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

# Coal and coal seam gas resource assessment for the Galilee subregion

## Product 1.2 for the Galilee subregion from the Lake Eyre Basin Bioregional Assessment

24 October 2014

A scientific collaboration between the Department of the Environment, 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 direct, indirect and cumulative 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. The Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia are collaborating to undertake bioregional assessments. For more information, visit <http://www.bioregionalassessments.gov.au>.

## Department of the Environment

The Office of Water Science, within the Australian Government Department of the Environment, is strengthening the regulation of coal seam gas and large coal mining development by ensuring that future decisions are informed by substantially improved science and independent expert advice about the potential water related impacts of those developments. For more information, visit <http://www.environment.gov.au/coal-seam-gas-mining/>.

## Bureau of Meteorology

The Bureau of Meteorology is Australia's national weather, climate and water agency. Under the *Water Act 2007*, the Bureau is responsible for compiling and disseminating Australia's water information. The Bureau is committed to increasing access to water information to support informed decision making about the management of water resources. For more information, visit <http://www.bom.gov.au/water/>.

## CSIRO

Australia is founding its future on science and innovation. Its national science agency, CSIRO, is a powerhouse of ideas, technologies and skills for building prosperity, growth, health and sustainability. It serves governments, industries, business and communities across the nation. For more information, visit <http://www.csiro.au>.

## Geoscience Australia

Geoscience Australia is Australia's national geoscience agency and exists to apply geoscience to Australia's most important challenges. Geoscience Australia provides geoscientific advice and information to the Australian Government to support current priorities. These include contributing to responsible resource development; cleaner and low emission energy technologies; community safety; and improving marine planning and protection. The outcome of Geoscience Australia's work is an enhanced potential for the Australian community to obtain economic, social and environmental benefits through the application of first class research and information. For more information, visit <http://www.ga.gov.au>.

**ISBN-PDF 978-1-4863-0417-2**

## Citation

Lewis S, Cassel R and Galinec V (2014) Coal and coal seam gas resource assessment for the Galilee subregion. Product 1.2 for the Galilee subregion from the Lake Eyre Basin Bioregional Assessment. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

Authorship is listed in relative order of contribution.

## Copyright

© Commonwealth of Australia 2014

With the exception of the Commonwealth Coat of Arms and where otherwise noted, all material in this publication is provided under a Creative Commons Attribution 3.0 Australia Licence <http://www.creativecommons.org/licenses/by/3.0/au/deed.en>.

## Disclaimer

The information contained in this report is based on the best available information at the time of publication. The reader is advised that such information may be incomplete or unable to be used in any specific situation. Therefore decisions should not be made based solely on this information or without seeking prior expert professional, scientific and technical advice.

The Bioregional Assessment Programme is committed to providing web accessible content wherever possible. If you are having difficulties with accessing this document please contact <bioregionalassessments@bom.gov.au>.

## Cover photograph

Artesian Spring Wetland at Doongmabulla Nature Refuge, Queensland, 2013

Credit: Jeremy Drimer, University of Queensland

Australian Government
Department of the Environment
Bureau of Meteorology
Geoscience Australia

V20141024

# Contents

**Contributors to the Technical Programme ........ vi**

**Acknowledgements ........ viii**

**Introduction ........ 1**

The Bioregional Assessment Programme ........ 1
Methodologies ........ 3
Technical products ........ 4
About this technical product ........ 5

**1.2.1 Available coal and coal seam gas resources ........ 10**

1.2.1.1 Coal ........ 12
1.2.1.1.1 Aramac Coal Measures ........ 15
1.2.1.1.2 Betts Creek beds ........ 17
1.2.1.1.3 Colinlea Sandstone ........ 18
1.2.1.1.4 Bandanna Formation ........ 18
1.2.1.1.5 Winton Formation ........ 19
1.2.1.2 Coal seam gas ........ 20

**1.2.2 Current activity and tenements ........ 27**

1.2.2.1 Coal ........ 29
1.2.2.1.1 Exploration permits for coal ........ 29
1.2.2.1.2 Mining leases and mineral development licenses ........ 31
1.2.2.2 Coal seam gas ........ 34
1.2.2.2.1 Exploration permits for petroleum ........ 34

**1.2.3 Proposals and exploration ........ 37**

1.2.3.1 Coal ........ 38
1.2.3.1.1 Alpha Coal Project ........ 41
1.2.3.1.2 Kevin's Corner Coal Project ........ 44
1.2.3.1.3 China First Coal Project ........ 47
1.2.3.1.4 Carmichael Coal Mine and Rail Project ........ 51
1.2.3.1.5 South Galilee Coal Project ........ 56
1.2.3.1.6 China Stone Coal Project ........ 59
1.2.3.1.7 Alpha North Coal Project ........ 61
1.2.3.1.8 Clyde Park Coal Project ........ 61
1.2.3.1.9 Alpha West Coal Project ........ 62
1.2.3.1.10 Carmichael East Coal Project ........ 63

1.2.3.1.11 West Pentland Coal Project ........ 63
1.2.3.1.12 Pentland Coal Project ........ 64
1.2.3.1.13 Degulla Coal Project ........ 64
1.2.3.1.14 Hyde Park Coal Project ........ 64
1.2.3.1.15 Blackall Coal Project ........ 65
1.2.3.1.16 Regional coal exploration in Galilee Basin ........ 66
1.2.3.1.17 Galilee Basin State Development Area ........ 71
1.2.3.2 Coal seam gas ........ 71
1.2.3.2.1 History of coal seam gas exploration ........ 71
1.2.3.2.2 Current coal seam gas exploration and testing ........ 72

**1.2.4 Catalogue of potential resource developments ........ 84**

**Appendix A ........ 92**

A.1 Classification scheme for coal ........ 92
A.2 Mineral and petroleum tenure types in Queensland ........ 93
A.2.1 Tenure types for coal ........ 93
A.2.2 Tenure types for petroleum ........ 93

# Figures

Figure 1 Schematic diagram of the bioregional assessment methodology .......... 2

Figure 2 The simple decision tree indicates the flow of information through a bioregional assessment .......... 5

