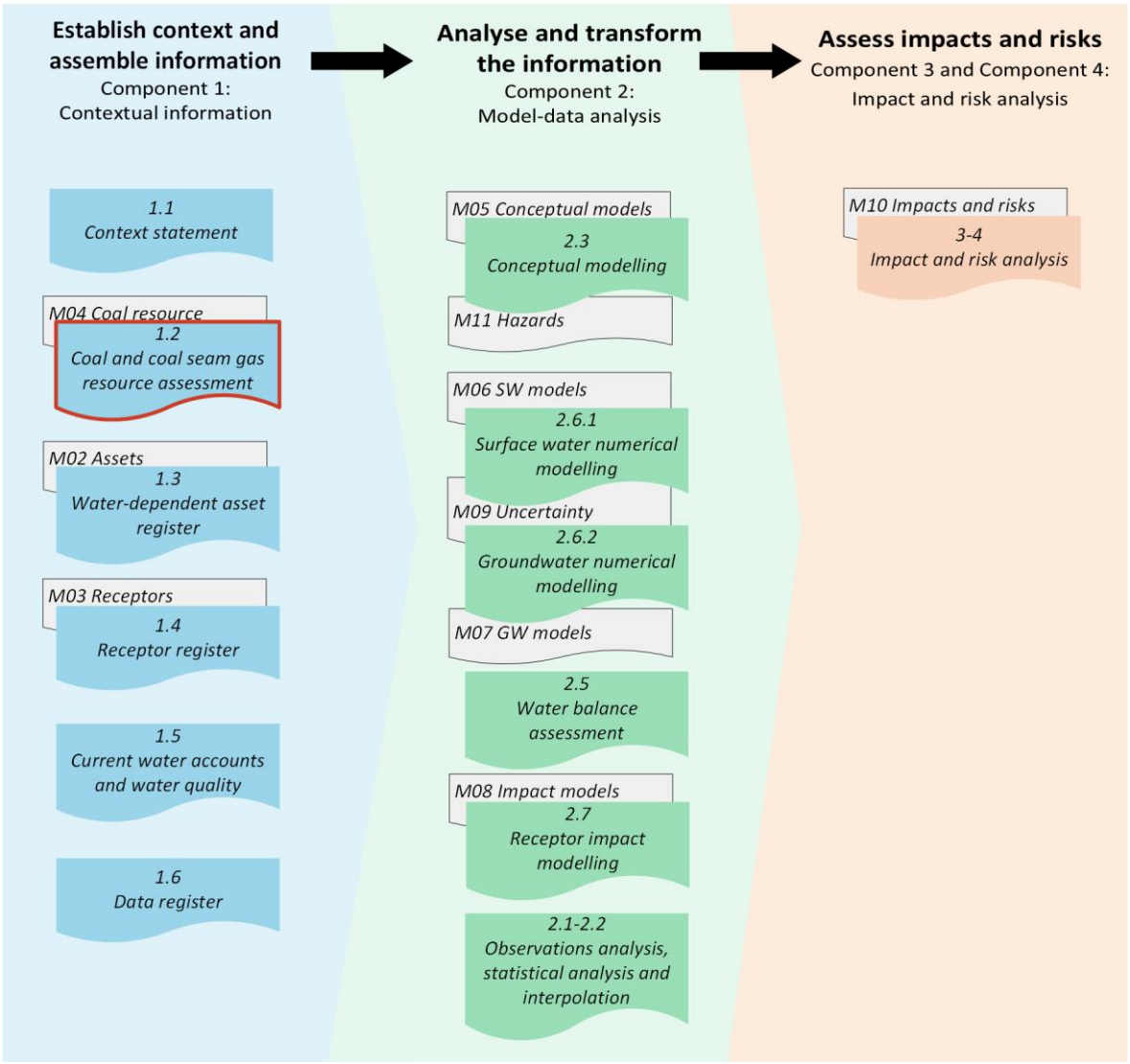


**Figure 2 Technical products and submethodologies associated with each component of a bioregional assessment**

In each component (Figure 1) of a bioregional assessment, a number of technical products (coloured boxes, see also Table 2) are potentially created, depending on the availability of data and models. The light grey boxes indicate submethodologies (Table 1) that specify the approach used for each technical product. The red outline indicates this technical product. The BA methodology (Barrett et al., 2013) specifies the overall approach.

### Table 2 Technical products delivered for the Sydney Basin bioregion

For the Sydney Basin Bioregional Assessment, technical products are delivered online at http://www.bioregionalassessments.gov.au, as indicated in the 'Type' column[a]. Other products – such as datasets, metadata, data visualisation and factsheets – are provided online. There is no product 1.4. Originally this product was going to describe the receptor register and application of landscape classes as per Section 3.5 of the BA methodology, but this information is now included in product 2.3 (conceptual modelling) and used in products 2.6.1 (surface water modelling) and 2.6.2 (groundwater modelling). There is no product 2.4; originally this product was going to include two- and three-dimensional representations as per Section 4.2 of the BA methodology, but these are instead included in other products.

| Component | Product code | Title | Section in the BA methodology[b] | Type[a] |
|---|---|---|---|---|
| **Component 1: Contextual information for the Sydney Basin bioregion** | 1.1 | Context statement | 2.5.1.1, 3.2 | PDF, HTML |
| | 1.2 | Coal and coal seam gas resource assessment | 2.5.1.2, 3.3 | PDF, HTML |
| | 1.3 | Description of the water-dependent asset register | 2.5.1.3, 3.4 | PDF, HTML, register |
| | 1.5 | Current water accounts and water quality | 2.5.1.5 | HTML-only |
| | 1.6 | Data register | 2.5.1.6 | Register |
| **Component 2: Model-data analysis for the Sydney Basin bioregion** | 2.1-2.2 | Observations analysis, statistical analysis and interpolation | 2.5.2.1, 2.5.2.2 | Not produced |
| | 2.3 | Conceptual modelling | 2.5.2.3, 4.3 | Not produced |
| | 2.5 | Water balance assessment | 2.5.2.4 | Not produced |
| | 2.6.1 | Surface water numerical modelling | 4.4 | Not produced |
| | 2.6.2 | Groundwater numerical modelling | 4.4 | Not produced |
| | 2.7 | Receptor impact modelling | 2.5.2.6, 4.5 | Not produced |
| **Component 3 and Component 4: Impact and risk analysis for the Sydney Basin bioregion** | 3-4 | Impact and risk analysis | 5.2.1, 2.5.4, 5.3 | Not produced |
| **Component 5: Outcome synthesis for the Sydney Basin bioregion** | 5 | Outcome synthesis | 2.5.5 | Not produced |

[a]The types of products are as follows:

- 'PDF' indicates a PDF document that is developed by the Sydney Basin Bioregional Assessment using the structure, standards and format specified by the Programme.
- 'HTML' indicates the same content as in the PDF document, but delivered as webpages.
- 'Register' indicates controlled lists that are delivered using a variety of formats as appropriate.
- 'HTML-only' indicates content that is only delivered as webpages (with no accompanying PDF document). This content is developed by the Sydney Basin Bioregional Assessment using the structure, standards and format specified by the Programme.
- 'Not produced' indicates that the product was not developed. A webpage explains why and points to relevant submethodologies (Table 1).

[b]*Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources* (Barrett et al., 2013)

# About this technical product

The following notes are relevant only for this technical product.

- All reasonable efforts were made to provide all material under a Creative Commons Attribution 3.0 Australia Licence. The copyright owners of the following figures, however, did not grant permission to do so: Figure 6 and 7. It should be assumed that third parties are not entitled to use this material without permission from the copyright owner.
- All maps created as part of this BA for inclusion in this product used the Albers equal area projection with a central meridian of 151.0° East for the Sydney Basin bioregion and two standard parallels of –18.0° and –36.0°.
- Contact bioregionalassessments@bom.gov.au to access metadata (including copyright, attribution and licensing information) for all datasets cited or used to make figures in this product. At a later date, this information, as well as all unencumbered datasets, will be published online.
- The citation details of datasets are correct to the best of the knowledge of the Bioregional Assessment Programme at the publication date of this product. Readers should use the hyperlinks provided to access the most up-to-date information about these data; where there are discrepancies, the information provided online should be considered correct. The dates used to identify Bioregional Assessment Source Datasets are the dataset's published date. Where the published date is not available, the last updated date or created date is used. For Bioregional Assessment Derived Datasets, the created date is used.

### *References*

Barrett DJ, Couch CA, Metcalfe DJ, Lytton L, Adhikary DP and Schmidt RK (2013) Methodology for bioregional assessments of the impacts of coal seam gas and coal mining development on water resources. A report prepared for the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development through the Department of the Environment. Department of the Environment, Australia. Viewed 8 March 2018, http://data.bioregionalassessments.gov.au/submethodology/bioregional-assessment-methodology.

IESC (2015) Information guidelines for the Independent Expert Scientific Committee advice on coal seam gas and large coal mining development proposals. Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development, Australia. Viewed 8 March 2018, http://www.iesc.environment.gov.au/publications/information-guidelines-independent-expert-scientific-committee-advice-coal-seam-gas.

# 1.2 Coal and coal seam gas resource assessment for the Sydney Basin bioregion

The coal and coal seam gas resource assessment summarises the known coal and coal seam gas resources, and developments both now and potentially in the future. The assessment is based on information available as of October 2016. The following data and information are presented:

- the geology and spatial distribution of known coal resources
- the baseline of current coal and coal seam gas extraction
- exploration and mining tenements
- proposed future developments (both new developments and expansion or closure of existing developments), including details of location, timing, methods and extraction volumes as determined from proposed development plans.

This information could be used to develop a coal resource development pathway in the future, although one is not being produced at this stage for this bioregion.

## 1.2.1 Available coal and coal seam gas resources


### *Summary*

Coal resources in the Sydney Basin bioregion occur in the Southern and Western Coalfields of the geological Sydney Basin. The primary coal-bearing stratigraphic unit recognised in the Sydney Basin bioregion is the Illawarra Coal Measures. From the Illawarra Coal Measures, the most significant resources are extracted from the Bulli Coal, Wongawilli Coal and Tongarra Coal, and the Balgownie Coal Member. The Illawarra Coal Measures are also prospective for coal seam gas (CSG) operations in the Southern Coalfield. However, the thermal maturity of the Illawarra Coal Measures in the Western Coalfield indicates low CSG potential.


### *1.2.1.1 Coal*

In 2013–2014 coal production in the Sydney Basin bioregion came from four mines in the Southern Coalfield and four in the Western Coalfield. The geographic locations of the Coalfields are shown in Figure 3. Raw production figures are provided in Table 3.

**Table 3 Coal production in Sydney Basin bioregion in 2013 to 2014 by mine**

| Coalfield | Mine | Open-cut or underground | Coal production (MT) |
|---|---|---|---|
| **Southern** | Appin – West Cliff | UG | 6.06 |
| | Dendrobium | UG | 3.82 |
| | Metropolitan | UG | 2.08 |
| | Tahmoor | UG | 2.53 |
| | **Subtotal** | | **14.49** |
| **Western** | Airly | UG | 0.14 |
| | Charbon | OC and UG | 1.34 |
| | Clarence | UG | 2.39 |
| | Springvale | UG | 3.50 |
| | **Subtotal** | | **7.57** |
| **Total** | | | **22.06** |

OC = open-cut; UG = underground
Source: NSW Department of Industry, Skills and Regional Development (2014, p. 53 and 67)

Approximately two-thirds of the coal produced in the Sydney Basin bioregion in 2013–2014 was from mines in the Southern Coalfield. Small portions of the Hunter and Newcastle coalfields sit within the north-eastern portion of the Sydney Basin bioregion. However, there are limited current coal workings in these areas. A description for the Hunter and Newcastle coalfields can be found in companion product 1.1 for the Hunter subregion (McVicar et al., 2016). The Western Coalfield (Figure 3) includes some mines (e.g. Ulan and Bylong), which are not part of the Sydney Basin bioregion as defined by the Bioregional Assessment (BA).

The Southern Coalfield is renowned for its premium quality, hard coking coals. They occur mainly in the Bulli Coal and are extracted from depths of over 400 m using underground methods and sold to both the domestic and international steel industry. Un-mined resources of prime coking coal are typically in the Bulli Coal and the Balgownie Coal Member under the Camden-Campbelltown-Picton region; however, this is a rapidly growing metropolitan area of Sydney, and subject to strategic release and other government policy, which limit opportunities for coal resource development (NSW Government Land & Property Information, 2015). In the Western Coalfield the Katoomba Coal Member and the Ulan, Lithgow and Lidsdale coals are of primary economic interest. Coal reserves for the various coalfields are given in Table 3, from NSW Trade and Investment (2014). The stratigraphic column in Figure 29 of companion product 1.1 for the Sydney Basin bioregion (Herron et al., 2018) shows the main coal-bearing geological units in the Western and Southern coalfields.

Section 1.2.1.1.1 and Section 1.2.1.1.2 discuss the stratigraphic nomenclature and classification of the main coal-bearing units of the Southern and Western coalfields, as well as some important coal characteristics. These coalfields are recognised to be within the Sydney Basin bioregion and are discussed in Section 1.1.3 (Geology) in companion product 1.1 for the Sydney Basin bioregion (Herron et al., 2018). The Central Coalfield, which is known to have coal reserves and historically has been mined (e.g. Sydney Harbour Colliery at Balmain between 1897 and 1931; NSW DPI (2007)), is not discussed in any detail in this product as urbanisation limits any future coal resource development. However, the stratigraphy of the Central Coalfield is considered to be similar to that of the Southern Coalfield (Haworth, 2003).

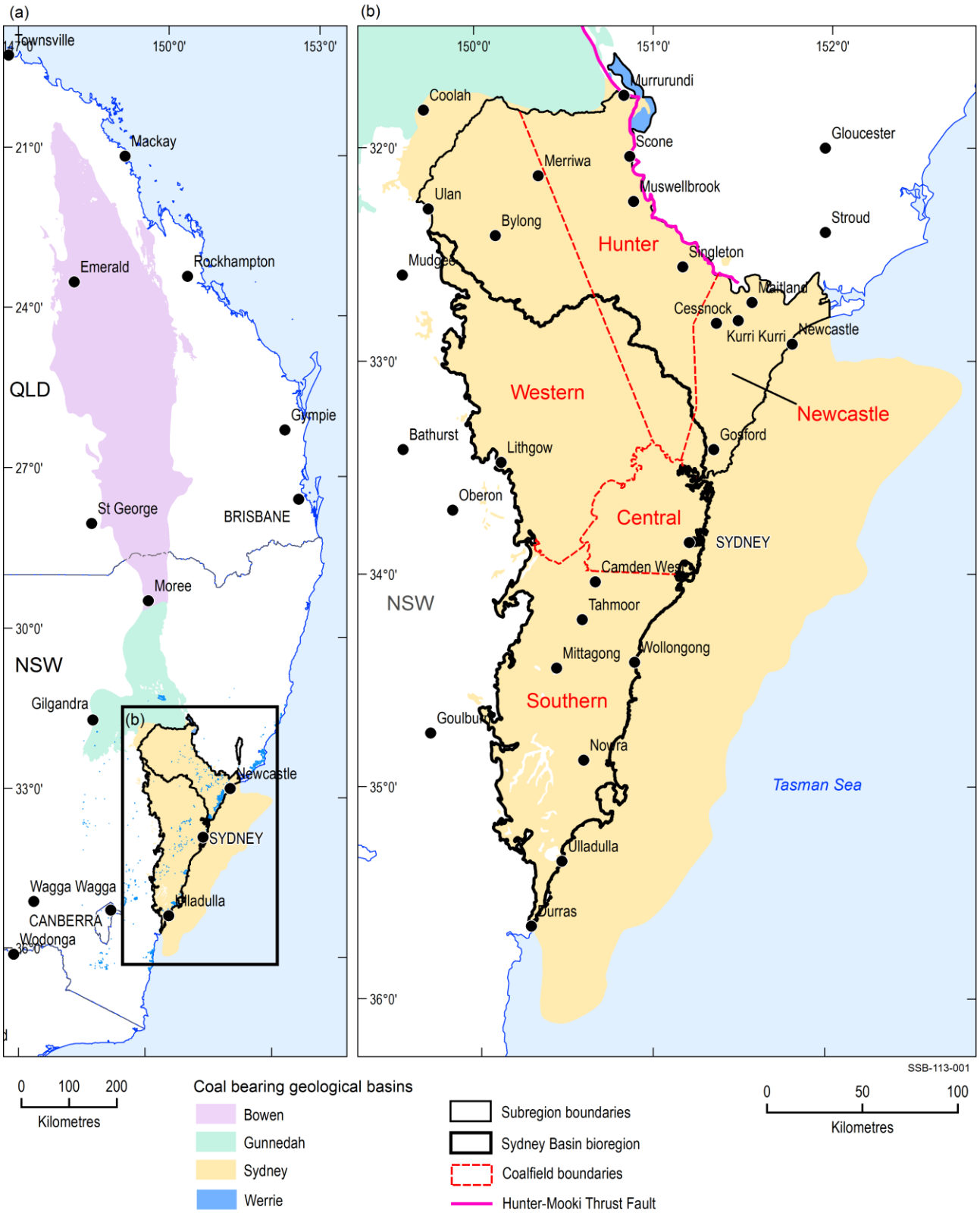


**Figure 3 Major coalfields in the geological Sydney Basin within the Sydney Basin bioregion**

Data: Geoscience Australia (Dataset 1)

#### 1.2.1.1.1 Southern Coalfield

The geology of the Southern Coalfield consists of the basal Permian Talaterang and Shoalhaven groups, overlain by the Permian Illawarra Coal Measures, and the Triassic Narrabeen Group. These, in turn, are overlain by the Hawkesbury Sandstone, Mittagong Formation and Wianamatta Group. An overview of the general stratigraphy for the Sydney Basin, relevant to coalfields, can be viewed in Section 1.1.3 (Geology) of companion product 1.1 for the Sydney Basin bioregion (Herron et al., 2018). The principal coal resource is situated within the Illawarra Coal Measures, although coal-bearing sequences also occur in the Clyde Coal Measures in the Talaterang Group. Hutton (2009, p. 43) noted there is little possibility of economic coal resources in the Clyde Coal Measures.

Coal in the Southern Coalfield is utilised as a resource for underground and open-cut mining (Saghafi et al., 2007; Ward and Kelly, 2013) and CSG operations, with gas from coal being extracted within the underground mines in addition to above ground CSG operations (Ward and Kelly, 2013). The coal in the Southern Coalfield differs in rank from the other coalfields of the Sydney Basin. It is generally low to high volatility bituminous coal, in contrast to the medium to high volatility bituminous coal which predominates in other regions (Saghafi et al., 2007). The coal is buried at depths of greater than 300 m in places, though shallower coal is present (Saghafi et al., 2007). Hutton (2009, p. 44) considers the only economic coals to be those of the Sydney Subgroup within the Illawarra Coal Measures, mainly from the Bulli Coal, the Balgownie Coal Member, the Wongawilli Coal and the Tongarra Coal, Darkes Forest, Kembla and Thirroul sandstones (Geoscience Australia, 2015). The Sydney Subgroup (Figure 4) contains all of the economic coal reserves of the Illawarra Coal Measures within the Southern Coalfield (Bamberry, 1991, p. 48). It is composed of conglomerate, sandstone, conglomeratic sandstone, coal, claystone, siltstone and some tuff (Bamberry, 1991, p. 48). The Cumberland Subgroup is considered to contain limited coal making it of little economic significance (Bamberry, 1991, p. 47). This subgroup mainly consists of marine, marginal marine and volcanic latite facies (Bamberry, 1991, p. 47).