Figure 3 Interpreted distributions of Permian coal-bearing formations in the Galilee Basin .......... 13

Figure 4 Stratigraphic frameworks of the Galilee and Eromanga basins, Queensland .......... 14

Figure 5 Main geological structures and depositional centres in the Galilee Basin .......... 16

Figure 6 Gas contents for the main coal seams of the Galilee Basin .......... 23

Figure 7 Gas compositions from coal seams in the Galilee Basin .......... 23

Figure 8 Aerial view of test pit mine at Alpha Coal Project in the Galilee subregion .......... 28

Figure 9 Exploration permits for coal in and around the Galilee subregion, July 2014 .......... 30

Figure 10 Mining leases and mineral development licences in the Galilee subregion, July 2014 .......... 33

Figure 11 Exploration permits for petroleum and production licences in and around the Galilee subregion, July 2014 .......... 35

Figure 12 Status of coal and coal seam gas resource projects in the Galilee subregion .......... 39

Figure 13 Geological cross-section (west to east) through central part of Alpha Coal Project in the Galilee subregion .......... 42

Figure 14 Concept design for China First Coal Project in the Galilee subregion .......... 48

Figure 15 Carmichael mine plan and associated infrastructure areas in the Galilee subregion .......... 54

Figure 16 Galilee Basin exploration tenements for Guildford Coal in the northern Galilee subregion .......... 68

Figure 17 Glenaras and Gowing wells with the 300 megalitre holding dam at the Glenaras pilot production site .......... 74

Figure 18 Gunn Coal Seam Gas Project area in Galilee Basin .......... 76

Figure 19 Classification of coals by rank .......... 92

# Tables


Table 1 Methodologies and associated technical products listed in Table 2 .................................... 3

Table 2 Technical products being delivered as part of the Lake Eyre Basin Bioregional Assessment ............................................................................................................................ 6

Table 3 Typical composition of sub-bituminous coal in the Winton Formation in the Galilee subregion ............................................................................................................................ 20

Table 4 Published contingent and prospective coal seam gas resources in the Galilee Basin.......... 22

Table 5 Mining lease applications for proposed coal mines in Galilee Basin, July 2014 .................. 31

Table 6 Mineral development licences for coal projects in Galilee Basin, July 2014 ........................ 32

Table 7 Alpha Coal Project resources in the Galilee subregion ...................................................... 43

Table 8 Composite stratigraphy of the Kevin's Corner Coal Project in the Galilee subregion .......... 46

Table 9 Composite stratigraphy of the Carmichael Coal Project in the Galilee subregion ............... 52

Table 10 Coal resource in D coal seam at South Galilee Coal Project ............................................. 56

Table 11 Planned stages in development of South Galilee Coal Project.......................................... 58

Table 12 Recent coal resource discoveries in Galilee Basin ........................................................... 69

Table 13 Catalogue of potential coal resource developments in the Galilee subregion.................. 86

Table 14 Catalogue of potential coal seam gas resource developments in the Galilee subregion... 90

# Contributors to the Technical Programme

The following individuals have contributed to the Technical Programme, the part of the Bioregional Assessment Programme that undertakes bioregional assessments. Leaders are underlined.

| | |
|---|---|
| Assistant Secretary | Department of the Environment: Gayle Milnes |
| Programme Director | Department of the Environment: Edwina Johnson |
| Technical Programme Director | Bureau of Meteorology: Bronwyn Ray |
| Projects Director | CSIRO: David Post |
| Principal Science Advisor | Department of the Environment: Peter Baker |
| Science Directors | CSIRO: Brent Henderson |
| | Geoscience Australia: Trevor Dhu |
| Integration Lead | Bureau of Meteorology: Richard Mount |
| Programme management | Bureau of Meteorology: Graham Hawke, Louise Minty |
| | CSIRO: Paul Hardisty, Warwick McDonald |
| | Geoscience Australia: Stuart Minchin |
| Project Leaders | CSIRO: Alexander Herr, Tim McVicar, David Rassam |
| | Geoscience Australia: Hashim Carey, Kriton Glenn |
| Assets and receptors | Bureau of Meteorology: <u>Richard Mount</u> |
| | Department of the Environment: Rachel Carter, Larry Guo, Brad Moore, Jin Wang |
| | Geoscience Australia: Joe Bell |
| Bioregional Assessment Information Platform | Bureau of Meteorology: <u>Brian Cannell,</u> Trevor Christie-Taylor, Mark Hatcher |
| | CSIRO: <u>David Lemon</u> |
| | Department of the Environment: Geraldine Cusack |
| | Geoscience Australia: <u>Neal Evans</u> |
| Communications | Bureau of Meteorology: Mel Martin |
| | CSIRO: Tsuey Cham, Leane Regan |
| | Department of the Environment: Sophie Alexander, Milica Milanja, Kirsty Rolls |
| | Geoscience Australia: David Beard, Chris Thompson |

| | |
|---|---|
| Coordination | Bureau of Meteorology: Julie Burke, Sarah van Rooyen<br><br>CSIRO: Ruth Palmer<br><br>Department of the Environment: James Hill, Sunita Johar, Broni McMaster, Carolyn Paris, Craig Watson<br><br>Geoscience Australia: Tenai Luttrell |
| Ecology | CSIRO: Tanya Doody, Brendan Ebner, Kate Holland, Craig MacFarlane, Tracey May, Patrick Mitchell, Justine Murray, Anthony O'Grady, Chris Pavey, Jodie Pritchard, Nat Raisbeck-Brown, Ashley Sparrow, Georg Wiehl |
| Geology | CSIRO: Deepak Adhikary, Luke Connell, Emanuelle Frery, Jane Hodgkinson, James Kear, Zhejun Pan, Kaydy Pinetown, Matthias Raiber, Hayley Rohead-O'Brien, Regina Sander, Peter Schaubs, Garth Warren, Paul Wilkes, Andrew Wilkins, Yanhua Zhang<br><br>Geoscience Australia: Tim Evans, Steven Lewis, John Magee, Martin Smith |
| Geography | Bureau of Meteorology: Natasha Herron |
| Geographic information systems | CSIRO: Caroline Bruce, Jody Bruce, Malcolm Hodgen, Steve Marvanek<br><br>Geoscience Australia: Gerard Stewart, Kirsten Walker |
| Groundwater modelling | CSIRO: Olga Barron, Russell Crosbie, Tao Cui, Warrick Dawes, Lei Gao, Sreekanth Janardhanan, Luk Peeters, Praveen Kumar Rachakonda, Wolfgang Schmid, Saeed Torkzaban, Chris Turnadge, Binzhong Zhou<br><br>Geoscience Australia: Wenping Jiang |
| Hydrogeology | CSIRO: Konrad Miotlinski<br><br>Geoscience Australia: Rebecca Cassel, Jim Kellett, Sarah Marshall, Rebecca Norman, Jessica Northey, Tim Ransley, Martin Smith, Baskaran Sundaram, KokPiang Tan, Luke Wallace, Gabrielle Yates |
| Information management | Bureau of Meteorology: Belinda Allison, Jill McNamara, Brendan Moran<br><br>CSIRO: Nick Car, Phil Davies, Andrew Freebairn, Mick Hartcher, Geoff Hodgson, Brad Lane, Ben Leighton, Trevor Pickett, Ramneek Singh, Matt Stenson, Garry Swan<br><br>Geoscience Australia: Luke Caruana, Penny Kilgour, Matti Peljo |
| Products | CSIRO: Maryam Ahmad, Daniel Aramini, Heinz Buettikofer, Simon Gallant, Karin Hosking, Frances Marston, Linda Merrin, Becky Schmidt, Sally Tetreault-Campbell, Catherine Ticehurst<br><br>Geoscience Australia: Veronika Galinec, Daniel Rawson |
| Risk and uncertainty | CSIRO: Simon Barry, Jeffery Dambacher, Jess Ford, Keith Hayes, Geoff Hosack, Yang Liu, Warren Jin, Dan Pagendam, Carmel Pollino |
| Surface water hydrology | CSIRO: Santosh Aryal, Mat Gilfedder, Fazlul Karim, Lingtao Li, Dave McJannet, Jorge Pena Arancibia, Xiaogang Shi, Tom Van Niel, Neil Viney, Bill Wang, Ang Yang, Yongqiang Zhang |

# Acknowledgements

This technical product was reviewed by several groups:

- Senior Science Leaders: David Post (Projects Director), Trevor Dhu (Science Director, Geoscience Australia), Brent Henderson (Science Director, CSIRO), Becky Schmidt (Products Manager, CSIRO)
- Technical Assurance Reference Group: Chaired by Peter Baker (Principal Science Advisor, Department of the Environment), this group comprises officials from the New South Wales, Queensland, South Australian and Victorian governments.
- Additional reviewers: Steve Cadman (Geoscience Australia) and GVK Coal Developers Pty Ltd.

Valuable comments were also provided by Tim Evans (Geoscience Australia), John Ross (AGL Energy Ltd), Nicola Fry (AGL Energy Ltd) and Amy I'Anson (AGL Energy Ltd).

Nicola Garland's (Queensland Resources Council) efforts were instrumental for gaining access to mining companies for review of this product.

# 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 on potential water-related impacts of coal seam gas (CSG) and large coal mining developments.

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 direct, indirect and cumulative 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, 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:

- 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.