The four principal coal-bearing units of the Illawarra Coal Measures are the Bulli, Balgownie, Wongawilli and Tongarra coal units, of which the Bulli Coal and the Wongawilli Coal have the largest resources (Hutton, 2009, p. 44–45; Ward and Kelly, 2013). Other coal members include the Cape Horn, Hargrave, Woronora, American Creek and Woonona; of these the Woonona Seam (correlated to the Lithgow Seam of the Western Coalfield) was previously mined, but is considered to be discontinuous (Hutton, 2009, p. 45). The other coal seams are uneconomic due to the high ash content, low thickness and thin coal intervals in addition to being laterally discontinuous (Hutton, 2009, p. 45). The remaining resource potential is largely in both the Bulli Coal and the Balgownie Coal Member in the Camden-Campbelltown region (Moffitt, 2000, p. 72). The following paragraphs summarise the economic coal interests within the Sydney Subgroup.

##### *1.2.1.1.1.1 Bulli Coal*

The Bulli Coal is present throughout most of the Southern Coalfield, but its absence has been documented at the southernmost region of the coalfield and basin (Hutton, 2009, p. 44). It is considered to contain the bulk of the Southern Coalfield's reserves (Hutton, 2009, p. 44). In addition, the Bulli Coal is the most economic, workable seam, and is extracted through open-cut mining where it reaches the surface in the Wollongong-Coalcliff region in the east (Moffitt, 2000,

p. 72; BHP, 2007 p. 2–10). Underground mining is also used to extract the Bulli Coal. Although initial development was restricted to open-cut mines, later shaft and draft mines were opened to allow further mining, though longwall mining is still preferred (Bamberry, 1991, p. 52–56). The Bulli Coal reaches depths of up to 800 m in the central north of the coalfield and is situated at more than 850 m below the surface in the north-west (Moffitt, 2000, p. 72; South 32, 2007, p. 2–10). To the north of the coalfield, the Bulli Coal is 5 m at its thickest and in other regions varies in thickness between 2 and 3 m (Moffitt, 2000, p. 72; Hutton, 2009, p. 44). The thicker sections of the Bulli Coal occur in synclines and down-thrown fault blocks (Moffitt, 2000, p. 72). Seams of the Bulli Coal vary in quality throughout the Southern Coalfield. In some places this coal-bearing unit is absent and in other places, it is described as grading to carbonaceous mudstone (Moffitt, 2000, p. 73).

Like many coal seams within the Southern Coalfield, the Bulli Coal consists of interbanded coal seams, composed of dull and bright plies; in addition to the coal, minor claystone and siderite is present (Bamberry, 1991, p. 56; Hutton, 2009, p. 44). Hutton (2009, p. 44) referred to the Bulli Coal as containing 8 to 9% ash, 21.5 to 27.5% volatile matter, 30 to 55% vitrinite and a high inertinite percentage (55%). However, Bamberry (1991, p. 56) referred to it as a prime quality coking coal with medium to high ash and low to medium volatiles, with an average raw coal production rate of 76%. Armstrong et al. (1995, p. 226) have compiled a more in-depth set of results for the Bulli Coal over two regions that show some variability from the coal parameters above (Table 4). The regional dip of the Bulli Coal towards the north-west is about 2.5 degrees (BHP, 2007, p. 2–10), meaning the coal becomes much deeper below the surface over a relatively short distance. Where igneous intrusive bodies occur near the Bulli Coal, the economic potential has been decreased due to thermal alteration of the coal, particularly in the Mittagong region and the Central Coalfield (Bamberry, 1991, p. 56, 60; Moffitt, 2000, p. 72).

#### *1.2.1.1.1.2 Tongarra Coal*

The Tongarra Coal of the Sydney Subgroup (sometimes referred to as the Tongarra Seam) provides an economic resource south of Wollongong where it is mined underground and used in electricity generation; however, it is present in an uneconomic form across the remainder of the Southern Coalfield (Bamberry, 1991, p. 71; Hutton, 2009, p. 45). The coal is interbanded with dull and bright plies and some claystone interbeds (Bamberry, 1991, p. 71; Hutton, 2009, p. 45). Only limited mining of the Tongarra Coal has occurred in the past due to the variability in the properties of the coal and its depth (Bamberry, 1991, p. 71; Moffitt, 2000, p. 75).

Despite this, Moffitt (2000, p. 78) suggested that the Tongarra Coal was economic in the area between the former Huntley Colliery and Sutton Forest. The seam is 1.8 m thick on average, although the working sections vary from between 1.5 m in most of the coalfield to 2.5 m in the south-east (Bamberry, 1991, p. 71). Splitting of the seam occurs to the west between Mittagong and the Warragamba River (Bamberry, 1991, p. 71). Igneous intrusions have resulted in very low coal quality in places due to thermal sterilisation (Bamberry, 1991, p. 71). The Tongarra Coal is not present in the south and south-western margins of the coalfield, although Moffitt (2000, p. 77–78) suggested the lower Wongawilli split is a remnant of the Tongarra Coal.

The Tongarra Coal is reported by Bamberry (1991, p. 71) and Hutton (2009, p. 45) as being medium to high ash coal (35%) with medium volatile and sulfur content; however, Armstrong et al.

(1995, p. 226) give the ash content as 15.6%, indicating a higher combustible component. Vitrinite content is reported to be similar to the Wongawilli Coal (Bamberry, 1991, p. 71). The coal's appearance is that of a bright and dull coal with interbedded tuffaceous and carbonaceous claystone beds (Moffitt, 2000, p. 75).

**Table 4 Indicative coal quality for the Illawarra Coal Measures in the Wollongong, Mittagong and Burragorang Valley areas**

| | Coal | Wollongong: Bulli | Wollongong: Balgownie | Wollongong: Wongawilli | Wollongong: Tongarra | Mittagong: Wongawilli | Burragorang Valley: Bulli |
|---|---|---|---|---|---|---|---|
| Proximate analysis (%)[a] | Inherent moisture | 0.9–2.4 | 1.1–1.4 | 1.1–2.0 | 1.4 | 2.0 | 1.7 |
| | Ash | 8.2–12.9 | 10.9–11.1 | 10.5–17.9 | 15.6 | 16.8 | 8.4 |
| | Volatile matter | 18.8–30.2 | 22.2–23.0 | 24.2–30.8 | 23.6 | 6.8 | 26.8 |
| | Fixed carbon | 60.6–70.2 | 66.1–66.7 | 52.3–63.2 | 60.8 | 77.2 | 64.8 |
| | Calorific value[b] (MJ/kg) | 35.6 | 35.8 | 37.0 | 34.5 | 35.0 | 35.4 |
| | Flow temperature (˚C) | +1600 | 1300 | 1550 | 1450 | 1500 | +1600 |
| | Rv max% | 0.91–1.31 | 1.32 | 1.36–1.43 | 1.42 | 0.8–1.0 | 0.8–1.0 |
| Ultimate analysis (%) | Carbon[b] | 85.4–88.9 | 87.5–89.0 | 86.5–87.3 | 87.1 | 91.7[d] | 86.0[d] |
| | Hydrogen[b] | 4.6–5.2 | 4.8–5.0 | 5.2–5.4 | 5.1 | 3.2[d] | 5.1[d] |
| | Nitrogen[b] | 1.4–1.9 | 1.6–1.7 | 1.7–1.9 | 1.9 | 2.0[d] | 1.8[d] |
| | Oxygen[b] | 4.2–8.1 | 3.9–5.2 | 4.6–9.0 | 5.5 | 2.4[d] | 7.0[d] |
| | Carbonates[b] | 0.1–0.7 | 0.3–0.5 | 0.1–0.6 | 0.8 | | |
| | Phosphorus[c] | 0.01–0.09 | 0.01 | 0.01 | 0.10 | 0.005 | 0.05 |
| | Chlorine[c] | 0.01–0.03 | | 0.01–0.02 | | | |
| | Total sulphur[c] | 0.3–0.5 | 0.4 | 0.5–0.7 | 0.6 | 0.7[d] | 0.4[d] |
| Maceral analysis (%) | Vitrinite | 30–59 | 61 | 66–79 | 51 | | 56 |
| | Liptinite | Tr-4 | Tr | Tr-7 | Tr | | 1 |
| | Micrinite | 8–22 | 5 | 2–8 | 11 | | 18 |
| | Semifusinite | 21–43 | 27 | 9–23 | 27 | | 21 |
| | Fusinite | 1–3 | 3 | 1–4 | 2 | | |
| | Mineral matter | 4–6 | 4 | 4–13 | 9 | | 4 |

[a]as analysed
[b]dry ash free basis
[c]dry basis
[d]dry, mineral matter free
Tr = trace
Data: Armstrong et al. (1995, p. 226)

#### *1.2.1.1.1.3 Wongawilli Coal*

The Wongawilli Coal is the second most important coal of economic interest after the Bulli Coal. It is considered to be even more laterally prevalent across the Southern Coalfield than the Bulli Coal (Bamberry, 1991, p. 68; Moffitt, 2000, p75; Hutton, 2009, p. 44). With a maximum thickness of 18 m (varying between 6 and 15 m on average) the Wongawilli Coal is notably thicker than the other seams of the Illawarra Coal Measures (Hutton, 2009, p. 44). The lowermost 3 m of the Wongawilli Coal is mineable throughout the coalfield. Above this, there is a tuffaceous claystone band (the Heights Claystone), which forms a barrier of about 1 m thick between the lower workable 3 m section and the overriding uneconomic portion of the coal (Bamberry, 1991, p. 68; Moffitt, 2000, p. 75; Hutton, 2009, p. 45). Mining was first undertaken through tunnel entries into known outcrop areas. In the south, adit entries were also used to mine the coal (Bamberry, 1991, p. 68). Today, both open-cut and underground mining occur. The Wongawilli Coal is near the surface and in some places outcrops along the south and east of the coalfield and is at a depth of around 900 m in the Central Coalfield (Moffitt, 2000, p76).

The Wongawilli Coal is a highly banded mix of dull and bright coal with carbonaceous and tuffaceous sediments (Bamberry, 1991, p. 68). The upper coal, which is largely uneconomic elsewhere, is mined towards the south of the coalfield, where the quality of the coal improves the economic viability. Ash content is variable, but commonly high. The unit grades from coal to interbedded coal to carbonaceous and tuffaceous rocks (Hutton, 2009, p. 45; Moffitt, 2000, p. 75). The lower, workable coal is bright with disseminated matter and stone bands, and has a vitrinite range of between 60% and 80% (Hutton, 2009, p. 45) and is a moderate to high ash coking coal (Bamberry, 1991, p. 68). Armstrong et al. (1995, p. 226) varied from these statements and provided a more complete view of the petrophysical properties for the Wongawilli Coal (Table 4). The Wongawilli Coal is considered a correlative of the Middle River Coal Member in the Western Coalfield (Hutton, 2009, p. 45). Igneous intrusives have affected a large portion of the mineable coal areas, although in some cases (e.g. at the no longer active Mount Alexander and Mount Waratah Collieries near Mittagong) the intrusion of igneous sills has locally increased coal rank (Bamberry, 1991, p. 68).

#### *1.2.1.1.1.4 Balgownie Coal Member*

The Balgownie Coal Member sits within the Eckersley Formation, a unit within the Sydney Subgroup. Bamberry (1991, p. 60) and Moffitt (2000, p. 74) state that the Balgownie Coal Member/Seam is as widespread as the Bulli Coal, but that it lacks its economic thickness. The Balgownie Coal Member is notably thinner than the Bulli Coal, measuring on average between 1.5 and 2 m thick. In some places it is less than 1 m, but has maximum thickness of 3.5 m in the Camden-Campbelltown region (Bamberry, 1991, p. 60; Moffitt, 2000, p. 74; Hutton, 2009, p. 44). The Balgownie Coal Member does reach workable thickness in the north and north-west of the coalfield (Bamberry, 1991, p. 60) and is absent in the south-west of the coalfield (Moffitt, 2000, p. 74). The coal member is interbanded consisting of bright and dull coal with mudstone bands, with siderite and calcite appearing on cleat surfaces (Moffitt, 2000, p. 74). It grades to a higher proportion of carbonaceous mudstone in the north (Moffitt, 2000, p. 74). There has been limited underground mining of the Balgownie Coal Member in the past and it is considered to hold no economic potential towards the south of the Southern Coalfield (Hutton, 2009, p. 44). The area of

main economic interest of the Balgownie Coal Member is similar to the Bulli Coal, within the Camden-Campbelltown region (Moffitt, 2000, p. 74).

The Balgownie Coal Member is considered to have similar petrographic properties to the Bulli Coal with an average value ash content (Bamberry, 1991, p. 60), although Hutton (2009, p. 44) reported some high ash contents. Armstrong et al. (1995, p. 226) listed the properties (Table 4) in more detail, showing limited agreement with Bamberry (1991, p. 60) and Hutton (2009, p. 44). Although in proximity to igneous intrusions (Bamberry, 1991, p. 60; Moffitt, 2000, p. 74), the economic significance of the Balgownie Coal Member is not considered to have been impacted by the intrusion as the seam remains thin in the affected regions (Bamberry, 1991, p. 61).

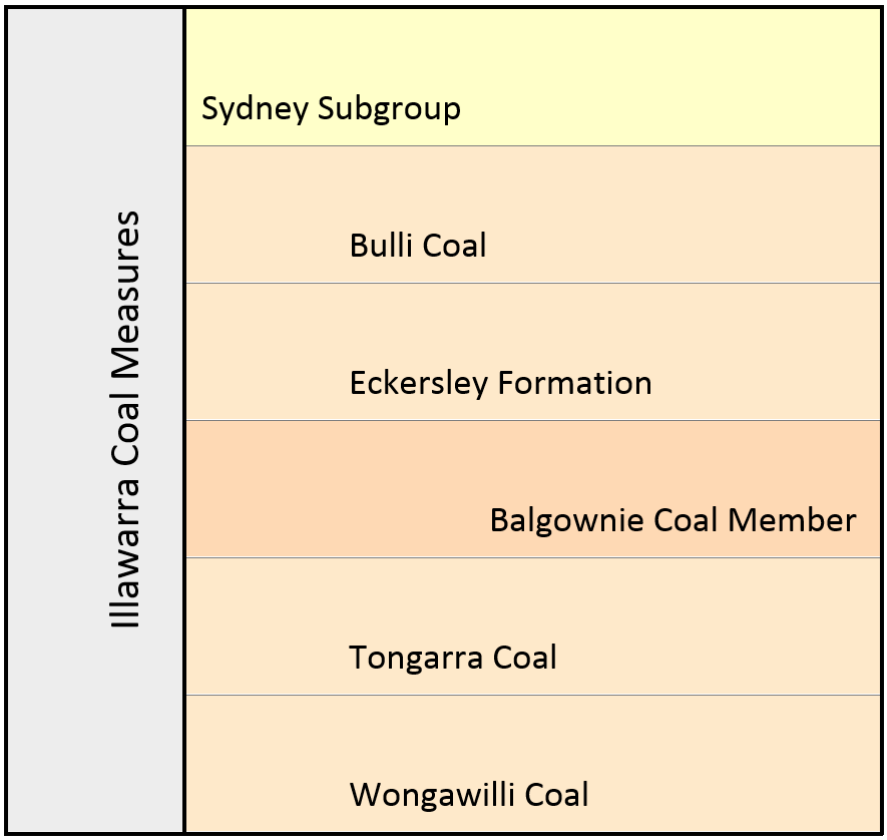


**Figure 4 Stratigraphic hierarchy for the Southern Coalfield Sydney Subgroup, within the Illawarra Coal Measures**

Data: Bamberry (1991, p. 48)

### 1.2.1.1.2 Western Coalfield

The stratigraphy of the Western Coalfield consists of the Permian Shoalhaven Group, overlain by the Permian Illawarra Coal Measures, which, in turn, are overlain by the Triassic Narrabeen Group. The Narrabeen Group is overlain by the Triassic Hawkesbury Sandstone and the Wianamatta Group. The Illawarra Coal Measures are the only economic coal resource of the Western Coalfield. Underground mining predominates (Brakel, 1991, p. 12) although there are also several open-cut mines (Saghafi et al., 2007).

#### *1.2.1.1.2.1 Illawarra Coal Measures*

The Illawarra Coal Measures of the Western Coalfield are subdivided into seven main constituent stratigraphic units (GA and ASC, 2015). These are the Nile Subgroup, Cullen Bullen Subgroup, Charbon Subgroup, Wallerawang Subgroup and State Mine Creek Formation, as well as the Lithgow Coal and the Irondale Coal (Geoscience Australia and Australian Stratigraphy Commission, 2015). Further internal divisions of the Cullen Bullen Subgroup, Charbon Subgroup, State Mine Creek Formation and Wallerawang Subgroup can be viewed in Figure 5, relevant to the Western Coalfield (Australian Stratigraphic Database, 2015). However due to differences in the stratigraphic hierarchy between authors, industry and governing bodies, the coal of the Western Coalfield is at times divided into four main divisions (Wallerawang, Charbon, Cullen Bullen and Nile subgroups) where the State Mine Creek Formation, Lithgow and Irondale coals are placed within other subgroups (Huleatt 1991, p. 39; Yoo et al., 1995, p. 243; RW Corkery & Co Pty Limited, 2008, p. 9; RW Corkery & Co Pty Limited, 2012, p. 8; Hutton 2009, p. 53; Centennial Coal, 2012, p. 7).