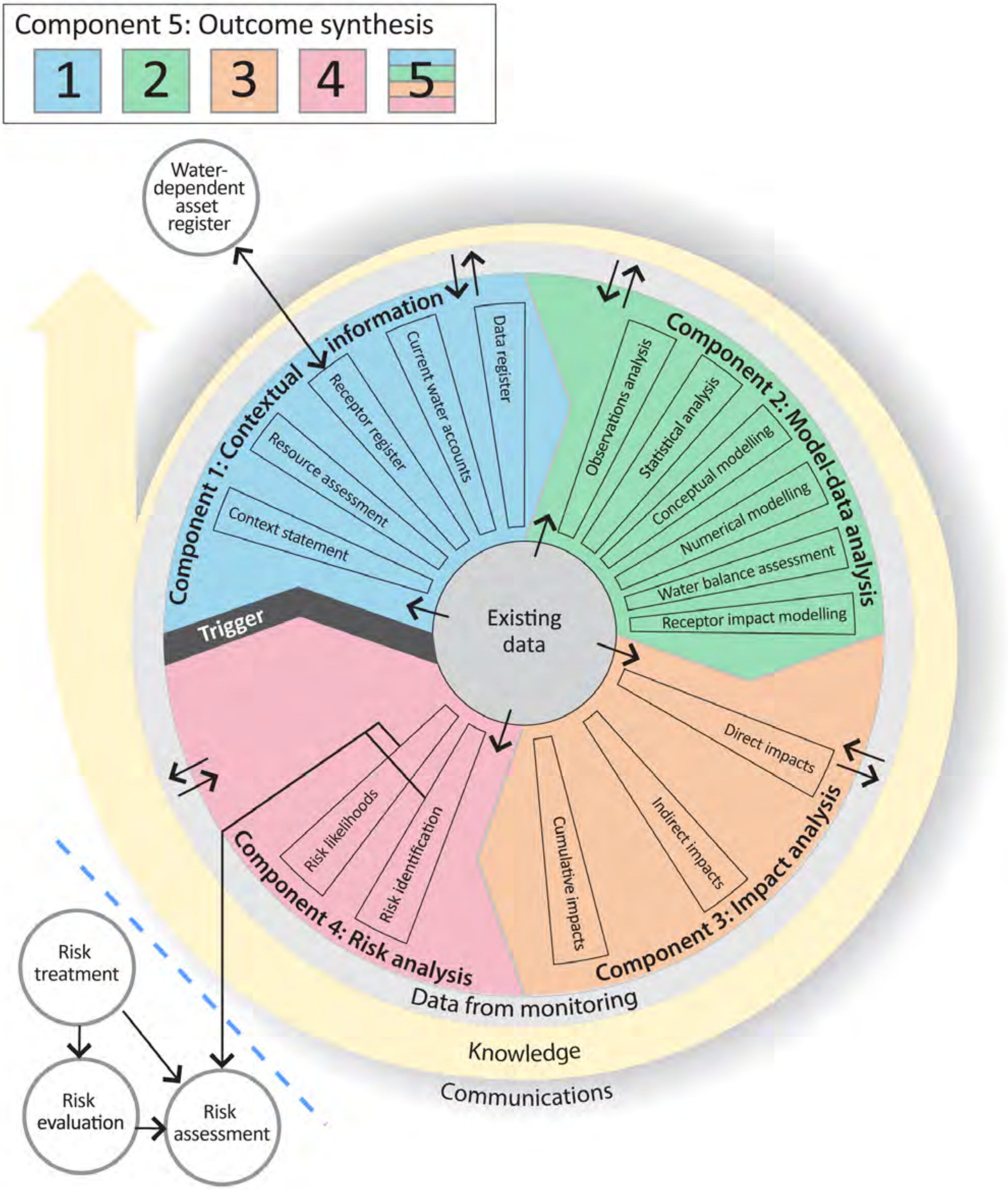



**Figure 1 Schematic diagram of the bioregional assessment methodology**

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 exernal 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

For transparency and to ensure consistency across all BAs, submethodologies have been developed to supplement the key approaches outlined in the *Methodology for bioregional assessments of the impact of coal seam gas and coal mining development on water resources* (Barrett et al., 2013). This series of submethodologies aligns with technical products as presented in Table 1. The submethodologies are not intended to be 'recipe books' nor to provide step-by-step instructions; rather they provide an overview of the approach to be taken. In some instances, methods applied for a particular BA may need to differ from what is proposed in the submethodologies – in this case an explanation will be supplied. Overall, the submethodologies are intended to provide a rigorously defined foundation describing how BAs are undertaken.

**Table 1 Methodologies and associated technical products listed in Table 2**

| Code | Proposed title | Summary of content | Associated technical product |
|---|---|---|---|
| M01 | *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 | All |
| M02 | *Compiling water-dependent assets* | Describes the approach for determining water-dependent assets | 1.3 Description of the water-dependent asset register |
| M03 | *Assigning receptors and impact variables to water-dependent assets* | Describes the approach for determining receptors associated with water-dependent assets | 1.4 Description of the receptor register |
| M04 | *Developing a coal resource development pathway* | Specifies the information that needs to be collected and reported in product 1.2 (i.e. known coal and coal seam gas resources as well as current and potential resource developments). Describes the process for determining the coal resource development pathway (reported in product 2.3) | 1.2 Coal and coal seam gas resource assessment<br>2.3 Conceptual modelling |
| M05 | *Developing the conceptual model for causal pathways* | Describes the development of the conceptual model for causal pathways, which summarises how the 'system' operates and articulates the links between coal resource developments and impacts on receptors | 2.3 Conceptual modelling |
| M06 | *Surface water modelling* | Describes the approach taken for surface water modelling across all of the bioregions and subregions. It covers the model(s) used, as well as whether modelling will be quantitative or qualitative. | 2.6.1 Surface water numerical modelling |
| M07 | *Groundwater modelling* | Describes the approach taken for groundwater modelling across all of the bioregions and subregions. It covers the model(s) used, as well as whether modelling will be quantitative or qualitative. It also considers surface water – groundwater interactions, as well as how the groundwater modelling is constrained by geology. | 2.6.2 Groundwater numerical modelling |

| Code | Proposed title | Summary of content | Associated technical product |
|---|---|---|---|
| M08 | *Receptor impact modelling* | Describes how to develop the receptor impact models that are required to assess the potential impacts from coal seam gas and large coal mining on receptors. Conceptual, semi-quantitative and quantitative numerical models are described. | 2.7 Receptor impact modelling |
| M09 | *Propagating uncertainty through models* | Describes the approach to sensitivity analysis and quantifying uncertainty in the modelled hydrological response to coal and coal seam gas development | 2.3 Conceptual modelling<br>2.6.1 Surface water numerical modelling<br>2.6.2 Groundwater numerical modelling<br>2.7 Receptor impact modelling |
| M10 | *Risk and cumulative impacts on receptors* | Describes the process to identify and analyse risk | 3 Impact analysis<br>4 Risk analysis |
| M11 | *Hazard identification* | Describes the process to identify potential water-related hazards from coal and coal seam gas development | 2 Model-data analysis<br>3 Impact analysis<br>4 Risk analysis |
| M12 | *Fracture propagation and chemical concentrations* | Describes the likely extent of both vertical and horizontal fractures due to hydraulic stimulation and the likely concentration of chemicals after production of coal seam gas | 2 Model-data analysis<br>3 Impact analysis<br>4 Risk analysis |

Each submethodology is available online at <http://www.bioregionalassessments.gov.au>. Submethodologies might be added in the future.

## Technical products

The outputs of the BAs include a suite of technical products variously presenting information about the ecology, hydrology, hydrogeology and geology of a bioregion and the potential direct, indirect and cumulative 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 information flow within a BA. 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 rectangles in both Figure 2 and Table 2 indicate the information included in this technical product.

This technical product is delivered as a report (PDF). Additional material is also provided, as specified by the BA methodology:

- all unencumbered data syntheses and databases
- unencumbered tools, model code, procedures, routines and algorithms
- unencumbered forcing, boundary condition, parameter and initial condition datasets
- the workflow, comprising a record of all decision points along the pathway towards completion of the BA, gaps in data and modelling capability, and provenance of data.

The PDF of this technical product, and the additional material, are available online at <http://www.bioregionalassessments.gov.au>.

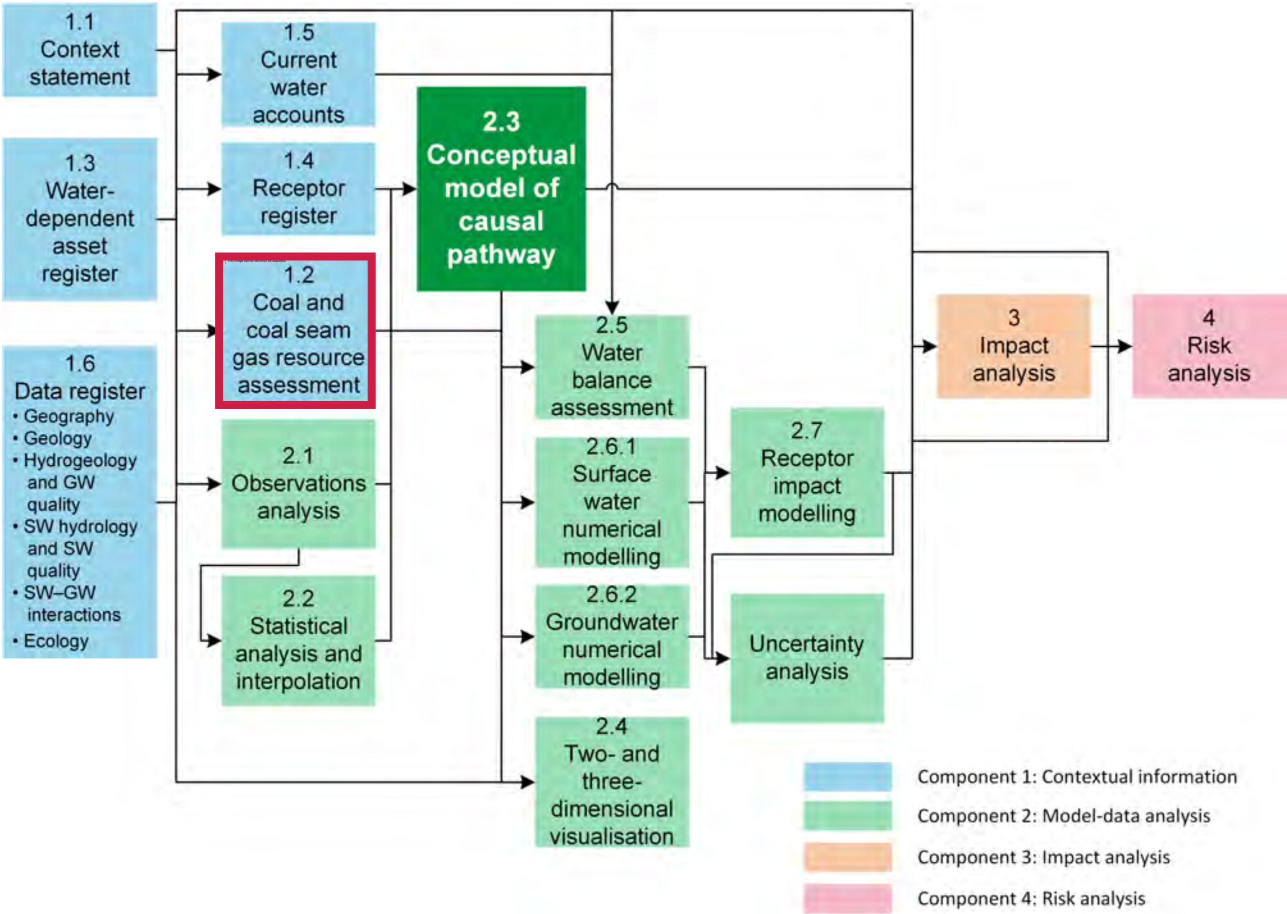



**Figure 2 The simple decision tree indicates the flow of information through a bioregional assessment**

The red rectangle indicates the information included in this technical product.

# 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, Figure 7, Figure 8 and Figure 13. 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 140.0° East for the Lake Eyre Basin bioregion and two standard parallels of –18.0° and –36.0°.

**Table 2 Technical products being delivered as part of the Lake Eyre Basin Bioregional Assessment**

For each subregion in the Lake Eyre Basin Bioregional Assessment, technical products will be delivered as data, summaries and reports (PDFs) as indicated by ■ in the last column of Table 2. The red rectangle indicates the information covered in this technical product. A suite of other technical and communication products – such as maps, registers and factsheets – will also be developed through the bioregional assessments.

| Component | Product code | Information | Section in the BA methodology[a] | Report |
|---|---|---|---|---|
| Component 1: Contextual information for the bioregion or subregion | 1.1 | Context statement | 2.5.1.1, 3.2 | ■ |
| | 1.2 | Coal and coal seam gas resource assessment | 2.5.1.2, 3.3 | ■ |
| | 1.3 | Description of the water-dependent asset register | 2.5.1.3, 3.4 | ■ |
| | 1.4 | Description of the receptor register | 2.5.1.4, 3.5 | ■ |
| | 1.5 | Current water accounts and water quality | 2.5.1.5 | ■ |
| | 1.6 | Data register | 2.5.1.6 | |
| Component 2: Model-data analysis for the bioregion or subregion | 2.1-2.2 | Observations analysis, statistical analysis and interpolation | 2.5.2.1, 2.5.2.2 | ■ |
| | 2.3 | Conceptual modelling | 2.5.2.3, 4.3 | ■ |
| | 2.4 | Two- and three-dimensional representations | 4.2 | [b] |
| | 2.5 | Water balance assessment | 2.5.2.4 | ■ |
| | 2.6.1 | Surface water numerical modelling | 4.4 | ■ |
| | 2.6.2 | Groundwater numerical modelling | 4.4 | ■ |
| | 2.7 | Receptor impact modelling | 2.5.2.6, 4.5 | ■ |
| Component 3: Impact analysis for the bioregion or subregion | 3 | Impact analysis | 5.2.1 | ■ |
| Component 4: Risk analysis for the bioregion or subregion | 4 | Risk analysis | 2.5.4, 5.3 | ■ |
| Component 5: Outcome synthesis for the bioregion | 5 | Outcome synthesis | 2.5.5 | ■ |

[a]Barrett et al. (2013)
[b]The two- and three-dimensional representations will be delivered in products such as 2.3, 2.6.1 and 2.6.2.