The Nile Subgroup contains no notable economic coal resources (Huleatt, 1991, p. 39). The thickness of the Illawarra Coal Measures of the Western Coalfield ranges between 50 m in the vicinity of Ulan (within the western part of the Hunter subregion) to 900 m near Wisemans Ferry, west of Gosford (Ward and Kelly, 2013). The Lithgow Coal, Lidsdale Coal, Ulan Coal and Katoomba Coal Member are of main economic interest in the Western Coalfields, with Irondale Coal and Middle River Coal Member locally important (Hutton, 2009, p. 53; Ward and Kelly, 2013). Hutton (2009, p. 53) also proposed that the Moolarben Coal Member was of some interest (Hutton, 2009, p. 53); it is mined at Charbon (RW Corkery & Co Pty Limited, 2008, p. 8).

| | Australian Stratigraphic Units Database (2015) Illawarra Coal Measures, as relevant to the Western Coalfield information within this chapter | Huleatt (1991, p. 39) Yoo et al. (1995, p. 243) Corkery and Co. (2008, p. 9) Corkery and Co. (2012, p. 8) Hutton (2009, p. 53) and Centennial Coal (2012, p. 7) Illawarra Coal Measures, as relevant to the Western Coalfield information within this chapter |
|---|---|---|
| Illawarra Coal Measures of the Western Coalfield | Wallerawang Subgroup | Wallerawang Subgroup |
| | Farmers Creek Formation | Farmers Creek Formation |
| | Katoomba Coal Member | Katoomba Coal Member |
| | Middle River Coal Member | Middle River Coal Member |
| | State Mine Creek Formation | State Mine Creek Formation*# |
| | Moolarben Coal Member | Moolarben Coal Member*# |
| | Charbon Subgroup | Charbon Subgroup |
| | Ulan Coal | Ulan Coal |
| | Lithgow Coal | Irondale Coal |
| | Irondale Coal | |
| | Cullen Bullen Subgroup | Cullen Bullen Subgroup |
| | Lidsdale Coal | Lidsdale Coal |
| | Nile Subgroup | Lithgow Coal |
| | | Nile Subgroup |
| | *included in the Chabon Subgroup by Huleatt (1991, p. 39)<br>#where no mention of the formation is made in Centennial Coal (2012) | |

**Figure 5 Comparative differences in stratigraphical hierarchy between the Australian Stratigraphic Units Database and other authors**

The Australian Stratigraphic Units Database (Geoscience Australia and Australian Stratigraphy Commission, 2015) lists seven key constituents: Wallerawang, Charbon, Cullen Bullen and Nile subgroups, along with the State Mine Creek Formation, and the Lithgow and Irondale Coals, whereas many publications list the State Mine Creek Formation, and the Irondale Coal and the Lithgow Coal as belonging to one of the four subgroups.
Data: Geoscience Australia and Australian Stratigraphy Commission (2015), Huleatt (1991), Yoo et al. (1995, p. 243), RW Corkery & Co Pty Limited (2008), RW Corkery & Co Pty Limited (2012), Hutton (2009, p. 53), Centennial Coal (2012).

### Middle River Coal Member

Part of the Farmers Creek Formation within the Wallerawang Subgroup, the Middle River Coal Member, forms coal seams of up to 4 m of high ash content and vitrinite dominated coal (Hutton, 2009, p. 53). It is correlated to the Wongawilli Coal of the Southern Coalfield and is generally classed as uneconomic (Hutton, 2009, p. 53). Yoo et al. (1995, p. 243), however, suggested that there was potential for economic recovery in the Newnes Plateau region where borehole data indicated a 2 m thick coal with ash content of less than 35%. RW Corkery & Co Pty Limited (2008, p. 8) referred to the localised thickness of the Middle River Coal Member as being between 7 and 8 m in thickness at the Charbon Colliery. The coal in the Charbon region has high ash content (less than 40%), where the coal is interbanded with claystone and carbonaceous shale, and the lowermost section of the seam is considered to contain more coal (RW Corkery & Co Pty Limited, 2008, p. 8). It is currently mined using underground and open-cut methods.

### Katoomba Coal Member

The Katoomba Coal Member, which is also part of the Farmers Creek Formation, has a highly variable thickness, varying from absent in some places to 6 m thick in other places and is

correlated to the Southern Coalfield Bulli Coal (Hutton, 2009, p. 53). However, Yoo et al. (1995, p. 243) have stated that the thickness ranges from 1.5 to 3 m. There is very minor claystone content within this coal-bearing unit (Yoo et al., 1995, p. 243; Hutton, 2009, p. 53) and it is considered a significant coal resource that is mined in the south and south-east of the Western Coalfield (Hutton, 2009, p. 53) where Yoo et al. (1995, p. 243) listed it as being significant. This coal is not present to the north and east of the Lithgow region due to surface erosion (Hutton, 2009, p. 53). The Katoomba Coal Member is also noted as being present east of Rylstone (north of Lithgow), where it ranges in thickness from 1 to 10 m and claystone bands are common.

The ash content varies from 11% to 23% (Yoo et al., 1995, p. 243; Hutton, 2009, p. 53) and volatile matter is reported as 28.9% (Hutton, 2009, p. 53). Yoo et al. (1995, p. 243) considered it to have low sulfur and high inertinite. The Katoomba Coal Member has been mined through underground methods in the Bell and Birds Rock-Newnes Junction regions (Yoo et al., 1995, p. 243).

**Moolarben Coal Member**

The Moolarben Coal Member is part of the State Mine Creek Formation. Hutton (2009, p. 53) described the Moolarben Coal Member (also referred to as the Moolarben Seam) as a narrow coal seam (less than 1 m, increasing to roughly 3 m in the Ulan region) of no visible economic potential. However, Yoo et al., (1995, p. 243) found that to the east of Ulan, the coal is 3.17 m thick (Hunter subregion) and described it as a dull coal with some bright plies, more notable in the lower section with several claystone beds. In the Moolarben area between Ulan Colliery and Wollar, the Moolarben Coal Member is considered to be a potential economic resource (Yoo et al., 1995, p. 243). The variation in thickness continues in the Bylong area of the Hunter subregion where the coal is noted as being 4.9 m thick (Yoo et al., 1995, p. 243). Changes in the composition of the Moolarben Coal Member are also noted from the coal described in the area east of Ulan (see above) with the measures at Bylong described as coal, claystone and carbonaceous claystone (Yoo et al., 1995, p. 243). Additionally, the Moolarben Coal Member is described as being 'coal-barren', composed of tuffaceous mudstone and claystone, at the Moolarben Coal Mine (Mine Subsidence Engineering Consultants, 2008, p. 8) suggesting that a wide variability in quality and lithology affects the economic potential of the Moolarben Coal Member.

Yoo et al. (1995, p. 243) found the coal member, where measured, has a high ash content (27% to 34%), and stated that small recovery through open-cut operations may be an option but this is most likely to be only within the Moolarben and Cockaburra Creek areas.

**Lithgow Coal**

The Lithgow Coal, as identified by the Australian Stratigraphic Units Database (Geoscience Australia and Australian Stratigraphy Commission, 2015), is a stand-alone unit of the Illawarra Coal Measures, although many publications (Huleatt, 1991, p. 39; Yoo et al., 1995, p. 243; RW Corkery & Co Pty Limited, 2008, p. 9; Hutton, 2009, p. 53; Centennial Coal, 2012, p. 7; RW Corkery & Co Pty Limited, 2012, p. 8) identify it as being the Lithgow Seam of the Cullen Bullen Subgroup.

Varying from 1 to 7 m thick, most mineable sections of the Lithgow Coal are between 2 and 4 m thick (Hutton, 2009, p. 53). However, Centennial Coal (2012, p. 6) stated that the Lithgow Coal (seam) varies from 1 to 9 m in thickness across the Western Coalfield. Yoo et al. (1995, p. 236) and

Centennial Coal (2012, p. 6) reported that the Lithgow Coal is a major resource, particularly in the Rylstone, Bylong and Lithgow areas. The Lithgow Coal is composed of dull coal, interbedded with carbonaceous claystone layers that are most common in the middle to upper sections (Yoo et al., 1995, p. 236). Minor bright bands of coal and conglomerate have also been identified as interbeds (Centennial Coal, 2012, p. 6). The coal has been extensively mined by underground and open-cut methods. The Lithgow Coal can be correlated to the Ulan Coal of the same coalfield (Hutton, 2009, p. 53).

At Bylong, the Lithgow Coal is dull with limited stone bands. Thinning is noted in this area as the coal is traced to the west, with thickening to the east to 5 m, where the ash content is less than 20% (Yoo et al, 1995, p. 241). Hutton (2009, p.53) reported that the Lithgow Coal has a low vitrinite content, moderate volatile matter and an ash content of 10% to 25% in southern areas of the coalfield where it is mined. In contrast, Yoo et al. (1995, p.241) stated that the Lithgow Coal has high levels of volatile matter and ash content of 14% to 35%, with low amounts of sulfur.

**Irondale Coal**

The Irondale Coal, as identified by the Australian Stratigraphic Units Database (Geoscience Australia and Australian Stratigraphy Commission, 2015), is a stand-alone unit of the Illawarra Coal Measures, though many publications (Huleatt, 1991, p. 39; Yoo et al., 1995, p. 243; RW Corkery & Co Pty Limited, 2008, p. 9; Hutton, 2009, p. 53; Centennial Coal, 2012, p. 7; RW Corkery & Co Pty Limited, 2012, p. 8) identify it as being the Irondale Seam of the Charbon Subgroup.

The Irondale Coal (or Wolgan Seam) has a maximum thickness of over 2 m in the Wolgan area although typically the Irondale Coal is around 1 m in thickness (Hutton, 2009, p. 53). The coal of this unit contains both dull and bright bands in addition to stone bands (Yoo et al., 1995, p. 238). It is reportedly correlated to the Ulan Coal (Yoo et al., 1995, p. 238). Mining has taken place to a small degree using open-cut and underground methods (Yoo et al., 1995, p. 238). Yoo et al. (1995, p. 238) noted that there was greater potential for economic recovery in the Wolgan and Cherry Tree Hill areas. The ash content of this seam is 10.8% and the vitrinite content is 35.7% (Hutton, 2009, p. 53). The coal in Wolgan area is considered to be highly volatile with a 9% to 11% ash content (Yoo et al., 1995, p238).

**Lidsdale Coal**

Sometimes referenced as being a split of the Lithgow Coal, the Lidsdale Coal within the Cullen Bullen Subgroup has similar properties to the Lithgow Coal (Hutton, 2009, p. 53). Hutton (2009, p. 53) referred to the Lidsdale Coal as a dull coal, broken by carbonaceous shale layers and as only being present to the west of the coalfield. However, Yoo et al. (1995, p. 241) stated that it occurs throughout the Western Coalfield. Sections have been previously mined, where the thickness reached 2 to 3 m in the Rylstone area (Yoo et al., 1995, p241; Hutton, 2009, p. 53). It is was previously mined at Charbon and Ivanhoe mines where the ash content ranges from 20% to 32% (Yoo et al., 1995, p. 241).

**Ulan Coal**

The Ulan Coal, within the Charbon Subgroup, sits within a thin, tuffaceous, claystone layer and has a thickness of around 14 to 15 m (Mine Subsidence Engineering Consultants, 2008, p. 8; Hutton, 2009, p. 53). The lower section is up to 7 m thick with ash content reported between 7% and 13%. The upper section is up to 7 m thick with ash content ranging from 11% to 45% (Yoo et al., 1995, p. 243). To the north of the Western Coalfield the Ulan Coal has an ash content of between 11% and 13% where coal is mined underground (Hutton, 2009, p. 53). Open-cut mining has also taken place in the area. The Ulan Coal is correlated to the Lithgow Coal of the same coalfield (Hutton, 2009, p. 53).

### *1.2.1.2 Coal seam gas*

This section presents information about coal seam gas (CSG) in the geological Sydney Basin (referred to throughout this section as the Sydney Basin), the Permian coal measures and the Southern and Western coalfields. The NSW Government has introduced CSG exclusion zones around existing and future residential areas within the bioregion (see Figure 17 in companion product 1.1 for the Sydney Basin bioregion (Herron et al., 2018)), which prohibit CSG development within a 2 km radius of these residential areas. Thus, many areas of identified coal resources cannot be developed.

#### 1.2.1.2.1 Coal seam gas in the Sydney Basin

The coals of the Sydney Basin are considered favourable for the development of methane (O'Neill and Danis, 2013, p. 23). Methane is the dominant gas produced within the coals of the Sydney Basin, although carbon dioxide, nitrogen and other high molecular weight hydrocarbons such as ethane are present in smaller quantities (Faiz et al., 2007; Pinetown, 2013; Ward and Kelly, 2013). Sporadic occurrences of elevated concentrations of carbon dioxide and ethane have also been reported (Faiz et al., 2007; Pinetown, 2013; Ward and Kelly, 2013). The varying gaseous compositions are related to the combination of sources (thermogenic, biogenic and magmatic) contributing to the overall coal seam gas content (Scott and Hamilton, 2006; Faiz et al., 2007; Pinetown, 2013; Ward and Kelly, 2013).

Natural gas flow within the Sydney Basin was discovered as early as the 1800s in the Clyde Coal Measures and the Illawarra Coal Measures (O'Neill and Danis, 2013, p. 23). The dry and ash-free gas content of the Sydney Basin coals span a wide range from less than 1 to 21 $m^3$/t (Scott and Hamilton, 2006; Faiz et al., 2007; Pinetown, 2013; Ward and Kelly, 2013). In most occurrences, the gas content of the coals increases with depth (Ward and Kelly, 2013). The vitrinite reflectance data of the coals in the Sydney Basin range from 0.7% in the north of the geological basin to 1.3% in the (north of the) Southern Coalfield (Ward and Kelly, 2013). The vitrinite reflectance data indicates the hydrocarbon (gas) production phase reached by the coals of interest; the values indicated here indicate the catagenesis stage (Figure 6). The permeability of the coals is thought to be low in general due to the mineralisation of cleats and the decrease of permeability with depth (Pinetown, 2013; Ward and Kelly, 2013). The maximum permeability of the Sydney Basin coals is less than 5 mD (Ward and Kelly, 2013). Much of the basin's coal has reached thermogenic maturation and is producing gas (Scott and Hamilton, 2006; Ward and Kelly, 2013).

Thomson et al. (2014) undertook a study on the distribution of CSG within the northern Sydney Basin (Hunter subregion) and defined four zones. These zones are based on the dominant gas content (Thomson et al., 2014). Similar investigations have not been carried out for the southern portion of the basin (Figure 3).

Many reports on CSG distribution and characteristics are available in the DIGS (Digital Imaging of Geological Systems) website (NSW Trade and Investment, 2015b).

#### 1.2.1.2.2 Permian coal measures

Permian coal deposits are numerous across the Sydney Basin (O'Neill and Danis, 2013, p. 23). These coal deposits have been identified as good potential reservoirs (O'Neill and Danis, 2013, p. 24). Furthermore, the total organic carbon (TOC) values and the analysis have indicated that the Illawarra Coal Measures are good quality potential gas source rocks (Cadman et al., 1998; O'Neill and Danis, 2013, p. 24). Exploration drilling has identified oil and gas shows throughout the basin, though gas is more common onshore (O'Neill and Danis, 2013, p. 24).

The lower Permian source rocks (Clyde Coal Measures) are thought to have reached hydrocarbon maturation (as per the CSG generation window; Figure 6) during the Triassic, reaching peak maturity in the late Jurassic (O'Neill and Danis, 2013, p. 24). The upper Permian source rocks (Illawarra Coal Measures) reached the initial hydrocarbon production window during the late Jurassic (O'Neill and Danis, 2013, p. 24). The Permian Illawarra Coal Measures of the central and eastern Sydney Basin are classed as being overmature and within the dry gas window, based on vitrinite reflectance data (Cadman et al., 1998; O'Neill and Danis, 2013, p. 24). The vitrinite reflectance data also point to a mature status (oil window) within the western portion of the basin, whereas both the southern and northern regions of the basin are classed as immature to mature (no production of hydrocarbons to production of oil) (Cadman et al., 1998; O'Neill and Danis, 2013, p. 24).

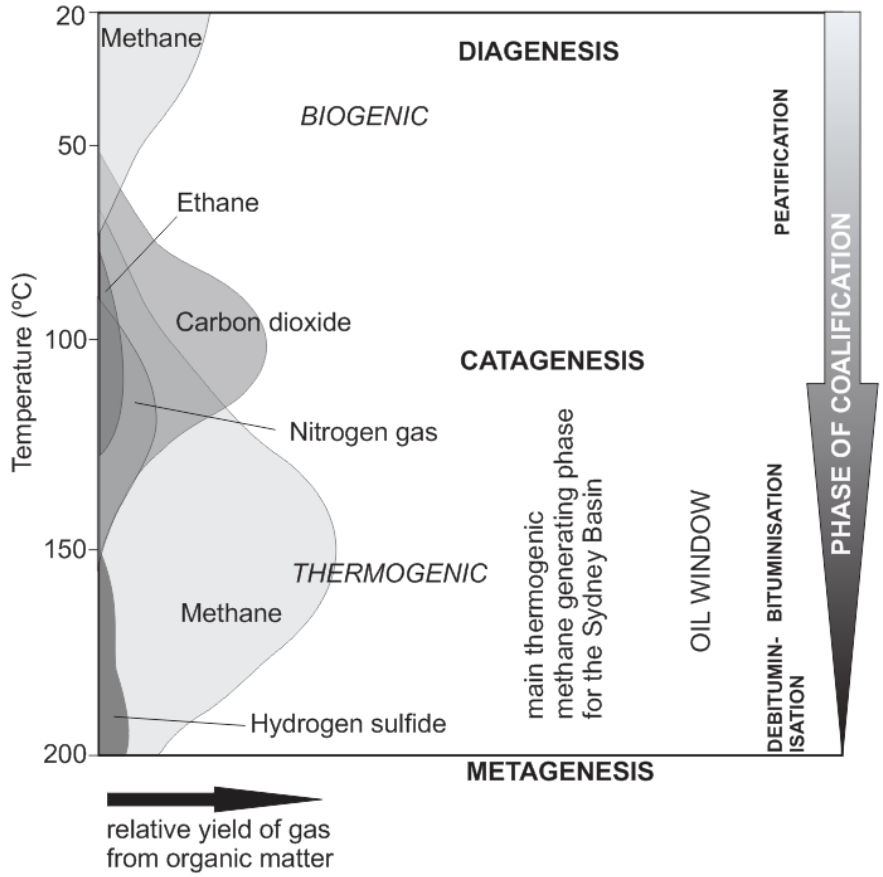


**Figure 6 Gas generation window for coal seam gas**

Coal seam gas is generally extracted down to about 1 km.
Source: after Thomson et al. (2014). Observations on the distribution of coal seam gas in the Sydney Basin and the development of a predictive model. Thomson S, Thomson D and Flood P. Australian Journal of Earth Sciences. Copyright © Geological Society of Australia, reprinted by permission of Taylor & Francis Ltd, www.tandfonline.com on behalf of Geological Society of Australia.

### 1.2.1.2.3 Southern Coalfield

The production of CSG from the Illawarra Coal Measures is currently taking place in the Camden-Campbelltown region as part of the AGL Energy Limited (AGL) operated Camden Gas Project in the Southern Coalfield (Sydney Catchment Authority, 2012, p. 3; O'Neill and Danis, 2013, p. 23). This is the Sydney Basin's only CSG production site (Sydney Catchment Authority, 2012, p. 8). The Camden Gas Project is located 64 km south-west of Sydney (Mine Subsidence Engineering Consultants, 2007, p. 5). Gas has been produced from the Camden Gas Project since 2001 (Ward and Kelly, 2013). There are currently 95 gas production wells in operation and several non-producing and sealed wells (AGL Energy Ltd, 2015). However, there have been some further CSG exploration activities within the basin (Sydney Catchment Authority, 2012, p. 4).

Production of CSG at the Camden Gas Project comes from the Illawarra Coal Measures (Sydney Catchment Authority, 2012, p. 4). The Illawarra Coal Measures are older and less permeable than the currently highest gas-producing coals in Australia, the Walloon Coal Measures of the Surat Basin (Sydney Catchment Authority, 2012, p. 4). The Illawarra Coal Measures are also considered to be at a more mature stage of hydrocarbon development (Sydney Catchment Authority, 2012, p. 4). The Illawarra Coal Measures are approximately 200 m thick in the Camden Gas Project

region (Camden-Campbelltown) (Sydney Catchment Authority, 2012, p. 42). The Camden Gas Project produces 6% of NSW domestic gas requirements (Sydney Catchment Authority, 2012, p. 4).