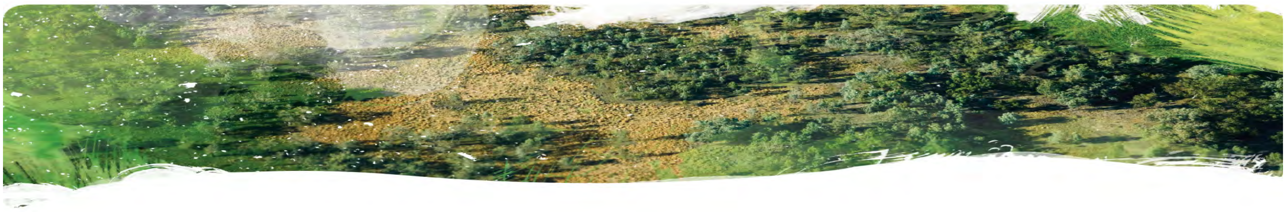
## *References*


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 24 October 2014, <http://www.environment.gov.au/coal-seam-gas-mining/pubs/methodology-bioregional-assessments.pdf>.

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 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 will be used to develop the coal resource development pathway (as reported in product 2.3), which articulates the most likely combination of developments at a subregion or bioregion scale, including all individual coal and coal seam gas resource projects that are expected.



# 1.2 Coal and coal seam gas resource assessment for the Galilee subregion

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 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 will be used to develop the coal resource development pathway (as reported in product 2.3), which articulates the most likely combination of developments at a subregion or bioregion scale, including all individual coal and coal seam gas resource projects that are expected.

## 1.2.1 Available coal and coal seam gas resources


***Summary***

Significant deposits of black coal were first identified in the geological Galilee Basin in the 1970s, although no commercial mines have yet been established due to the basin's relative remoteness and absence of mine-enabling infrastructure. However, a widespread exploration boom since the mid-2000s has helped transform the understanding of the basin's coal and coal seam gas (CSG) resources, and there are currently six high-value greenfield mining ventures slated for initial development prior to 2020. These large scale open-cut and underground mining operations propose to target the laterally extensive coal seams hosted in the Late Permian aged strata of the Betts Creek beds (and their stratigraphic equivalents the Colinlea Sandstone and Bandanna Formation in the central-eastern part of the Galilee Basin).

The Betts Creek beds (and equivalents) are a mixed sedimentary sequence predominantly comprising sandstone, conglomerate, shale and coal. The units occur across most of the Galilee Basin, although it is only near the eastern basin margin that the coal seams are close enough to surface to permit economic extraction. There are six main coal seams recognised in the formation (seams A through F), and in places such as the Koburra Trough these occur as well-defined seams of uniform thickness that dip regionally to the west at low angles (1 to 5°). Most of the basin's Late Permian coals (originally deposited from 262 to 252 million years ago) are low rank (sub-bituminous) with low sulfur and relatively high ash content. Moisture levels are typically 7 to 9%. They are non-coking coals, suitable mainly for thermal uses such as power generation.

Coal also occurs in Early Permian strata in the Galilee Basin, particularly the Aramac Coal Measures. The Aramac Coal Measures are not as spatially extensive as the Late Permian coal-bearing formations and are mainly restricted to the central and western parts of the basin, such as the Lovelle Depression and Aramac Trough. The Aramac Coal Measures typically comprise about 10% coal, with the remainder of the unit consisting of interbedded sandstone, siltstone and shale. Coals in the Aramac Coal Measures are high volatile bituminous coals that are typically more thermally mature than those in the Betts Creek beds. The Aramac Coal Measures are buried too deeply throughout the basin for them to be mined economically, although they are a secondary CSG target.

Within the Galilee subregion, large tonnages of low rank coal (ranging from lignite to sub-bituminous) occur in Cretaceous strata of the Eromanga Basin. These coals are about 150 million years younger than those in the Late Permian formations, and are mainly concentrated in southern parts of the subregion, south of Blackall. There are several major deposits with over 1 billion tonnes of identified coal resources buried at relatively shallow depths, although the much higher moisture levels of these coals mean that they are less profitable as an export product.

Exploration for CSG resources in the Galilee Basin has mainly focused on the Betts Creek beds, although the deeper Aramac Coal Measures have also been intersected in many CSG

exploration wells. Gas sourced from both of these coal-bearing units has similar properties, and is predominantly methane with gas content typically less than 5 $m^3$/t (dry ash free, DAF). Most coals in the Galilee Basin have gas saturation levels of around 30% (undersaturated), although there is a considerable range (5 to 75%). Isotopic evidence suggests that most CSG in the Betts Creek beds and Aramac Coal Measures is of biogenic origin, and derived mainly from bacterial reduction of carbon dioxide.

The Galilee Basin is a large (about 250,000 $km^2$) geological basin which underlies the Galilee subregion in central Queensland, and contains world-class resources of high volatile, low rank black coal. According to the 2014 Australian Energy Resource Assessment (AERA), the Galilee Basin contains total Identified Resources of 23,248 million tonnes (Mt), with recoverable economic demonstrated resources (EDR) of 6281 Mt (GA and BREE, 2014). These coal resources are hosted in Permian age sedimentary strata at relatively shallow depths along much of the eastern flank of the basin. Coal has been known to occur in the Galilee Basin for about the last 100 years, although there are currently no commercially operating coal mines or coal seam gas (CSG) production facilities in this region. The main factor that has so far discouraged the development of these significant resources is the relative remoteness and lack of existing infrastructure necessary for mining and transport to markets. As recently as the early 2000s there were only three coal resources identified in the Galilee Basin, these being the thermal coal deposits at Alpha, Kevin's Corner and Pentland (Mutton, 2003).

Since the mid-2000s there has been a major upsurge in coal exploration activity, driven largely by a significant rise in global coal prices coupled with increased funding from international investors, mainly from China and India. This has led to a number of proposals for new high value mining projects, many of which are currently subject to the pre-development approvals process. These greenfield mining operations are being developed as large scale mines that are profitable because of the economies of scale that come from major open-cut and underground mining operations which employ an integrated approach to mine management, railway transport and port facilities.

The Galilee Basin is also recognised as an emerging CSG province, although the scale and pace of CSG exploration and development is significantly behind that of the basin's coal resources. Although the Galilee Basin has a history of CSG exploration dating back to the early 1990s (EEA, 1992), commercial production has yet to be achieved, and recent exploration results have not proven as encouraging as in the nearby Bowen and Surat basins. Nonetheless, several CSG companies remain active in the region, and two pilot test operations in different parts of the central basin have indicated that future full-scale development may occur, although possibly not for at least ten to fifteen years.

If all of the planned Galilee Basin mining development goes ahead, Australia's thermal coal exports could increase by almost 240 million tonnes (Mt) per year. The development of associated transport (rail) and port infrastructure may also potentially underpin other Galilee Basin coal projects long into the future.

Significant black coal mines currently slated for development in the Galilee Basin include:

- *Alpha* (joint venture between GVK Coal Developers Pty Ltd and Hancock Prospecting Pty Ltd (Hancock Prospecting), known as GVK Hancock) – mining 30 million tonnes (Mt)/year at $10 billion development cost including infrastructure, rail and port facilities
- *Kevin's Corner* (GVK Coal Developers Pty Ltd (GVK Coal Developers)) – 30 Mt/year at $4.2 billion development cost including infrastructure
- *China First* (Waratah Coal Pty Ltd (Waratah Coal)) – 40 Mt/year at $6.5 billion development cost including infrastructure
- *Carmichael* (Adani Mining Pty Ltd (Adani Mining)) – 60 Mt/year at $16 billion development cost including infrastructure and rail
- *South Galilee* (joint venture between AMCI (Alpha) Pty Ltd and Alpha Coal Pty Ltd (Alpha Coal)) – 17 Mt/year at $4.2 billion development cost
- *China Stone* (Macmines Austasia Pty Ltd (Macmines Austasia)) – 60 Mt/year at $6 billion development cost.

Further information about each of these developments is in Section 1.2.3 of this report.

### *1.2.1.1 Coal*

Two regionally significant periods of coal deposition occurred in the Galilee Basin, initially in the Early Permian followed by a more extensive Late Permian episode. These coal-forming events were interrupted by a major depositional hiatus in the Middle Permian (Wells, 1989). Across most of the Galilee Basin the Permian strata are unconformably overlain by younger rocks of the Jurassic to Cretaceous Eromanga Basin, except in an arcuate zone on the eastern basin margin (as shown in Figure 18 of product 1.1 for the Galilee subregion (Evans et al., 2014)). It is only along the far central-eastern and north-eastern margins of the Galilee Basin that coals are likely to be mined in future, due to their relatively shallow depth below surface.

The focus of this section is on the four main coal-bearing geological formations that occur within the Permian strata of the Galilee subregion (Figure 3 and Figure 4), namely the:

- Aramac Coal Measures (Early Permian)
- Betts Creek beds (Late Permian)
- Colinlea Sandstone (Late Permian, stratigraphically equivalent to the lower part of Betts Creek beds)
- Bandanna Formation (Late Permian, stratigraphically equivalent to the upper part of Betts Creek beds).

Additional to these Permian coals, low rank coals occur in rocks of the Rolling Downs Group within the Eromanga Basin. These commonly overlie the Permian and Triassic strata of the Galilee Basin and are mostly hosted in the Cretaceous Winton Formation (Figure 4). These Mesozoic coal resources within the Galilee subregion are also briefly described within this section.