The Southern Coalfield is considered to have a high potential for CSG resources with the main phase of thermal gas generation having been reached (Scott and Hamilton, 2006; Ward and Kelly, 2013). Scott and Hamilton (2006) conducted an in-depth analysis of suitable CSG locations across the Sydney and Gunnedah basins. Of the suitable sites presented in the analysis, only two sites fall within the Sydney Basin bioregion. These are a north-south trending belt on the western side of the Cumberland Plain (along the Nepean River and Hawkesbury River valleys) and an area of the Illawarra escarpment which includes a number of Sydney's water supply catchments and storages. The late Permian coal has a maximum net thickness of 10 m at the first of these sites and 25 m at the other, and the coal has reached the thermogenic gas generation window, with the possibility for biogenic maturation (Scott and Hamilton, 2006). Both sites have a high gas content, though carbon dioxide is present and permeability of the host rocks can be variable (Scott and Hamilton, 2006; Ward and Kelly, 2013). In the Southern Coalfield underground mining operations use underground CSG extraction techniques to reduce the risks associated with mining the gaseous coals (Hanes et al., 2009). Much of the extracted gas is used for power production at the Appin and the former Tower mine sites (Ward and Kelly, 2013, p. 40).

#### 1.2.1.2.4 Western Coalfield

Scott and Hamilton (2006) also identified some prospective CSG regions bordering, but not contained within, the Western Coalfield (Ward and Kelly, 2013). The geological conditions of the Western Coalfield are not considered to be favourable for CSG development, as these coals are considered to be thermally immature.

Nevertheless, there may be potential for some CSG extraction in the Bylong Coal Project within the northern portion of the Western Coalfield (within the Hunter subregion) in coal intervals that are not mined for coal (Hansen Bailey, 2015, p. 31), although this is generally limited. Gas can be extracted in areas that have not been affected by igneous intrusions and where the gas contents range from 0.56 to 2.34 $m^3/t$ (Hansen Bailey, 2015, p. 31). This level of gas content is considered unusually high for the Western Coalfield; investigations by Thomson et al. (2014) found that the gas contents of the region were generally low at around 0.7 $m^3/t$ at a depth of 60 m. The gas is also mainly composed of carbon dioxide (Thomson et al., 2014). There are currently no producing CSG wells (NSW Trade and Investment, 2015a) and minimal CSG exploration in the Western Coalfield.

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## 1.2.2 Current activity and tenements


***Summary***

There are currently eight commercially producing coal mines in the Sydney Basin bioregion including the Appin–West Cliff Mining Complex which consists of two individual mines, Appin Mine and West Cliff Colliery. Most coal mines in the Sydney Basin bioregion are underground operations producing both thermal and coking coal for domestic and export markets. These mining operations occur within two distinct parts of the bioregion, commonly known as the Western Coalfield and the Southern Coalfield. The Western Coalfield occurs in the Blue Mountains region near Lithgow, whereas the Southern Coalfield is in the Illawarra region near Wollongong.

In addition to the producing mines there are nine mines that are currently under care and maintenance. These mines have mainly been put into care and maintenance due to reserve depletion or prevailing economic conditions.

There is one producing coal seam gas (CSG) operation in the Sydney Basin bioregion, AGL Energy's Camden Gas Project.


### *1.2.2.1 Coal*

As of February 2016, there are currently eight active coal mines and nine mines under care and maintenance (Table 5). It is unclear on the basis of available evidence when (and if) all of the mines currently in care and maintenance will resume commercial production. Hence the status shown for each operation in Table 5 may change in the future. Figure 7 shows the locations of the mines discussed in this section.

**Table 5 List of mines discussed showing owner and activity status at the time of writing and coalfield in which it resides**

| Name | Owner | Status | Coalfield |
|---|---|---|---|
| Airly Coal Mine | Centennial Coal | Active | Western Coalfield |
| Appin–West Cliff Mining Complex | South32 | Active | Southern Coalfield |
| Charbon Coal Mine | Centennial/SK Energy | Active | Western Coalfield |
| Clarence Colliery | Centennial Coal | Active | Western Coalfield |
| Dendrobium Coal Mine | BHP Billiton Illawarra Coal | Active | Southern Coalfield |
| Metropolitan Coal Mine | Peabody Energy | Active | Southern Coalfield |
| Springvale Coal Mine | Centennial Springvale Pty Ltd/Springvale SK Kores Pty | Active | Western Coalfield |
| Tahmoor Coal Mine | Glencore | Active | Southern Coalfield |
| Angus Place Colliery | Centennial Springvale Pty Ltd/Springvale SK Kores Pty | Care and maintenance | Western Coalfield |
| Baal Bone Colliery | Glencore | Care and maintenance | Western Coalfield |
| Berrima (Medway) Colliery | Boral | Care and maintenance | Southern Coalfield |
| Cullen Valley Coal Mine | Coalpac | Care and maintenance | Western Coalfield |
| Invincible Colliery | Coalpac | Care and maintenance | Western Coalfield |
| Ivanhoe Colliery | Centennial Coal | Care and maintenance | Western Coalfield |
| Pine Dale Coal Mine | Enhance Place | Care and maintenance | Western Coalfield |
| WCL Russell Vale Colliery | Wollongong Coal Limited | Care and maintenance | Southern Coalfield |
| WCL Wongawilli Colliery | Wollongong Coal Limited | Care and maintenance | Southern Coalfield |

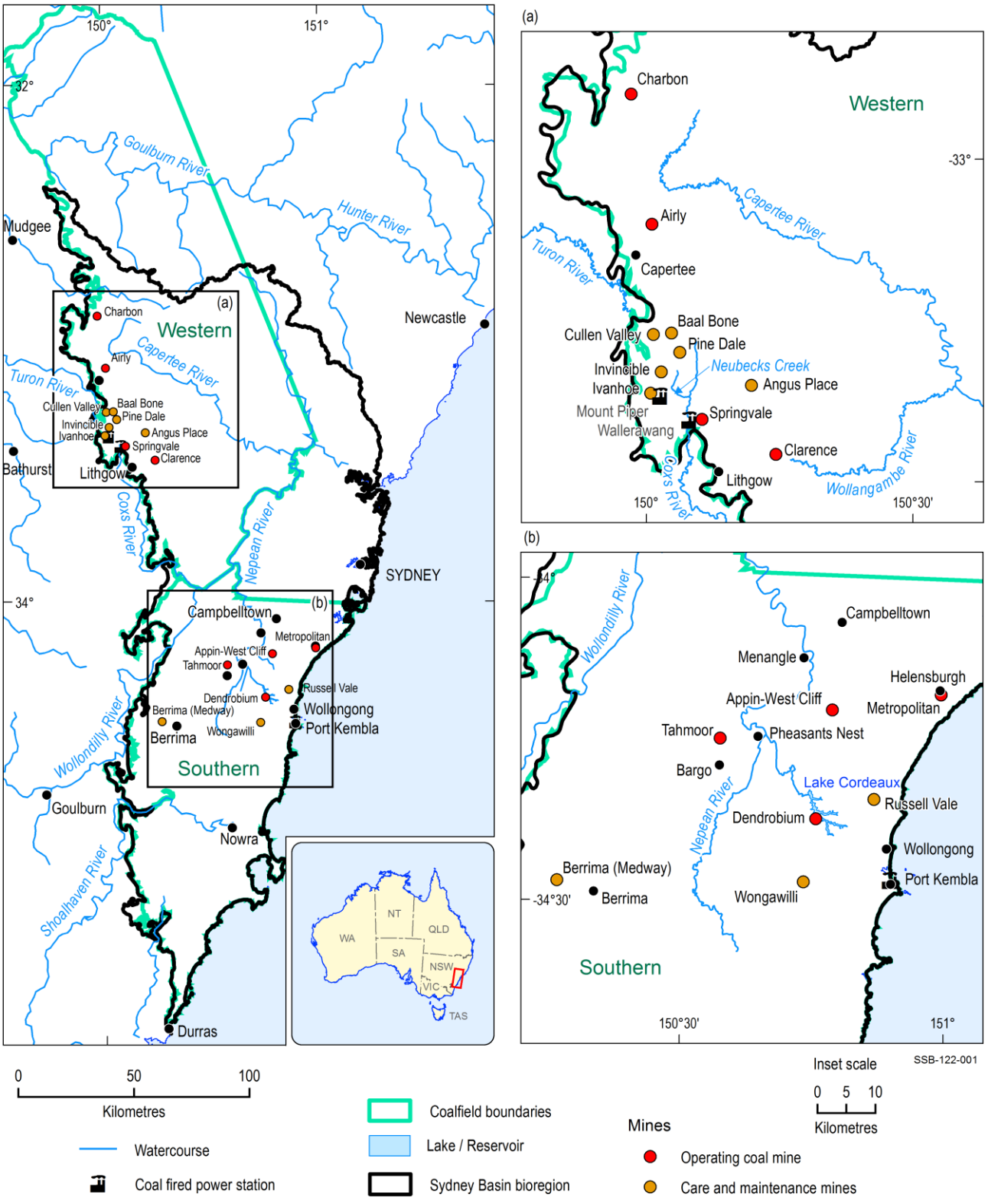


**Figure 7 Mines and infrastructure in the Sydney Basin bioregion, as at 18 January 2016**

Data: Bioregional Assessments Programme (Dataset 1)

### 1.2.2.1.1 Airly Coal Mine (Western Coalfield)

Airly is an underground mine producing thermal coal. It is operated by Centennial Airly Pty Ltd, a wholly owned subsidiary of Centennial Coal (Centennial Coal, 2014a, p. 4). Airly Mine is situated in the Western Coalfield, approximately 40 km north-north-west of Lithgow and 4 km north-east of

Capertee (Centennial Coal, 2014a, p. 4). Airly Mine was first granted development consent (DA 162/91) in 1993 (GHD, 2014, p. 2) while under the ownership of Novacoal. Airly was sold to Centennial Coal on 30 December 1997 and construction commenced in March 1998 (GHD, 2014, p. 3). The first expiration of the mining lease occurred in October 2014. Centennial Coal applied for a modification to extend life of the mine for 12 months, and the Planning Assessment Commission (PAC) granted approval to continue operations until 31 October 2015 (DP&E, 2015a, p. 4). In August 2015, development consent was modified to extend the expiry date of the consent to April 2016 (PAC, 2015a, p. 1). The company has requested an extension to the mine for 20 years of additional mining followed by 5 years of decommissioning and rehabilitation (DP&E, 2015b). The extension project is discussed further in Section 1.2.3.

Operations at Airly are approved under Mining Lease (ML) 1331, which covers about 2745 ha, as well as Authorisation A232, which covers 3054 ha (Centennial Coal, 2014a, p, 6). Although the mine was put into care and maintenance in late 2012, it re-opened in February 2014 and coal production recommenced during March 2014. The mine has been designed for a life of 25 years from 2009 at 1.8 Mt/year (Centennial Coal, 2012a; Centennial Coal, 2014a, p. 10).

Thermal coal is mined at Airly for the export market (Centennial Coal, 2012a), and is extracted from the Lithgow Coal within the Illawarra Coal Measures using bord and pillar mining methods (DP&E, 2015a). Full production capacity is 1.8 Mt/year, with remaining reserves of 33.7 Mt equivalent to 18.7 years of production (Centennial Coal, 2012a; Banpu, 2015). Production in 2015 (to October 2015) is reported as approximately 460,000 t (Centennial Coal, 2014b, p. 10).

The operation uses a continuous miner system to extract coal from underground (Centennial Coal, 2012a). On-site facilities include a coal handling and preparation plant (CHPP), as well as a rail loop and loading facility for rail transport to Port Kembla (Centennial Coal, 2012a).

#### 1.2.2.1.2 Appin–West Cliff Mining Complex (Southern Coalfield)

The Appin–West Cliff Mining Complex has previously been known by many other names, including the Bulli Seam Operations, Bulli Seam Operations Project, Appin Coal Mine and West Cliff Colliery Complex, and Appin and West Cliff Collieries. The Appin–West Cliff Mining Complex is owned and run by South32, which in turn is owned by BHP Billiton Illawarra Coal Holdings Pty Ltd (Illawarra Coal). The mining complex is in the Southern Coalfield of the geological Sydney Basin, located 15 to 20 km west of Wollongong (Figure 7). The Appin–West Cliff Mining Complex comprises two underground mines, the Appin Mine and the West Cliff Colliery (DP&E, 2015c, p. 2).

Appin Coal Mine commenced production in 1962, working the 2 to 3 m thick Bulli Coal at a depth of about 500 m. In 1979 there was a fatal gas explosion, and gas drainage of the mine workings remains a primary concern (BHP Billiton, nd. p. 3–20). The West Cliff Colliery was granted authority to mine in 1969, and commenced activity in 1976, with longwall production starting in 1982 (BHP Billiton, nd. p. 3). The mine is approximately 480 m below surface (BHP Billiton, nd. p. 3).

As of 2011 the Appin–West Cliff Mining Complex was approved to extract up to 10.5 Mt/year of run-of-mine (ROM) coal using longwall and conventional underground mining methods until 2041 (NSW Planning and Environment, 2015, p. 2). This equated to an expected total production at the complex of 260 Mt of product coal over 30 years (PAC, 2010, p. i). The operations area for the

Appin–West Cliff Mining Complex is divided into seven mining domains (PAC, 2010, p. 10), named by Illawarra Coal as North Cliff, Area 2, Area 3, West Cliff Area 5, Area 7, Area 8 and Area 9 (PAC, 2010, p. 10).

Coal is mined from the Bulli Coal and is high quality black coking coal, used for the steel making industry. Joint reserves and resources for the Appin-West Cliff Mining Complex are in Table 6.

**Table 6 Resources and reserves for the Appin Coal Mine and West Cliff Colliery as at 30 June 2014**

| Mine | Proved coal reserves (Mt) | Probable coal reserves (Mt) | Measured coal resources (Mt) | Indicated coal resources (Mt) | Inferred coal resources (Mt) |
|---|---|---|---|---|---|
| Appin Coal Mine | 24 | 133 | 157 | 256 | 289 |
| West Cliff Colliery | 5.4 | 0.4 | 21 | 21 | 68 |

Data: South32 (2015a, p. 54)

The complex is authorised to transport up to 9.3 Mt/year ROM coal using road and rail, to Port Kembla for export, as well as to transport and emplace coal rejects at the West Cliff Emplacement (DP&E, 2015c, p. 2; South32, 2015b).

A condition of approval by the Director General to compensate for the impacts of underground mining at Appin–West Cliff Mining Complex and Dendrobium Coal Mine included a requirement to prepare and implement a biodiversity offset strategy (DP&E, 2015c p. 2). In response, a biodiversity offset has been developed to compensate for residual impacts on upland swamps and a second offset plan to compensate for the loss of water quality and loss of groundwater flows, vegetation clearing and ground disturbance in the Sydney Catchment (DP&E, 2015c, p. 2). A third proposed offset is a conservation bank (DP&E, 2015c, p. 2). South32 is currently seeking modifications to the biodiversity offset to satisfy Appin–West Cliff Mining Complex and Dendrobium Coal Mine requirements and act as a conservation bank for Illawarra Coal to draw down to compensate any subsidence impacts that may occur as mining progresses (DP&E, 2015c, p. 3).

#### 1.2.2.1.3 Charbon Coal Mine (Western Coalfield)

Charbon Coal Mine (Charbon) ceased production in August 2015 and is currently under care and maintenance with ongoing rehabilitation of main disturbance areas (Centennial Coal, 2015a, p1, Charbon Coal Pty. Limited, 2016). The mine previously operated as both an underground and an open-cut mine (RW Corkery & Co Pty Limited, 2008, p. 5; NSW Department of Planning, 2010, p. 1). Charbon has beens a joint operation between Centennial Coal (95% share) and SK Energy Australia Pty Ltd (a wholly owned subsidiary of SK Corporation, Korea), and was acquired in 1994 from Boral (Centennial Coal, 2015b), operated by Charbon Coal Pty Ltd (NSW Department of Planning, 2010, p. 1–2). The mine is in the Western Coalfield, about 3 km south of Kandos and 50 km south-east of Mudgee (Figure 7) (NSW Department of Planning, 2010, p. 1).

Mining at Charbon commenced in 1920 and mine upgrades at the site have occurred steadily since (NSW Department of Planning, 2010, p. 2). Coal mined at the site was extracted from the Permian Illawarra Coal Measures, which includes the Charbon and Cullen Bullen subgroups. Five coal-

bearing units occur within the colliery boundary, namely the Middle River Coal Member (of the Farmers Creek Formation), Moolarben Coal Member (of the State Mine Creek Formation), Irondale Coal, Lidsdale Coal and Lithgow Coal (RW Corkery & Co Pty Limited, 2008, p. 9). Remaining coal reserves reported by Centennial Coal in 2013 were approximately 1.8 Mt (proved and probable), with total resources of 4.1 Mt (Banpu, 2015).

Coal mined at Charbon was sold to the domestic and export thermal coal markets (Centennial Coal, 2015b). Locally, coal was trucked to Boral's nearby lime and cement works and the former Wallerawang and the current Mount Piper power stations near Lithgow (NSW Department of Planning, 2010, p. 1). Coal was transported by rail to Port Kembla for the overseas market (Centennial Coal, 2015b). Full production capacity was 1.3 Mt/year ROM coal (Centennial Coal, 2015b; NSW Department of Planning, 2010, p. 2). The site consisted of five small open-cut pits and an underground mine that used a continuous miner system (NSW Department of Planning, 2010, p. 1). The pits are known as Southern Extension, Central, 8 Trunk, Western Outlier and Southern Outlier (NSW Department of Planning, 2010, p. 2)

On-site facilities included a CHPP, rail loop and rail loading facilities (Centennial Coal, 2015b). The mine was licensed for groundwater extraction of up to 30 ML/year from bores and up to 5 ML/year from the Charbon Underground Mine (Centennial Coal, 2014b, p. 7).

#### 1.2.2.1.4 Clarence Colliery (Western Coalfield)

The Clarence Colliery Pty Ltd (Clarence) underground coal mine is a wholly owned subsidiary of Centennial Coal (itself wholly owned subsidiary of Banpu Public Company). Situated in the Western Coalfield approximately 15 km east of Lithgow, Clarence produces thermal coal for the domestic and export thermal coal markets (transported by road and rail respectively) (Centennial Coal, 2015c). The operation includes Consolidated Coal Lease (CCL) 705 and Mining Lease (ML) 1583, which are valid until 2027 (Centennial Coal, 2013, p. 13). Mining commenced in 1979 (Centennial Coal, 2013, p. 10) and the mine was acquired by Centennial Coal in 1998 (Centennial Coal, 2015c; Centennial Coal, 2013, p. 10). Centennial Coal owns 85% of the mine in a joint venture with SK Energy Australia Pty Ltd (15%) (Centennial Coal, 2015c).

Coal is extracted from seams within the Permian Illawarra Coal Measures, namely the Katoomba Coal Member (of the Farmers Creek Formation) and the Lithgow Coal using bord and pillar methods (Centennial Coal, 2013, p. 10, NSW Department of Planning, 2005, p. 1). Reserves remaining as at 2013 were estimated at 48.8 Mt (proved and probable), with total resources of 209.5 Mt (Banpu, 2015). The underground mine operates with continuous miner technology (Centennial Coal, 2015c). Clarence is authorised to extract up to 3 Mt/year of ROM coal and may transport up to 200,000 t/year of coal by road to Mount Piper Power Station (NSW Department of Planning, 2005, p. 3–4). Full production capacity of the mine is 2.5 Mt/year, although actual production rates commonly vary between 2 and 2.5 Mt/year (Centennial Coal, 2015d). For example, in 2011, the mine reported extraction of 2 Mt of coal, whereas production in 2013 was 2.4 Mt (Centennial Coal, 2015d).

Clarence operates a flexible conveyor train, which is a high capacity continuous haulage system for transporting ROM coal around the site (Centennial Coal, 2015c). Coal is transported by conveyor to the on-site CHPP and water treatment plant. Coal is then stockpiled on site prior to dispatch.

Product coal is transported by rail link to Port Kembla for export market by rail via the mine's rail loop and the main Western Railway (NSW Department of Planning, 2005, p. 1). Up to 200,000 t/year of product coal is transported to local domestic markets on public roads (NSW Department of Planning, 2005, p. 1).

Clarence Colliery is licensed to dewater the mine for safety reasons. Water is extracted via two boreholes and is transported by overland pipeline to the water treatment plant and released offsite through a licensed discharge point. Partial extraction method is used at Clarence, which reduces impact on the surrounding groundwater resources in accordance with licence requirements (Centennial Coal, 2013, p. 20). All mine water make is passed to the Clarence Colliery Water Treatment Plant (CCWTP), which has specifically been designed to remove naturally occurring manganese and iron from the raw mine water (Centennial Coal, 2013, p. 21–22).

In July 2015, a spill occurred from a coal reject stockpile at the Clarence Colliery, resulting in many tonnes of fines and coarse reject material being dispersed in the surrounding environment, including the Wollangambe River. The incident was reported to the NSW Environment Protection Authority who, in turn, inspected the site and issued a Clean-up Notice outlining the requirements (EPA, 2015). In response, the company removed the spilt reject material between the mine and river and installed 22 silt fences between the mine and the river to prevent further impact (EPA, 2015).

#### 1.2.2.1.5 Dendrobium Coal Mine (Southern Coalfield)

Dendrobium Coal Mine (Dendrobium) is owned and operated by South32, which is owned by BHP Billiton Illawarra Coal Holdings Pty Ltd (Illawarra Coal). The mine is adjacent to Lake Cordeaux in the Southern Coalfield, approximately 15 km west of Wollongong (DP&E, 2015c, p. 1), and 80 km south-west of Sydney (Figure 7) (South32, 2015a, p. 31). Dendrobium produces coking coal that is sold to both domestic and international markets (Cardno Forbes Rigby, 2007, p. 18). The Dendrobium operations are linked to other South32 operations at nearby Appin–West Cliff Mining Complex and are closely situated. Coal rejects at Dendrobium are transported and emplaced at West Cliff Coal Wash Emplacement Area (DP&E, 2015c, p. 1). Consent to mine at Dendrobium was granted to Illawarra Coal in November 2001 (Cardno Forbes Rigby, 2007, p. 1). Although the mine has not been sold since, BHP Billiton simplified its portfolio in May 2015 by demerging a group of assets and creating an independent mining company, South32 (BHP Billiton, 2015), the current owner of the mine. The mine is at CCL 768 and the consent provided for three underground longwall areas (Area 1, Area 2 and Area 3) to be mined (Cardno Forbes Rigby, 2007, p. 1).

Coal is extracted from the Wongawilli Coal, a stratigraphic unit in the Sydney Subgroup (Cardno Forbes Rigby, 2007, p. 13). Dendrobium has development consent to extract 5.2 Mt/year of ROM coal using longwall and conventional underground methods until 2030 (DP&E, 2015c, p. 1). Mining is currently taking place in 'Area 3B'. Resources and reserves at Dendrobium are summarised in Table 7.

**Table 7 Coal resources and reserves at Dendrobium Coal Mine, as at 30 June 2014**

| Proved coal reserves (Mt) | Probable coal reserves (Mt) | Measured coal resources (Mt) | Indicated coal resources (Mt) | Inferred coal resources (Mt) |
|---|---|---|---|---|
| 21 | 24 | 86 | 91 | 118 |

Data: South32 (2015a, p. 54)

ROM coal may only be transported from the site by rail (DP&E, 2015c, p. 3). Coal is transported to the Dendrobium Coal Preparation Plant at Port Kembla Steelworks for processing. Coal rejects are transported to the West Cliff Coal Wash Emplacement Area.

Biodiversity offset programs have been developed for the Dendrobium and Appin–West Cliff Mining Complex sites as a requirement of the conditions of approval by the Director-General, to compensate for the impacts of underground mining on water quality and groundwater flow into the catchment area, upland swamps, land disturbance and vegetation clearing (DP&E, 2015c, p. 2).

#### 1.2.2.1.6 Metropolitan Coal Mine (Southern Coalfield)

Metropolitan Coal Mine (also known as Metropolitan Collieries and Metropolitan Coal) is an underground mine, wholly owned and operated by Peabody Energy Australia Pty Ltd (Peabody Energy, 2015b). The mine is approximately 30 km north of Wollongong and adjacent to the town of Helensburgh (Figure 7) (Peabody Energy, 2015a, p. ES-1). Current approval was granted in 2009, which allows mining to take place until 2021 (Peabody Energy, 2015a, p. 7; NSW Government, 2013, p. 3) at leases CCL 703, ML 1610 and ML 1702 (Peabody Energy, 2015a, p. 1). The mine produces coking coal for domestic and export markets (Peabody Energy, 2015b).

Mining has taken place at the site since 1884 (OE&H, 2015). Longwall mining of the Bulli Seam commenced in 1995 (Helensburgh Coal Pty Ltd, 2002, p. 2). The mine has previously been known as Helensburgh Mine and Helensburgh Colliery (Helensburgh Coal Pty Ltd, 2002, p. 2; Peabody Energy, 2015a). The mine was purchased from Helensburgh Coal Pty Ltd (a wholly owned subsidiary of Peabody Pacific Pty Limited) by Peabody Energy Australia Pty Ltd and an upgrade, extension and continuation project for Metropolitan was approved in 2009 (Peabody Energy, 2015a, p. ES-1).

The mine is currently authorised to extract up to 3.2 Mt/year of ROM coal (NSW Government, 2013, p. 3) and transport a maximum of 2.8 Mt/year (NSW Government, 2013, p. 3). In 2014, Metropolitan produced 2.4 Mt of saleable coal (Peabody Energy, 2015b). The mine may operate under the current agreement until 2032 (NSW Government, 2013, p. 3). According to the OZMIN database, in 2014 Metropolitan had existing proved and probable coal reserves of about 28 Mt.

Metropolitan targets the Bulli Coal, part of the Sydney Subgroup within the Permian Illawarra Coal Measures of the Southern Coalfield (Helensburgh Coal Pty Ltd, 2002, p. 2). Mining operations use longwall technology and ROM coal is transferred by conveyor to on-site processing facilities (Peabody Energy, 2015b). From the CHPP, coal is shipped by rail to Port Kembla Coal terminal for domestic and overseas customers (Peabody Energy, 2015b).

Metropolitan pioneered the use of polyurethane resin (PUR) injections to fill localised shallow surface cracking to restore surface flows in the Sydney Drinking Water Catchment, and continues

to work on this technology for further remediation purposes (Peabody Energy, 2015b). The mine is trialling underground emplacement of reject material from the CHPP, by pumping the processed reject material through pipeline into disused adits in the underground mine. Approximately 81,000 t of reject material was disposed of in this way from 2012 to 2014 (Peabody Energy 2015a, p. 329), leading to a reduction of truck movements at and from the site (Peabody Energy 2015a, p. 328).

#### 1.2.2.1.7 Springvale Coal Mine (Western Coalfield)

Springvale is an underground longwall coal mine in the Western Coalfield of the geological Sydney Basin (Centennial Coal, 2014c, p. 5). The mine is owned by Centennial Springvale Pty Ltd (50%) and Springvale SK Kores Pty Ltd (50%), forming the Springvale unincorporated joint venture (Centennial Coal, 2014d, p. i). Mining is undertaken by Springvale Coal Pty Ltd for and on behalf of the joint venture (Centennial Coal, 2014c, p. 5; Centennial Coal, 2014d, p. i). Springvale is 10 km north-west of Lithgow and 120 km west-north-west of Sydney (Centennial Coal, 2014a, p. 5). The mine produces thermal coal for domestic and international markets (Centennial Coal, 2014a, p. 5).

Mining commenced at Springvale in 1995 (Centennial Coal, 2014c, p. 5) and operates within ML 1303, ML 1323, ML 1326, ML 1537, ML 1588, ML 1670, Mining Purposes Lease 314 and CCL 377 (DP&E, 2015d, p. 2). The previous consent for mining expired on 15 September 2015 and although an environmental impact statement was submitted to the NSW Department of Planning and Environment in April 2014 to extend the period of mining at the site, approvals for the continuation of operations were not finalised until October 2015. Operations at Springvale ceased for about two months in August 2015 due to delays in securing mining approvals, and resumed again in October 2015 following granting of the necessary approvals.

Thermal coal is produced at Springvale from the Lithgow Coal (Centennial Coal, 2014d, p. i). Remaining reserves as at end of 2013 were reported as 41.1 Mt and resources as 155.4 Mt (Banpu, 2015). The mine is currently authorised to extract up to 4.5 Mt/year ROM coal (Centennial Coal, 2014c, p. 5). In 2013 and 2014, the mine produced 2.7 Mt (Centennial Coal, 2015f) and 3.48 Mt (Centennial Coal, 2015f) respectively.

Springvale has dedicated conveyors to transport coal to the nearby Mount Piper Power Station, as well as rail loading facilities to transport coal to Port Kembla for export (Centennial Coal, 2015f). The site also has a crushing house, CHPP (Western Main) and overland conveyors to the plants (Centennial Coal, 2015f).

#### 1.2.2.1.8 Tahmoor Coal Mine (Southern Coalfield)

Tahmoor Coal Mine (Tahmoor) is an underground longwall coal mine (Glencore, 2015a) owned and managed by Glencore plc (Glencore, 2015a). The mine is in the Southern Coalfield approximately 80 km south-west of Sydney (Figure 7) (Glencore 2014, p. 3). Operations at Tahmoor are variously referred to as Tahmoor Underground Glencore (Glencore 2014, p. 8), Tahmoor Colliery, Tahmoor Coal, Tahmoor North Underground or Tahmoor Mine. Additionally, Tahmoor South Underground is a current development project (see Section 1.2.3.1.5). Coal produced at Tahmoor is mostly of coking quality and used for steel making. A small amount

of thermal grade coal is also produced and sold for domestic power generation (AECOM, 2012, p. 1). Current mining is forecast to continue until 2019 (Tahmoor Coal, 2016).

Tahmoor was originally constructed by Clutha Development in 1975 and mining commenced in 1980 (Glencore, 2014, p. 8). The Tahmoor Washery was commissioned in 1981. In 1985 BP Coal acquired the mine from Clutha Development (Glencore, 2014, p. 8). A gas extraction facility was commissioned in 1987 at which time longwall mining commenced. BP Coal sold its interest to Conzinc Rio Tinto Australia (CRA) in 1989 (Glencore, 2014, p. 8). Austral Coal Ltd acquired Tahmoor Coal from CRA in 1997, with Centennial Coal acquiring a majority share in Austral Coal Ltd in 2005. In 2007, Xstrata Coal Pty Ltd acquired 100% shareholding in Austral Coal Ltd and with it, the ownership of Tahmoor Coal (Glencore, 2014, p. 8). In May 2013, Xstrata Coal Pty Ltd and Glencore plc merged.

Until 1987 mining at Tahmoor was undertaken using bord and pillar methods, after which longwall mining was introduced (Glencore, 2015a). The Tahmoor Mine targets the Bulli Coal, although several other coal-bearing units occur in the mine area including the Balgownie Coal Member and the Wongawilli Coal. Both of these units are relatively gassy and are major sources of carbon dioxide and methane at the mine (Glencore, 2014, p. 61). Consequently, these seams are accessed and degassed at Tahmoor for safety reasons. Some of the methane produced via this mine gas drainage is used for electricity generation by Energy Developments Ltd, with the remainder being flared (Glencore, 2014, p. 61). Operations at Tahmoor North occur within several mining leases, including ML 1376, ML 1308, ML 1539, ML 1642, and CCL 716. At Tahmoor South, the relevant consolidated coal leases are CCL 716 and CCL 747 (Glencore, 2014, p.2; AECOM, 2012, p. 1).

Tahmoor North underground workings extend north under the township of Tahmoor towards Thirlmere and Picton. Exploration and potential development activity at Tahmoor South extends south towards Bargo and east around Pheasants Nest (Glencore, 2014, p. 8). The mine currently has consent to produce up to 3 Mt /year of ROM coal (Glencore, 2015a). In 2014, the mine produced 2.4 Mt ROM coal (Glencore, 2014, p. 14). Total coal reserves (proved plus probable) at Tahmoor are estimated at 63 Mt, comprising 25 Mt proved and 38 Mt probable (Geoscience Australia, Dataset 2). Total identified coal resources (inclusive of reserves) are 65 Mt measured, 340 Mt indicated and 250 Mt inferred.

On-site facilities and infrastructure at Tahmoor include a CHPP, which can process up to 650 tonnes of coal per hour. The CHPP separates coking coal from steaming blend coal, and also removes rock and other non-coal material through screening and cyclonic processes (Glencore, 2015a).

#### 1.2.2.1.9 Angus Place Colliery (Western Coalfield)

Angus Place Colliery is an underground coal mine owned by Centennial Springvale Pty Ltd (50%) and Springvale SK Kores Pty Ltd (50%). The Angus Place Colliery is part of the Centennial Coal asset portfolio and is operated by Centennial Angus Place on behalf of the Angus Place/Springvale joint venture (Centennial Coal, 2014c, p. 5). In March 2015 mining operations at Angus Place Colliery ceased due to the ongoing economic downturn and the mine was placed under care and maintenance. Two development crews and some equipment were redeployed to Centennial's

nearby Springvale coal mine (Centennial Coal, 2015b). As of February 2016, it is unclear when Angus Place Colliery will resume commercial operations.

Angus Place Colliery is 15 km north-west of Lithgow and 120 km west-north-west of Sydney (Centennial Coal, 2014c, p. 5). The mine produced thermal coal (Centennial Coal, 2015d) for the former power station Wallerawang and the current power station Mount Piper (Centennial Coal, 2015d). Development consent remains current and will expire at the mine in August 2024 (Centennial Coal, 2014c, p. 5).

Mining has occurred at the site for nearly 70 years (Centennial Coal, 2015d). Angus Place Colliery production commenced in 1979 as an extension of the original mine at the location, Newcorn Mine at Kerosene Vale, and was set up as a dedicated mine for producing thermal coal for local power stations. At this time it was owned by the NSW Government (Centennial Coal 2012b, p. 52), with Centennial Coal purchasing the mine in 2002 as part of the 'Powercoal acquisition' from NSW (Centennial Coal, 2015c).

Coal at Angus Place Colliery is extracted from the Lithgow Coal (Centennial Coal, 2012b, p. 44), which is part of the Illawarra Coal Measures. The coal measures are overlain by massive sandstone- and conglomerate-rich units. The seam is relatively horizontal, but depth of cover varies considerably at the mine site due to surface topography (Centennial Coal, 2012b, p. 6). The mine is within Mining Lease (ML) 1424 and Consolidated Coal Lease (CCL) 704 and CCL 702. Remaining coal reserves are reported as 54 Mt (Centennial Coal, 2015d).

Both longwall and continuous miner methods were most recently used to extract coal at Angus Place Colliery (Centennial Coal, 2015d). In 2014, approximately 3.4 Mt of coal was mined (Centennial Coal, 2015d). Full production capacity of the mine is 4 Mt/year. On-site facilities and infrastructure include a coal crushing plant and private haul roads to the nearby power stations (Centennial Coal, 2015d).

Water is currently pumped from the underground workings to the surface and transferred to the former Wallerawang Power Station using the Springvale–Delta Water Transfer Scheme (Centennial Coal, 2012b, p. 10). An emergency discharge point is authorised at Kangaroo Creek (a tributary of Coxs River) if water is unable to be transferred to the power station (Centennial Coal, 2012b, p.10). An extension has been sought to construct and operate facilities that will dewater boreholes and deliver water into the existing Springvale–Delta Water Transfer Scheme (Centennial Coal, 2012b).

#### 1.2.2.1.10 Baal Bone Colliery (Western Coalfield)

Baal Bone Colliery is owned by Glencore, and is located 32 km north of Lithgow and approximately 130 km from Sydney. Baal Bone Colliery is operated by Wallerawang Collieries Pty and is both an underground and open-cut operation. The mine is situated at the location of a former mine, Ben Bullen open-cut mine, which was abandoned in 1982 (Glencore, 2015b). The development of Baal Bone Colliery was to replace the diminishing reserves as the former Wallerawang Colliery, which is situated south of Baal Bone Colliery. Final mining took place at Baal Bone Colliery in 2011. Washing and transport of coal continued until mid-2012 when the site was placed on care and maintenance (Umwelt, 2015, p. i). The mine was used until September 2012 as a training facility for Xstrata

employees to provide experience and skills in underground mining (Glencore, 2015b; Glencore, 2013, p. 1). Extraction of remnant coal areas is approved until 30 December 2019 (Umwelt, 2015, p. i). In 2014 Glencore called for expressions of interest to purchase Baal Bone Colliery although the timing and nature of any further planned activity is not currently known.

#### 1.2.2.1.11 Berrima (Medway) (Southern Coalfield)

Berrima (Medway) Colliery (also referred to as Berrima Colliery) is an underground bord and pillar coal mine in the village of Medway, 8 km west of New Berrima in the Southern Coalfield of the geological Sydney Basin (Figure 7). The mine is owned by Boral Ltd and managed by its subsidiary, Boral Cement Ltd. Mining operations were undertaken by Delta Mining (EMGA Mitchell McLennan, 2011, p. S.1; Boral, 2015a). Thermal coal produced at the mine was supplied to Boral's neighbouring cement works. The mine entered care and maintenance in late 2013 when production was suspended due largely to unfavourable market conditions (Boral, 2014).

Mining in the area dates back to 1872 (the Rock Roof Colliery) and the Berrima Colliery commenced in 1924, operating continuously until 2013 (Boral, 2012, p. 5; Boral, 2015a; EMGA Mitchell McLennan, 2011, p. S.1). Mining targeted the Wongawilli Coal, part of the Illawarra Coal Measures, and coal was originally manually excavated (pick and shovel) using horse-drawn skips along underground rail tracks. In 1956 a continuous miner mechanism was commissioned; later three breaker line supports for roof control were installed (Boral, 2012, p. 11).

The Berrima Colliery includes the mine, a stockpiling site at a nearby historical mine (Loch Catherine) and a conveyor system (Boral, 2015a; EMGA Mitchell McLennan, 2011, p. S.1). Medway Village was originally established as an ancillary settlement for mine employees, although during the 1990s the sale of surplus land generated additional residences (Boral, 2015a). The mine had the capacity to produce up to 500,000 t/year, making it one of the smallest commercially producing coal mines in Australia (EMGA Mitchell McLennan, 2011, p. S.1). The mine operated mainly under CCL 748 (EMGA Mitchell McLennan, 2011, p. S.1). In July 2014, Boral announced it would seek approval from the NSW Government to permanently close the site (Boral, 2014, 2015b). The final closure plan seeks to permanently seal the mine entrances, construct bulkheads in the underground workings to permanently flood the underground mine, demolish and remove all surface infrastructure, remediate areas of contamination, and rehabilitate the pit top and coal storage area (Boral, 2015b, p. 30).

#### 1.2.2.1.12 Cullen Valley Coal Mine (Western Coalfield)

Cullen Valley is an open-cut coal mine in the Western Coalfield, owned and managed by Coalpac Pty Ltd (Coalpac, 2013, p. iv). The Cullen Valley Mine is north-west of the township of Cullen Bullen, 5 km from the Mount Piper Power Station and adjacent to both the Baal Bone and Invincible collieries (Coalpac, 2015a; Coalpac, 2013, p. iv). The mine was put into care and maintenance in December 2012 and no mining activities have taken place since (Coalpac, 2013, p. iv). In October 2014, a proposal to extend the approved area for open-cut and highwall mining was rejected by the NSW Planning Assessment Commission (PAC, 2014, p. 1) and, as a result, the company has gone into liquidation.

Cullen Valley Coal Mine site contains the former mining areas of the Tyldesley and Beaumaris collieries where underground mining commenced in the late 1800s (Coalpac, 2013, p. v). Since that time a range of both open-cut and underground mining activities have taken place in the area (Coalpac, 2013, p. v). In 2000, Lithgow Coal Company commenced open-cut mining at the site (Coalpac, 2013, p. v). A mining consent modification was granted in 2004 that allowed the mine to operate for up to 21 years (until 2025) on ML 1556 and ML 1557. Following this decision, further areas of open-cut mining commenced at the site (Coalpac, 2013, p. 1). The consent also allowed for transport of up to 250,000 t of coal by year to domestic destinations other than Mount Piper Power Station (NSW Government, 2004, p. 5).

In 2007, the mine was put into care and maintenance as it was unable to renew a supply contract to the Mount Piper Power Station (Coalpac, 2013, p.2). However, commercial production resumed at the mine in 2008 when Coalpac acquired the mine from Lithgow Coal Company. Open-cut and highwall mining commenced at that time (Coalpac, 2013, p. 2). In 2010, Coalpac submitted a project application for a major expansion of both the Invincible Colliery and Cullen Valley Mine (Coalpac Consolidation Project). The proposal sought to expand open-cut and highwall mining areas into the adjacent state forest (Ben Bullen) and increase production to 2.5 Mt/year over 21 years (PAC, 2014, p. 2). The application was withdrawn by the proponent in 2013 (PAC, 2014, p. 3).

The Cullen Valley Coal Mine extracted from the Lithgow Coal of the Illawarra Coal Measures, which outcrop in some nearby areas (Coalpac, 2013, p. 11, 20). The mine had consent to produce up to 1 Mt/year, although production was typically around 700,000 t/year (Coalpac, 2015a). In 2013, when the mine went into care and maintenance, economically recoverable, accessible coal reserves were largely exhausted (PAC, 2014, p. 1).

#### 1.2.2.1.13 Invincible Colliery (Western Coalfield)

The Invincible Colliery previously comprised both underground and open-cut coal mining operations. It is owned and managed by Coalpac Pty Ltd (Coalpac, 2015b). Invincible is located in the Western Coalfield about 160 km west of Sydney, and 25 km north-west of Lithgow, near the township of Cullen Bullen (Coalpac, 2015b; Hansen Bailey, 2014; p. i). Although it has been in care and maintenance since 2013, the colliery has had a long history of producing thermal coal for the domestic energy market.

Mining commenced at the site in the early 1900s. The mine was acquired by Coalpac in 1989 when it was a bord and pillar operation. In 2006 Coalpac started mining in an expansion area approved to produce annually up to 350,000 t of ROM coal from an open-cut mine (Coalpac, 2015b; NSW Department of Planning, 2014). Longwall underground mining was decommissioned at the site in 1988 due to an economic downturn in the coal industry (Coalpac, 2015b). Open-cut mining ceased in 2013 when the mine was put into care and maintenance by its owner. The current approval under which the mine may operate is a 2008 Ministerial Approval (PA 07-0127) (PAC, 2014, p. 1), which authorised coal extraction until 2016 in ML 1636 and ML 1638 (Hansen Bailey, 2014, p. i).

In 2010, Coalpac submitted a project application for a major expansion of the Invincible Colliery and the nearby Cullen Valley Mine (known as the Coalpac Consolidation Project). The proposal sought to expand the open-cut and highwall mining areas into the adjacent state forest and

increase production to 2.5 Mt/year until 2025 (PAC, 2014, p. 2). However, this initial development proposal was refused by the PAC in June 2013. In July 2013, Coalpac submitted a revised development proposal and various addenda were subsequently made. In March 2014, Coalpac applied to modify existing approvals for the Invincible Colliery and the Cullen Valley Mine. The proposal for the Invincible Colliery included an extension of life for up to four years (to 2020), extension of the mining area for additional highwall mining and a water-sharing facility with Cullen Valley Mine (Hansen Bailey, 2014, p. i-ii, PAC, 2014, p. 2–3). However, in October 2014, the PAC again refused Coalpac's expansion proposal (PAC, 2014). Accessible coal reserves have been exhausted and, together with the Cullen Valley Mine, Invincible remains in care and maintenance and the nature of any future operations at the site as at 28 January 2016 is currently uncertain (PAC, 2014, p. 1–2).

#### 1.2.2.1.14 Ivanhoe Colliery (Western Coalfield)

Ivanhoe Colliery (Ivanhoe) occurs in the Western Coalfield near Lithgow, about 2.5 km south-east of Cullen Bullen and 7 km north-west of Wallerawang (Figure 7). Previous mining operations at the site, originally referred to as the Cullen Main West open-cut mine, began shortly after the Second World War, and have since been known by several names, including the Boulder Road Colliery, Ivanhoe No. 2 and Ivanhoe North. The most recent mining operations at Ivanhoe were undertaken by Centennial Coal Company Ltd (Centennial Coal), a subsidiary of the Thai-based Banpu Public Company Ltd (Banpu). This involved a small-scale mining rehabilitation project at Ivanhoe North, which focused on rehabilitating the previously abandoned (in 1953) pit workings at Cullen Main West. The approved project began in 2010 and was completed at the end of 2012, and included mining of remaining exposed coal and rehabilitation of the abandoned site (RW Corkery & Co Pty Limited, 2006, p. 1–1).

Previous operations at Ivanhoe have largely involved open-cut mining, although the Ivanhoe No. 2 underground longwall mine operated for approximately 18 months in the mid-2000s. The former Ivanhoe North open-cut mine targeted seams in the Irondale Coal, Lidsdale Coal and Lithgow Coal of the Illawarra Coal Measures (Bayly, 2012, p. 5). The Ivanhoe No 2 underground mine extracted the merged seams of the Lithgow Coal and Lidsdale Coal (Bayly, 2012, p. 5; Cordell, 2015).

The most recent open-cut truck and shovel operation ceased in 2012 (Centennial Coal, 2015e) having recovered approximately 610,000 t of coal over three years (Centennial Coal, 2015e). Coal was crushed on site and transported by truck to Mount Piper and the former Wallerawang power stations, and by rail to port for export. By the end of 2013, coal reserves were depleted and remaining measured and indicated resources were reported as 6.7 Mt (Banpu, 2015). The site was rehabilitated; remedial works included backfilling the open-cut, contouring the land surface, removing infrastructure and revegetating. Centennial have stated that an ongoing monitoring program will aim to restore the mined area to match the natural surroundings (Centennial Coal, 2015e).

#### 1.2.2.1.15 Pine Dale Coal Mine (Western Coalfield)

Pine Dale Coal Mine (Pine Dale) is an open-cut operation owned by Enhance Place Pty Ltd, a wholly owned subsidiary of Energy Australia (Enhance Place Pty Ltd, 2014a). Pine Dale is in the Western Coalfield, approximately 17 km north-west of Lithgow and 5 km north of Wallerawang

(Energy Australia, 2015). The mine is adjacent to former (now closed) coal mines, Wallerawang Colliery and Enhance Place Coal Mine, and the existing Springvale coal mine and Angus Place Colliery (NSW Department of Planning, 2011, p. 1). Coal extracted at Pine Dale was from the Lithgow Coal of the Illawarra Coal Measures. The coal was used as feedstock for the Mount Piper Power Station (NSW Department of Planning, 2011, p. 4); although since May 2014 the mine has been in care and maintenance (Energy Australia, 2015).

Pine Dale is part of the former Wallerawang Colliery and the Commonwealth Colliery. Wallerawang Colliery commenced operations underground in 1910. It closed in 1987 when underground reserves were depleted. A small, open-cut mine operated at Wallerawang Colliery from 1952 to 1954, followed 13 years later by a smaller open-cut mine, which was active from 1967 to 1969. Both of these operations were within the Wallerawang Colliery Pit Top area, partly located in the more recent Pine Dale Coal Mine and Yarraboldy Extension area (Enhance Place Pty Ltd, 2014d, p. 1). During the 1940s and 1950s the Commonwealth Colliery comprised two open-cut mines, one of which now forms a lake known as Blue Lake at the confluence of the Coxs River and Neubecks Creek (Enhance Place Pty Ltd, 2014b, p.2). The operation ceased in the 1990s and remediation included backfilling of the remaining void and surface contouring and revegetation (Enhance Place Pty Ltd, 2014d, p. 2).

The most recent phase of commercial operations at Pine Dale began in early 2006 and continued until December 2010. The most recent mining at the site occurred at the Yarraboldy (Stage 1) Extension area of Pine Dale (Energy Australia, 2015). Approval for mining to extract 350,000 t/year ROM coal (to a maximum of 800,000 t for life of approval) expired on 31 December 2014 (PAC, 2012, p. 23). However, coal reserves were exhausted to their limits prior to this, and led to the mine being put into care and maintenance in April 2014 (URS, 2014, p. iii).

Energy Australia acquired Pine Dale in 2012, just prior to the mine going into care and maintenance (Energy Australia, 2015; NSW Department of Planning, 2011, p. 1). Since that time there has been ongoing environmental monitoring of the site and some rehabilitation works. A development consent is being sought to continue mining operations (Energy Australia, 2015), although the next phase of planned mine development will require detailed planning, including public consultation and assessment by the PAC. Coal crushing and processing facilities remain on site (NSW Department of Planning, 2011) as well as loading facilities that provide for the coal to be transported to the power station via a private haul road and the local highway.

Development of a potential further expansion project (referred to as Stage 2 or Yarraboldy Stage 2 Extension project) has been referred to in the literature and is discussed in Section 1.2.3.1.7. The timing of progression of the proposed future development at Pine Dale through the relevant government assessment processes remains uncertain.

#### 1.2.2.1.16 Russell Vale Colliery (Southern Coalfield)

Russell Vale Colliery (Russell Vale) is an underground mine owned and operated by Wollongong Coal Limited (WCL, 2015e) (formerly Gujarat NRE Coking Coal Ltd who changed their name in February 2014). The mine is located in the Southern Coalfield, approximately 8 km north of Wollongong and 70 km south of Sydney. Russell Vale produced coking coal for export via Port Kembla Coal Terminal (PAC, 2015c, p. 5), although mining operations ceased in September 2015

and the mine is now in care and maintenance due to the ongoing economic downturn and its effects on international coal markets and difficult operating conditions (WCL, 2015b).

Operations at Russell Vale originally began in the 1880s when bord and pillar techniques were used to extract coal from the Bulli and Balgownie seams (PAC, 2015b, p. 1), with underground longwall mining commencing in the late 1960s (WCL, 2015e). The mine was previously also known as the South Bulli Colliery, first owned by the Osborne family and under the management of W. Wilson. The mine was sold around 1890 to Ebenezar Vickery and later sold to Bellambi Coal Company in 1901. In 2002 it was sold to Bellpac and subsequently sold to Gujarat NRE in 2004 (IQPC, 2015). Mining at Russell Vale targets the Wongawilli Coal and the Bulli Coal, although previously the Balgownie Coal Member of the Eckersley Formation (Sydney Subgroup) was also mined (WCL, 2015e). Bord and pillar mining was undertaken in the early years of operations, particularly in the top seam (Bulli Coal). Later the middle seam (Balgownie Coal Member) was extracted using longwall techniques from 1970 to 1982, and then later from 2001 to 2003. The mine is approved to extract up to 1 Mt/year, using continuous miner and longwall techniques, until December 2015 (PAC, 2015b, p. i).

Prior to operations ceasing in September 2015, coal production during 2015 had been intermittent, producing up to 1 Mt/year of coking coal (WCL, 2015b, 2015c). Coal is mined from the Bulli and Wongawilli seams. Total coking coal resources within the Bulli and Wongawilli coals at Russell Vale were estimated at 314.9 Mt, including 92 Mt of proved and probable reserves. An expansion project is currently (December 2015) under review by PAC and is discussed further in Section 1.2.3.1.3. Reported reserves and resources for Russel Vale are listed in Table 8.

**Table 8 Reported coal reserves and resources for WCL Russell Vale Colliery (as of 2010)**

| Proved coal reserves (Mt) | Probable coal reserves (Mt) | Measured coal resources (Mt) | Indicated coal resources (Mt) | Inferred coal resources (Mt) |
|---|---|---|---|---|
| 14.9 | 77.1 | 25.5 | 127.5 | 161.9 |

Note that resource figures are inclusive of reserves.
Data: Geoscience Australia (Dataset 2)

Infrastructure at the site includes administration offices and amenities, workshops, ROM stockpile area, conveyors, coal breaker, truck load-out facilities, water treatment and management facilities, fuel and oil storage, and electrical substation (PAC, 2015b, p. 4).

### 1.2.2.1.17 Wongawilli Colliery (Southern Coalfield)

WCL Wongawilli Colliery (Wongawilli Colliery) is an underground coal mine owned by Wollongong Coal Limited (WCL). Wongawilli Colliery is approximately 14 km south-west of Wollongong in the Southern Coalfield (WCL, 2015a, p. 1). It produced coking coal and was authorised to operate until 31 December 2015 (WCL, 2015a, p. 2). WCL ceased production at Wongawilli in May 2014, and the mine has since been put into care and maintenance. On 18 December 2015, WCL announced that they expect to recommence operations in early 2016 (WCL, 2015d). Wongawilli Colliery began mining in 1916 by G and C Hoskins Ltd to supply coking coal to Lithgow. Subsequently consolidated with the nearby Kemira and Nebo coal mines, it became known as the Elouera Colliery. In 2004 its then owner (BHP Billiton) proposed that the operation should cease

production and become a tourist mine after its planned closure. However, in 2007, BHP Billiton sold the mine to an Indian-based company, Gujarat NRE Coking Coal Ltd (Gujarat), which continued production operations at the mine as NRE Wongawilli Colliery. In 2011 Wongawilli was approved by the NSW Government to mine within six longwall panels until December 2015. The company changed its name to Wollongong Coal Limited (WCL) in February 2014 and the mine is now known as Wongawilli Colliery (WCL, 2015f).

Coal was mined from seams within the Wongawilli Coal and Tongarra Coal (WCL, 2015f). At the site, coal was loaded onto trains for transport to the Port Kembla Coal Terminal (WCL, 2015a, p. 2). In addition to coal rail loading facilities, the site also has its own coal handling and processing plant (CHPP), water management and waste management facilities (WCL, 2015a, p. 2).

The mine is currently authorised to operate six longwall panels and to process and transport up to 2 Mt/year ROM coal (WCL, 2015a, p. 2). The OZMIN database (Geoscience Australia, Dataset 2) reports total coal reserves at Wongawilli of 33.4 Mt, comprising 16.5 Mt proved and 16.9 Mt probable reserves. The total identified resource estimated in the OZMIN database is 337 Mt (inclusive of reserves).

In late November 2015 the PAC approved WCL's application for a 5-year extension to extract coal at Wongawilli (PAC, 2015c, p. 1). The timing for mining operations to recommence at Wongawilli currently remains uncertain. Further information about the time extension for Wongawilli is in Section 1.2.3.1.6.

#### *1.2.2.2 Coal seam gas*

As of February 2016, there is only one commercially producing coal seam gas (CSG) operation in the Sydney Basin bioregion (Figure 8), the Camden Gas Project. This operation consists of five CSG-related tenements (petroleum production licences, PPL). There are currently no petroleum exploration leases (PEL) in the subregion.

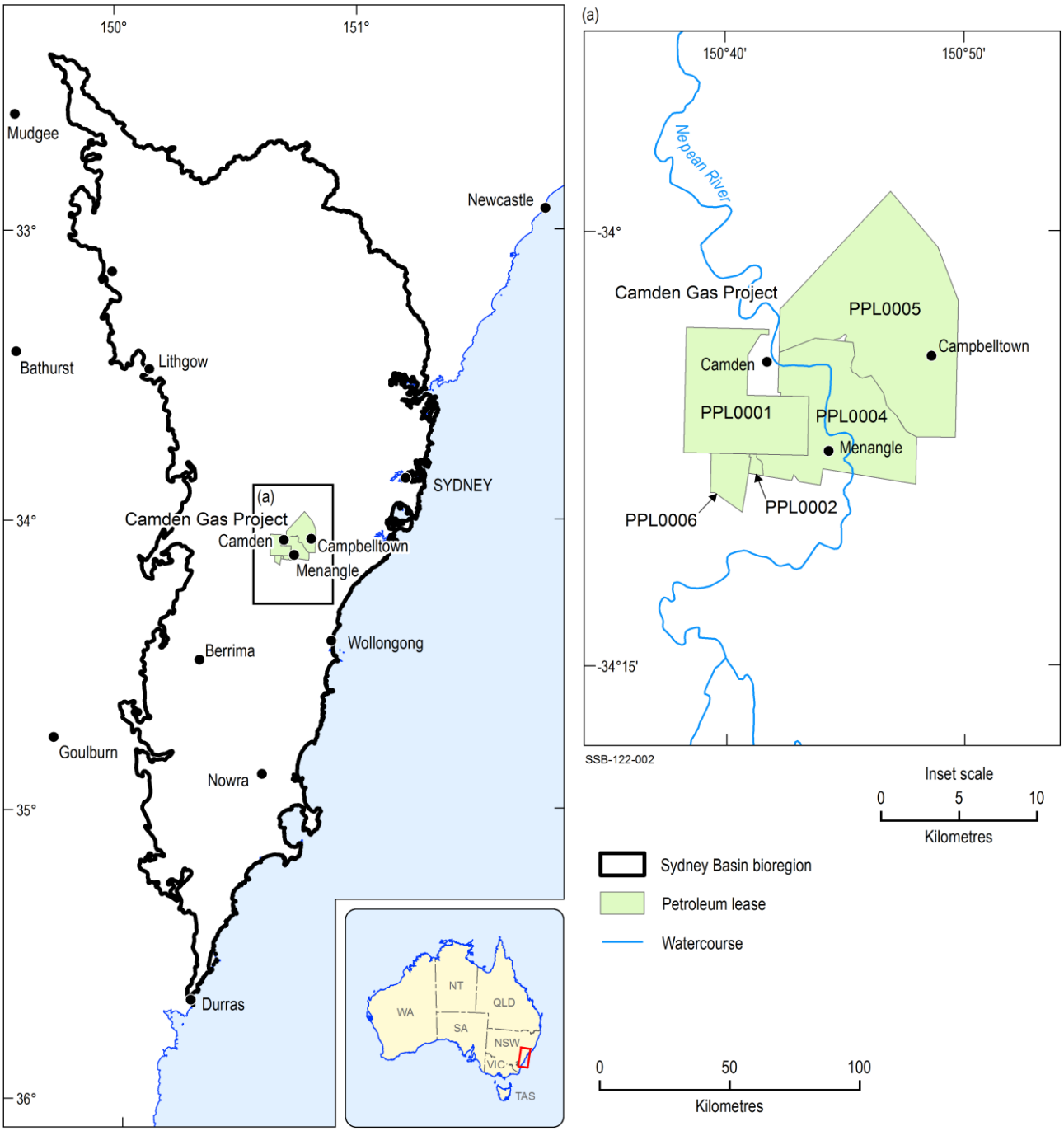


**Figure 8 Coal seam gas production leases in the Sydney Basin bioregion as at February 2016**

Note that all tenements are owned by AGL Energy Limited.
Data: NSW Department of Trade and Investment (Dataset 3)

#### 1.2.2.2.1 Camden Gas Project

Camden Gas Project (CGP) is owned and operated by AGL Energy Ltd (AGL). As at December 2015, it has 144 gas wells, 95 of which are currently producing gas and the remainder having been suspended or plugged and abandoned. Of the 144 wells, 117 have been hydraulically fractured. About 70 of those wells used water and sand and the remaining fractured wells used a mixture of sand, water and additives (AGL, 2013a). The project also consists of 100 km of low pressure underground gas gathering lines and the Rosalind Park Gas Plant in the Menangle area (AGL, 2015a). CGP is approximately 65 km south-west of Sydney, and has been producing natural CSG since 2001 (AGL, 2015a).

The project was initiated in 2001 by Sydney Gas Ltd when 14 Elizabeth MacArthur Agricultural Institute wells and 10 Razorback wells were approved throughout the period from 2001 to 2006. The wells were drilled in 2007 and were acquired by AGL in 2009 from Sydney Gas Limited, making AGL 100% owner operator of CGP (AGL, 2015a). Since then, there have been many modifications to the original project proposal, including more production wells. The most recent application was the Camden North Expansion Project that would have involved 12 well locations each containing up to six well heads. However, in July 2015, AGL announced that they would not proceed with this proposal (AGL, 2015a). In February 2016, AGL announced that it had taken the decision to not proceed with the Gloucester Gas Project (in the Gloucester subregion) and will cease production at the Camden Gas Project in 2023, twelve years earlier than previously proposed.

CGP extracts CSG from a number of coal seams within the Permian Illawarra Coal Measures (HLA, 2006, ES1). Particular stratigraphic units targeted at Camden include the Bulli Coal, Balgownie Coal Member, Wongawilli Coal and Tongarra Coal (HLA, 2006, ES8). The target seams are approximately 700 m below surface (AGL, 2015a).

As at 30 June 2015, proved (1P) reserves were 37 PJ, proved plus probable (2P) reserves were 41 PJ and proved, probable and possible (3P) reserves were 41 PJ (AGL, 2015b, p. 2). CGP produces on average 6 PJ of CSG per year (Geoscience Australia, 2013, p. 20).

The Rosalind Park Gas Plant (RPGP) is at Menangle, approximately 6 km south-east of Campbelltown. It collects gas from the network of operational production wells in the CGP, and then dries and compresses the gas and distributes it to the Sydney gas consumer network (AECOM, 2014, p.1). The RPGP also filters particles from the gas, meters the quality and quantity of gas, and injects odour to the gas for leak detection (AECOM, 2014, p. 3). Water collected by the plant is cleaned and processed, then released into a pond where it is evaporated or used off site for a variety of approved purposes, such as making bricks (AECOM, 2014, p. 4; AGL, 2013c, p. 4).

The amount of water pumped out of the coal to allow methane to desorb (co-produced water) at the CGP is relatively small as coal seams have very low permeability ($1x10^{-5}$ m/s) (AGL, 2013b, p.12) and contain little water. In the 2013–14 financial year, approximately 3.6 ML of water was produced from the coal seams (AGL, 2015c, p. 2) and in the 2014–15 financial year, approximately 2.2 ML of water was produced (AGL, 2015d, p. 2).

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## 1.2.3 Proposals and exploration


***Summary***

This section summarises coal resource development and exploration projects in the Sydney Basin bioregion as at January 2016. There are currently 12 projects at various stages of assessment in the Sydney Basin bioregion, 7 of which are coal mine development projects and 5 of which are known deposits that are currently not undergoing mine development. Ten of the projects are for underground mining operations. Half of these proposed developments seek to expand or extend (in time) existing mines including Airly Mine, Angus Place Colliery, WCL Russell Vale Colliery, Springvale, WCL Wongawilli Colliery and Pine Dale Coal Mine. The development applications for the Airly Mine and WCL Russell Vale Colliery seek to extend the right to mine beyond their approved expiration date in 2015. The previous Springvale mine agreement expired in September 2015, and in October 2015, the Australian Government approved the project until October 2035 with conditions attached. Angus Place Colliery seeks to extend mining beyond 2024. WCL Wongawilli Colliery has sought a time extension to allow for previously approved mining activities to occur, which had been severely interrupted due to past ownership changes. Hume Coal Project near Sutton Forest is for a new underground mine. Pine Dale Coal Mine is currently in care and maintenance as authorised reserves have been exhausted, but the extension would seek to recommence activity at the mine through open-cut operations.

There are five black coal deposits in the Western Coalfield that have been previously identified but are not yet at the stage of any mine development proposals. They are (i) the (previously mentioned) Neubeck, Boulder and Running Stream projects – all of which were drilled in the past but at which further activity has not been reported, (ii) the Inglenook Project, where drilling has been performed (iii) the East Lithgow Project, where extensive drilling was performed in the 1980s and although a resource was identified and hydrogeological studies were also carried out, no recent activity for this project has been reported. The Neubeck Project has been deemed a 'controlled action' by the Department of the Environment, but to date no Independent Expert Scientific Committee (IESC) advice has been requested. At March 2016, Neubeck Project is considered an explored and undeveloped coal deposit.

There are no new coal seam gas (CSG) development projects currently expected in the bioregion.


### *1.2.3.1 Coal*

There are currently 12 coal mine development projects in the Sydney Basin bioregion, half of which are for time extensions to existing activities. One new mine is proposed and there are five identified coal deposits that have exploration either completed or ongoing.

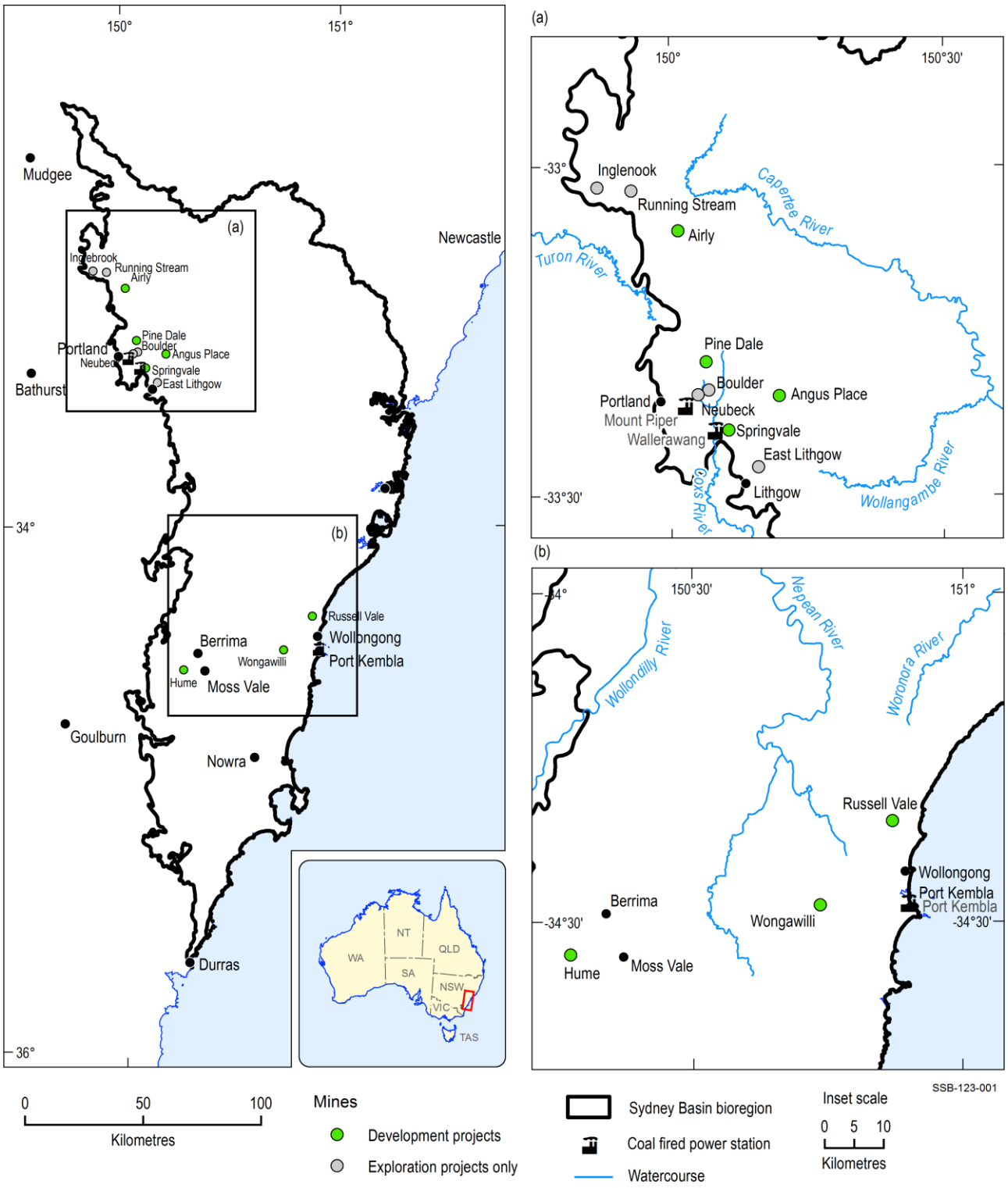


**Figure 9 Coal resource development proposals in the Sydney Basin bioregion as at January 2016**

Data: Bioregional Assessment Programme (Dataset 1)

#### 1.2.3.1.1 Airly Mine Extension Project (Western Coalfield)

Airly Mine (Airly) is an underground coal mine operated by Centennial Airly Pty Ltd, a wholly owned subsidiary of Centennial Coal Company Ltd (Centennial Coal) (Centennial Coal, 2012b) (Centennial Coal, 2014b, p. 4). Airly is in the Western Coalfield, approximately 40 km north-north-west of Lithgow and 4 km north-east of Capertee (Centennial Coal, 2014a, p. 4). Airly produces thermal coal for the export market (DP&E, 2015d, p. 1). The mine is currently authorised to extract up to 1.8 Mt/year (Centennial Coal, 2012b) (Centennial Coal, 2014b, p. 10). Thermal coal mined at Airly is extracted from the Lithgow Coal.

Airly has operated under development consent (DA 162/91), which was modified in August 2015 extending its expiry date to April 2016 (Centennial Airly Pty Ltd, 2014, p. 1). The Airly Mine Extension Project proposed to extend mining operations into the eastern part of the existing mining lease to extend the life of the mine for a further 25 years. The proposal sought to expand underground mining operations beneath Genowlan Mountain, while maintaining the existing maximum rate of extraction of up to 1.8 Mt/year (Centennial Coal, 2014a, p. 4; NSW Planning and Investment, 2015a, p .3; DP&E, 2015k, p. 8). The proposed development was designated a 'controlled action' under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and was assessed through an accredited assessment process under NSW planning legislation (Department of the Environment, 2013a). A variation to proposed action was subsequently made, which excluded mining operations in the previously approved MOD3 area (Department of the Environment, 2014).

In order for authorised mining operations to continue during the time required for the NSW Planning Assessment Commission (PAC) to carry out a review of the project and hold public hearings, Centennial Coal applied to extend DA 162/91 for a further six months from 31 October 2015 until 30 April 2016 (DP&E, 2015d, p. 4). This extension until April 2016 was approved in August 2015.

On 12 November 2015 the NSW PAC determined that the Airly Mine Extension Project could be approved, subject to stringent conditions (DP&E, 2015c, 2015l). There were 9 NSW PAC recommendations made, with the most significant one being around monitoring of potential subsidence impacts. The NSW PAC informed the NSW Minister for Planning about these outcomes on 12 November 2015, and the final determination to proceed now rests with the Minister (PAC, 2015b).

The operation proposes to use a combination of bord-and-pillar mining, panel-and-pillar mining and partial pillar extraction, depending on depth of cover and the void width required in each part of the mine. These methods have been selected to reduce subsidence impacts on sensitive surface morphology (Golder Associates, 2014, p. 488). Longwall methods were not deemed suitable to meet the design criteria.

Subject to conditions and limits, the project plans to use existing infrastructure and facilities including the rail loop and loading facility for rail transport of product coal to Port Kembla (Centennial Coal, 2012b; DP&E, 2015d, p. 4–5). The proposal includes construction of a new coal preparation plant, ROM stockpile and coal reject emplacement area (DP&E, 2015k, p. 8). On

28 August 2015, NSW Department of Planning and Environment recommended consideration and approval of the application (DP&E, 2015d, p. 5).

The 25-year extension will include 20 years of mining followed by 5 years of post-mining decommissioning and rehabilitation (DP&E, 2015k, p. 8).

#### 1.2.3.1.2 Angus Place Mine Extension Project (Western Coalfield)

Angus Place Colliery is jointly owned by Centennial Springvale Pty Ltd (50%) and Springvale SK Kores Pty Ltd (50%) and operated by Centennial Angus Place. It is 15 km north-west of Lithgow and 120 km west-north-west of Sydney (Centennial Coal, 2014b, p. 5). Angus Place Colliery is adjacent to another of Centennial Coal's Springvale operation. Angus Place Colliery produces thermal coal (Centennial Coal, 2015a) for Mount Piper Power Station and previously also for the now closed Wallerawang Power Station (Centennial Coal, 2015a), although the mine was put into care and maintenance in March 2015. The existing development consent for mining operations will expire in August 2024 (Centennial Coal, 2014b, p. 5). Centennial Angus Place has applied for the Angus Place Mine Extension Project to ensure the mine is operational beyond August 2024 (Centennial Coal, 2012a).

Coal currently extracted from the Lithgow Coal (Centennial Coal, 2012b, p. 44) is processed at on-site facilities. Infrastructure includes a coal crushing plant and private haul roads to the power stations (Centennial Coal, 2015a). The project plan involves use of the currently approved operations, facilities and infrastructure of the Springvale mine, and aims to continue extracting up to 4 Mt/year of coal, with underground access from the current mining area. Secondary extraction (by retreat longwall mining) is also planned while continuing to use surface facilities at the Angus Place Colliery pit top (Centennial Coal, 2014c, p. 5). The project also aims to install dewatering and reinjection boreholes, install pipeline infrastructures and manage water through a combination of direct transfer, the Springvale Delta Water Transfer Scheme and licensed discharge points (Centennial Coal, 2014c, p. 6).

An environmental impact statement (EIS) was submitted to the NSW Department of Planning and Environment in April 2014 and a response to submissions was lodged by Centennial Coal on 1 October 2014 (Centennial Coal, 2014b, p. 5). The project has been determined to be a 'controlled action' under the EPBC Act, by the Department of the Environment (DP&E, 2015h). The IESC provided advice on this proposal in 2014 highlighting specific issues including subsidence, erosion and contamination, landforms, water, and other potential impacts as being relevant to this project (IESC, 2014). The project status as at 5 January 2016, is 'proponent is preparing a response to submissions' (DP&E, 2015h).

#### 1.2.3.1.3 Russell Vale Underground Expansion Project (Southern Coalfield)

WCL Russell Vale Colliery (Russell Vale) is an underground mine owned and operated by Wollongong Coal Limited (Wollongong Coal, 2015) (see Section 1.2.2). It is approximately 8 km north of Wollongong, 70 km south of Sydney. The mine produces coking coal for export via Port Kembla Coal Terminal (PAC, 2015c, p. 5).

The mine was approved to extract up to 1 Mt/year until December 2015 (PAC, 2015c, p. i). Coal production during 2015 was intermittent but longwall operations recommenced after refinancing was secured (Wollongong Coal, 2015). As of September 2015, Russell Vale has been in care and maintenance.

The Russell Vale Underground Expansion Project that was proposed in August 2009 by the former owner (PAC, 2015c, p. 2) originally sought to extract 31 Mt of coal over 18 years. The plan includes the mining of new longwall panels. Since the proposal was originally made, the plan has been revised, now seeking to mine 4.7 Mt over a period of up to 5 years through a reduced area of new longwall panels (PAC, 2015c, p. 3). The project plan includes new stockpiles, truck loading facilities and a designated coal dispatch road and a 6 ML settling pond in addition to an upgrade to the water management system (PAC, 2015c, p. 5). The plan is to extract from the Wongawilli Coal close to Cataract Reservoir, which is a protected part of Sydney's drinking water catchment. The mine is currently approved to extract 1 Mt/year until the end of December 2015 (PAC, 2015c, p. i).

The project has been deemed to be a 'controlled action' under the EPBC Act (DP&E, 2015m; IESC, 2015). Water NSW and the IESC have stated concerns about the risk of water losses to the catchment, water quality impacts and associated treatment costs (PAC, 2015c, p. i) in addition to potential impacts on the ecology (IESC, 2015). In February 2015 a public hearing was held for the project and the PAC received submissions for and against the approval. The mine submitted its responses to the submissions in July 2015. As at 5 January 2016, the project is being assessed by the NSW Department of Planning (DP&E, 2015a, 2015m).

Note that the proposed underground expansion project for Russell Vale submitted a referral under the EPBC Act provisions, and was deemed a 'controlled action' in November 2014. Thus, it requires approval under the EPBC Act, which means approval from the Commonwealth Minister (unless referred) as part of the EIS approval process undertaken by the NSW Government.

#### 1.2.3.1.4 Springvale Mine Extension Project (Western Coalfield)

Springvale is an underground, longwall coal mine (Centennial Coal, 2014c, p. 5) jointly owned by Centennial Springvale Pty Ltd (50%) and Springvale SK Kores Pty Ltd (50%) as the Springvale unincorporated joint venture (Centennial Coal, 2014d, p. i). The Springvale mine is operated by Springvale Coal Pty Ltd for and on behalf of the joint venture (Centennial Coal, 2014c, p. 5, Centennial Coal, 2014d, p. i). It is located 10 km north-west of Lithgow and 120 km west-north-west of Sydney (Centennial Coal, 2014c, p. 5) and produces thermal coal for domestic and international markets (Centennial Coal, 2014c, p. 5). Further information on mining operations at Springvale is in Section 1.2.2.

As the mine will operate with a significant water surplus of up to 18 ML/day, the mine is licensed to discharge water into the Coxs River (DP&E, 2015b, p. 2). In 2014, the IESC provided advice on the project to the Department of the Environment and the DP&E (IESC, 2014). A potential impact raised by the IESC was in relation to water storage in Cataract Reservoir and whether it may become impacted by loss of streamflow and baseflow. A potential impact identified by the IESC was that subsidence-induced cracking could create potential connectivity between the mine workings and the reservoir (IESC, 2014, p. 1–2).

The most recent mining consent for Springvale expired on 15 September 2015. The Springvale Mine Extension Project extends the life of the mine by 13 years followed by a period of rehabilitation to extract up to 4.5 Mt/year of ROM coal from the Lithgow Seam (Centennial Coal, 2014d, p. i; DP&E, 2015g, p. 4; DP&E, 2015b, p. 2;). Rehabilitation is also intended to be carried out as mining progresses (Centennial Coal, 2014d, p. ii).

In June 2015, the PAC reviewed and reported on the proposal (PAC, 2015d). The mine responded to the PAC review report and Centennial Coal consulted with the EPA and other stakeholders to develop a suitable management program (Centennial Coal, 2015d). In August 2015, the NSW Department of Planning and Environment (DP&E) issued a report that stated that the project is 'on balance, in the public interest, and recommends that it be approved, subject to the recommended conditions of consent' (DP&E, 2015b, p. 1). DP&E recommended that the PAC hold a public hearing on matters relating to the draft State Environmental Planning Policy (SEPP) to consider submissions in relation to the SEPP and report on those matters (DP&E, 2015b, p. 28). On 21 September 2015, PAC stated that it was satisfied that the benefits outweigh the potential impacts and determined that the project should be approved subject to recommended conditions (PAC, 2015a, p. 2).

Development consent was granted on 21 September 2015 (DP&E, 2015b, 2015e). On 15 October 2015, the Australian Government, under the EPBC Act, approved the project until October 2035 with conditions attached related to threatened species and communities, swamps, and water resources (Department of the Environment, 2015a).

The proposal seeks to develop new underground access headings and roadways from the current mining area towards the east to provide access to the proposed operations (Centennial Coal, 2014d, p. i). The proposal also aims to transfer the operational management and physical infrastructure for coal processing and distribution infrastructure to the Western Coal Services Project (Centennial Coal, 2014d, p. ii). The proposal seeks to continue authorisation to transport up to 50,000 t/year of coal to local domestic customers by road haulage (Centennial Coal, 2014d, p. ii) and to install and operate two additional dewatering bores and upgrade the existing access tracks to bore facilities. The application states the mine will continue to use the existing Springvale Delta Water Transfer Scheme but also upgrade the construction to increase water delivery capacity from the existing 30 ML/day up to 50 ML/day (Centennial Coal, 2014d, p. ii; DP&E, 2015b, p. 2).

#### 1.2.3.1.5 Wongawilli Mine Extension (Southern Coalfield)

WCL Wongawilli Colliery (Wongawilli Colliery) is an underground mine owned by Wollongong Coal Limited (WCL), approximately 14 km south-west of Wollongong (WCL, 2015b, p. 1). The mine produces coking coal and was authorised under previous conditions to operate until 31 December 2015 (WCL, 2015b, p. 2). Section 1.2.2 provides further information about recent activity at Wongawilli Colliery.

Coal is mined from the Wongawilli Coal and the Tongarra Coal (WCL, 2015a) and transported to the Port Kembla Coal Terminal (WCL, 2015b, p. 2). The mine is currently authorised to operate six longwall panels and to process and transport up to 2 Mt/year ROM coal (WCL, 2015b, p. 2). Since September 2014, Wongawilli Colliery has been in care and maintenance.

In May 2015, WCL applied to NSW Government for an extension of operations to allow mining activities to continue until 31 December 2020 (WCL, 2015b, p. 1). No change to existing pit top facilities were proposed as part of the submission (WCL, 2015b, p. 2). Current approvals allow operations for a period of 50 months, but due to changes in mine ownership, only 8.5 months of development work and longwall coal extraction have taken place, with extraction from only one of the six approved longwall panels. WCL's proposal to extend the timing of operations will allow extraction of the remainder of the 3.3 Mt resource (of which approximately 0.5 Mt has thus far been removed) (WCL, 2015b, p. 3). On 30 September 2015, DP&E recommended that the PAC determine that the modification be approved subject to conditions (DP&E, 2015n, p. 9). The project was approved on 27 November 2015 (DP&E, 2015j, p. 1) but as of May 2016, mining has not yet recommenced.

#### 1.2.3.1.6 Pine Dale Yarraboldy Stage 2 Extension Project (Western Coalfield)

Enhance Place Pty Ltd has sought to expand the existing Pine Dale Coal Mine under the Yarraboldy Stage 2 Extension Project. The plan aims to extract approximately 14.2 Mt of ROM coal up to a maximum of 2 Mt/year product coal by open-cut methods (PAC, 2012, p. 24) for a life of approximately 10 to 15 years (PAC, 2012, p. 24). The plan includes expanding open-cut pits by 210 ha, extracting up to 2 Mt/year for up to 15 years life of project, constructing and operating surface infrastructure, processing plant and transport by rail, public, and private roads (NSW Planning & Infrastructure, 2012, p. 2). In 2011, the Department of the Environment reviewed the project and reported that the project is not a 'controlled action' as the proposed project is unlikely to have an impact on water resources (SEWPaC, 2011, p. 1). An independent environmental audit (Enhance Place Pty Ltd, 2014a; URS, 2014) stated that there had been unforeseen delays in the progress of the Yarraboldy Stage 2 Extension project application, so the site has remained in care and maintenance for an extended period (Enhance Place Pty Ltd, 2014b, p. 1). The timing of progression of the proposed future development at Pine Dale Coal Mine through the relevant assessment processes remains uncertain.

#### 1.2.3.1.7 Hume Coal Project (Southern Coalfield)

Hume Coal Pty Limited proposes to develop and operate an underground coal mine with associated mine infrastructure, approximately 3 km west of Moss Vale (DP&E, 2015i, p. 1) and approximately 100 km south-west of Sydney (EMM, 2015a, p. E.1). Extensive exploration has been performed in the area since the 1950s; the current exploration authorisation was granted in 1985 and was acquired by Hume Coal in 2010 (EMM, 2015b, p. E.1).

The Hume Coal Project plans to operate for 22 years, mining coking and thermal coal from the Wongawilli Seam for international and domestic markets using a new 'non-caving' method developed to reduce the impact of subsidence (EMM, 2015a, p. 1; EMM, 2015b, p. E.1). The method will allow the strata overlying the mine to remain intact, supported using a system of engineered coal pillars. The mine will be partially backfilled with reject material and each panel will be immediately sealed after extraction and backfilling (EMM, 2015a, p. E.1–E.2). The project plans to extract over 50 Mt ROM coal over the life of the mine, at approximately 3.4 Mt/year (DP&E, 2015i, p. 1).

Rehabilitation is planned to occur progressively with post-mining closure and rehabilitation over a two-year period to a state that will support similar land uses to current land uses (DP&E, 2015i, p. 1; EMM, 2015a, p. 1). The proposed mining lease area is approximately 5000 ha where the water supply has been described as reliable with annual rainfall in the range between 570 and 870 mm/year (EMM, 2015a, p. 11).

The company applied for a site verification certificate in August 2015 (DP&E, 2015i). Hume Coal was issued with the environmental assessment requirements in August 2015 (DP&E, 2015f). The EIS is scheduled for completion in 2016 (EMM, 2015b, p. E.5). On 1 December 2015, the project was declared by Department of the Environment to be a 'controlled action'. The project therefore requires assessment and approval under the EPBC Act before it may be processed, and will be assessed under the bilateral agreement with NSW (Department of the Environment, 2015b).

#### 1.2.3.1.8 Boulder Project (Western Coalfield)

Boulder Mining Pty Ltd is considered here as an exploration project/pre-feasibility study. It is situated 6 km east of Portland. As reported in the OZMIN database (Geoscience Australia, Dataset 2), Boulder has an identified coal resource of 4.9 Mt (measured resource). The tenement is EL 5899, which covers an area of 62 ha. The licence was extended in 2014 for a further term until 23 October 2018 (NSW Government, 2014a, p. 2883). However, there has been little evidence of recent activity at Boulder and no immediate development plans are evident.

#### 1.2.3.1.9 Neubeck Project (Western Coalfield)

The Neubeck Project is an exploration area near Wallerawang, 18 km north-west of Lithgow (Centennial Coal, 2015c; Department of the Environment, 2013b). It is within existing mining titles held by Centennial Coal. Centennial Coal is considering a relatively small open-cut operation to supply thermal coal to Mount Piper Power Station using existing private haul roads (Centennial Coal, 2015c). The project is considered to be a State Significant Development in accordance with the SEPP as reported in the briefing paper by Centennial Coal (Centennial Coal, 2012c, p. 5)

The OZMIN database (Geoscience Australia, Dataset 2) reports that Neubeck has a probable reserve of 18.1 Mt and total resource of 32.9 Mt of thermal coal. The project is anticipated to extract up to 1.2 Mt/year ROM coal for up to 11 years. Exploration drilling has taken place at the project area since 2005 and more recently groundwater monitoring equipment was installed. Geological evaluations were carried out in 2011 and 2012 to assess feasibility.

The project was previously known as Neubeck Wolgan Road Project (Centennial Coal, 2012c, p. 17). The project proposes to develop site and environmental infrastructure, clear and move topsoil for later use in rehabilitation, remove overburden and interburden, back fill mining strips, crush and screen ROM coal at Springvale Coal Services prior to supply to the power stations, and progressively rehabilitate the mine areas (Centennial Coal, 2012c, p. 6).

The project is listed as a 'controlled action' by the Department of the Environment and will require an assessment and approval under the EPBC Act before it can proceed (Department of the Environment, 2013b). As at 29 January 2016, IESC advice has not been requested.

#### 1.2.3.1.10 Inglenook Project (Western Coalfield)

Inglenook is an exploration project owned by Centennial Coal, located near Ilford between Lithgow and Mudgee (Centennial Coal, 2015b). The Inglenook Project is a collective of three exploration licences adjacent to the western rail line, thereby enabling direct access from the resource to Port Kembla coal terminal. Centennial Coal has previously undertaken exploration drilling at Inglenook to help define and characterise the coal resource, although no drilling has been undertaken since about 2014. More recently, onsite work has been limited to surface water and groundwater monitoring and the collection of meteorological data, although according to Centennial Coal, further exploration drilling may occur in the future (Centennial Coal, 2015b). As reported in the OZMIN database (Geoscience Australia, Dataset 2), Inglenook has an indicated coal resource of 54.4 Mt and an inferred resource of 202 Mt of black coal. There are no clear development plans or timeframes publicly available for the Inglenook Project.

#### 1.2.3.1.11 Running Stream Project (Western Coalfield)

Running Stream is an undeveloped coal deposit and exploration project approximately 60 km northwest of Lithgow, 35 km north of the Mount Piper Power Station. The lease is owned by Glencore (Xstrata, 2012, p. 11), listed under the Oakbridge Group. Analysis of the OZMIN database (Geoscience Australia, Dataset 2) indicates identified resources of 19.6 Mt measured, 69.7 Mt indicated and 190 Mt inferred. As at January 2016 there are no published recent reports of activity on this project.

#### 1.2.3.1.12 East Lithgow Colliery Project (Western Coalfield)

East Lithgow Colliery project, owned by Austen and Butta Limited from approximately 1976, is an exploration project that originally proposed to reactivate the previously active Hartley Vale Colliery that lies completely within the East Lithgow Colliery area (McElroy Bryan & Associates Pty Limited, 1979, p. 1). Austen and Butta Limited was taken over by Shell Australia Limited (Shell) in 1992 (delisted Australia, 2016). An extensive drilling program was conducted from 1977 to 1981, when 42 boreholes were drilled that indicated 123 Mt of coal resource within the Katoomba and Lithgow seams (Shell, 1994). Hydrogeological studies were also carried out. Economic conditions in 1982 dictated that the East Lithgow Colliery Project could not be justified. Since that time further discussions and analyses were undertaken by Shell, who in 1994 announced that discussions had taken place with adjacent collieries (Shell, 1994) and stated that an Authorisation renewal had been sought for renewal until December 1994. It was not clear whether the extension was granted but further activity has not been reported since 1994.

### *1.2.3.2 Coal seam gas*

There are currently no proposed coal seam gas (CSG) developments seeking to progress beyond early stage exploration in this bioregion. A series of actions have been put in place by NSW Government to control future exploration, which are currently limiting CSG-related activity in the Sydney Basin bioregion (NSW Government, 2014b, p. 7–10). These include:

- accepting all the recommendations made by the Chief Scientist and Engineer's Independent Review (NSW Government, 2014c)

- introducing a new strategic framework to ensure new exploration licences are only issued in areas released after careful assessment of economic, environmental and social factors
- applications being processed during 2014 were dissolved and no new applications are to be considered until a new strategic framework is in place
- introducing a one-off buy-back offer that commenced in December 2014 to purchase unused exploration licences; petroleum exploration licences over national parks will be removed
- enforcing potential title cancellation for companies where current title holders are unable to demonstrate a serious commitment to investment in the state by the end of 2015 (NSW Government, 2014b, p. 7–10).

The activities listed above have resulted in 17 petroleum exploration licence (PEL) buy-back offers (DIR&E, 2016c), one of which (PEL 2) was in the Sydney Basin bioregion. As at 12 January 2015, there are no recorded PEL applications in NSW (DIR&E, 2016a) and no current petroleum production lease applications (PLAs) in the bioregion (DIR&E, 2016b).

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## 1.2.4 Catalogue of potential resource developments


***Summary***

This section summarises proposals to develop identified coal resources in the Sydney Basin bioregion post-December 2012, as outlined in Section 1.2.3.

As at March 2016, seven coal resource developments, having a post-December 2012 commencement date, have been proposed. They include five underground developments at existing coal mines: Airly Mine, Angus Place Colliery, WCL Russell Vale Colliery, Springvale and WCL Wongawilli Colliery, and one open-cut development at the existing Pine Dale Coal Mine. Development of a new underground coal mine at Hume, has also been proposed and an EIS is expected by end of 2016.

Five exploration projects have been identified (Boulder, East Lithgow, Inglenook, Neubeck and Running Stream) but there are no known development plans for these areas as at March 2016. These areas are all at pre-EIS stage.

There are no new coal seam gas (CSG) development projects proposed in the bioregion.


Information provided in Section 1.2.3 forms the basis for a catalogue of potential coal resource developments in the Sydney Basin bioregion post-December 2012. The catalogue in Table 9 identifies 12 potential developments. Six proposals relate to extensions and/or expansions of existing coal mines. There is one potential new mine – at Hume. The areas of Boulder, Inglenook, Neubeck, Running Stream and East Lithgow have identified coal resources and have been included in Table 9 but there is insufficient activity and no published material to indicate that these projects will progress to mine development proposals. The locations of the potential developments are shown in Figure 10.

As at March 2016, environmental impact statements (EIS) had been submitted for five of the proposals, of which two of these (Springvale and Wongawilli) have been approved; one company was preparing an EIS. Inclusion of an entry in Table 9 does not mean the development will proceed.

There are currently no new CSG development proposals in the Sydney Basin bioregion. CSG has been produced by AGL Energy Limited (AGL) at the Camden Gas Project south-west of Sydney since 2001.

**Table 9 Potential coal resource developments in the Sydney Basin bioregion as at 15 March 2016**

| Project name | OC/UG[a] | Company | Longitude | Latitude | Material[b] | Total coal resources[c] (Mt) | Status of EIS[d] | Notes |
|---|---|---|---|---|---|---|---|---|
| Airly Mine Extension Project | UG | Centennial Coal | 150.015 | –33.098 | Thermal | 116 | Submitted September 2014 | NSW Planning Assessment Commission (PAC) recommended 20-year extension in November 2015. Awaiting approval from Minister. |
| Angus Place Mine Extension Project | UG | Centennial Coal | 150.199 | –33.349 | Thermal | 246 | Submitted April 2014 | Seeking extension to beyond 2024. At 5 January 2016, Centennial Coal was preparing a response to submissions. |
| Pine Dale Yarraboldy Stage 2 Extension Project | OC | Energy Australia | 150.065 | –33.297 | Unspecified | 14.2 to be extracted | No new EIS | Yarraboldy stage 2 extension. Pine Dale is currently in care and maintenance. |
| Russell Vale Underground Expansion Project | UG | Wollongong Coal | 150.87 | –34.347 | Coking | 4.7 to be extracted | Submitted February 2013 | Mining was approved until end December 2015. In care and maintenance since September 2015. At 5 Jan 2016, project was with NSW PAC for assessment. |
| Springvale Mine Extension Project | UG | Centennial Coal | 150.106 | –33.401 | Thermal | up to 58.5 to be extracted | Submitted April 2014 | Consent for mining expired 15 September 2015. On 15 October 2015 approval for mine extension was granted under EPBC Act to continue to 2035. |
| Wongawilli Mine Extension | UG | Wollongong Coal | 150.736 | –34.475 | Coking | 3.3 to be extracted | Submitted February 2013 | Application for mine extension submitted in May 2015 to continue mining to end 2020. Project approved 27 November 2015. |
| Hume Coal Project[e] | UG | Hume Coal | 150.273 | –34.55 | Coking and thermal | 50+ to be extracted | EIS in preparation Due December 2016 | Proposal to operate for 22 years. Requires assessment and approval under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). |
| Boulder Project | UG | Boulder Mining | 150.07 | -33.34 | n/a | 4.9 Mt measured | Pre-EIS | Exploration project. Identified deposit. Little evidence of recent activity. No development plans available. |

| Project name | OC/UG[a] | Company | Longitude | Latitude | Material[b] | Total coal resources[c] (Mt) | Status of EIS[d] | Notes |
|---|---|---|---|---|---|---|---|---|
| East Lithgow Colliery Project | na | Shell Australia | 150.160 | -33.457 | n/a | 123 measured | Pre-EIS | Exploration project. Identified deposit. No reported activity since 1994. |
| Inglenook Project | OC | Centennial Coal | 149.868 | –33.032 | Unspecified | 256.4 | Pre-EIS | Three exploration licences operating as at January 2016. |
| Neubeck Project | OC | Centennial Coal | 150.05 | –33.347 | Thermal | 32.9 | Pre-EIS | Exploration project for an anticipated 11-year operation. Deemed a controlled action, which would require assessment and approval under the EPBC Act. |
| Running Stream Project | UG | Glencore | 149.93 | -33.037 | n/a | 279.3 | Pre-EIS | Exploration project. Identified deposit. No recent report of activity. |

[a]OC is open cut; UG is underground
[b]'Material' refers to class of coal: thermal, coking, pulverised coal injection (PCI) and unspecified.
[c]this is calculated by summing the resources with Joint Ore Reserves Committee (JORC) codes of measured, indicated and inferred.
[d]the status of the mine with regard to preparation of an environmental impact statement (EIS): pre-EIS, EIS in preparation, EIS submitted, EIS closed, supplementary EIS and EIS approved
[e]new mine proposal
na = not applicable

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