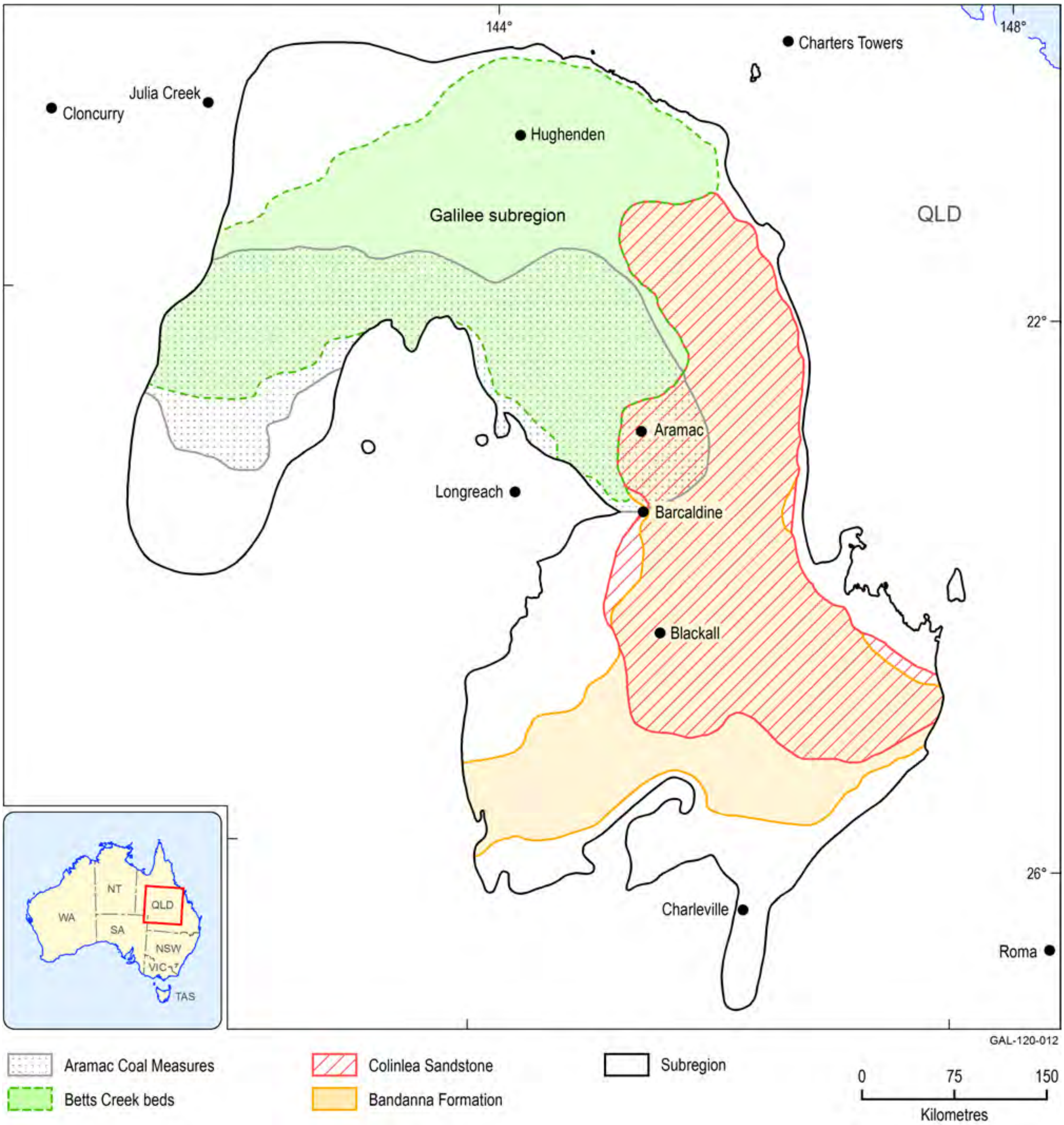



**Figure 3 Interpreted distributions of Permian coal-bearing formations in the Galilee Basin**

Source data: derived from data described in Scott et al. (1995)

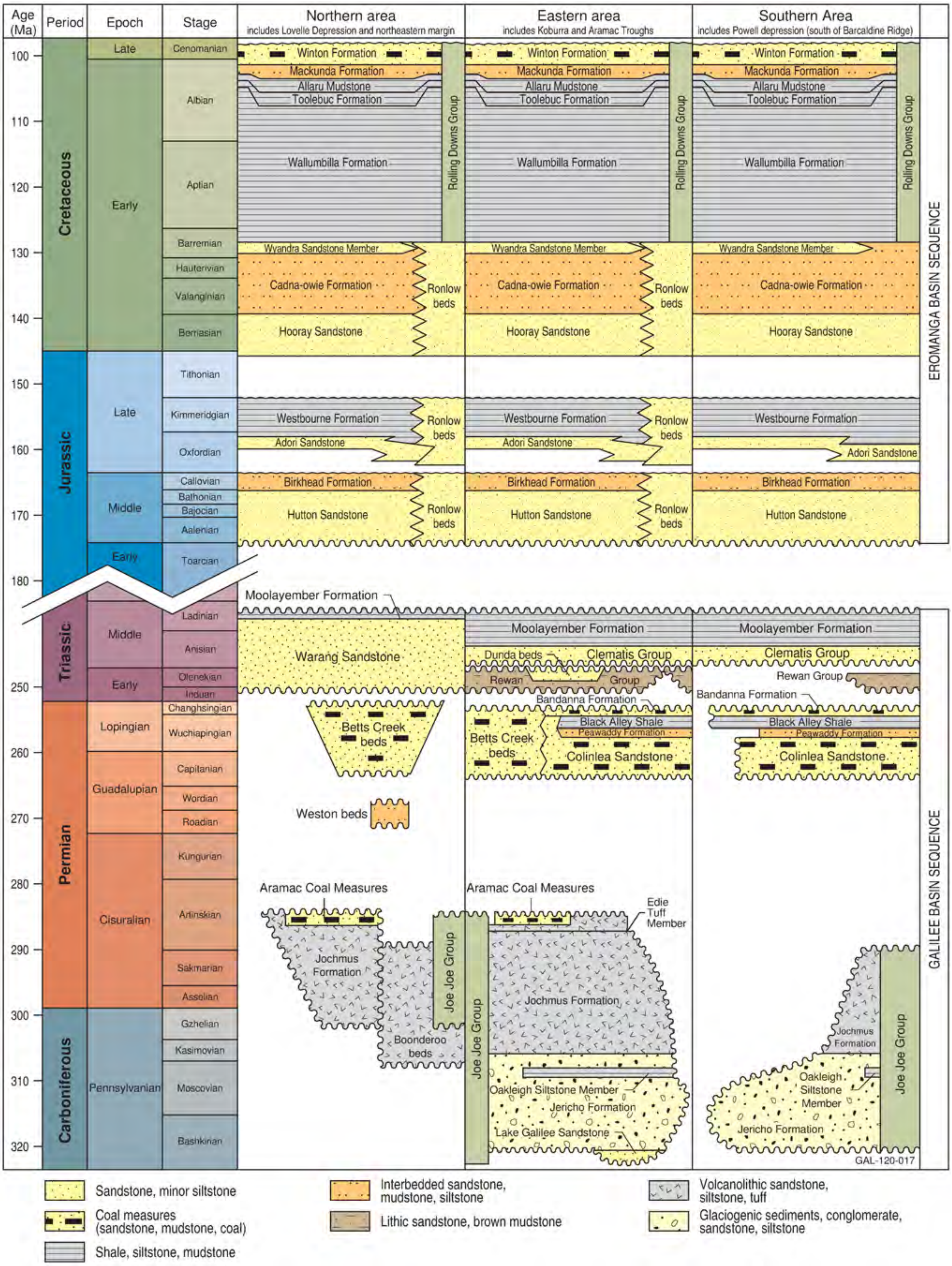



**Figure 4 Stratigraphic frameworks of the Galilee and Eromanga basins, Queensland**

Much of the geological timescale from the Middle Triassic to the Middle Jurassic (a period of about 65 million years) has been removed from this figure as there are no sedimentary units known from this period in the Galilee Basin (depositional hiatus).

#### 1.2.1.1.1 Aramac Coal Measures

The basal stratigraphic sequence within the Galilee Basin is the Late Carboniferous to Early Permian Joe Joe Group, deposited from about 320 to 280 million years ago (Ma). The Joe Joe Group consists of four main stratigraphic units, namely the Lake Galilee Sandstone (lowermost), Jericho Formation, Jochmus Formation and the Aramac Coal Measures (Figure 4). The stratigraphic and areal extent of these formations varies across the Galilee Basin, with the maximum known thickness of the Joe Joe Group being 1781 m (Lake Galilee 1 petroleum exploration well; GA and ASC, 2014). Following the cessation of deposition in the Late Permian, much of the upper part of the Joe Joe Group (including the Aramac Coal Measures) was removed by erosion in the Middle to Late Permian.

The main coal-bearing unit in the basal group of the Galilee Basin is the Aramac Coal Measures. Minor coal occurs sporadically in some of the other units within the Joe Joe Group but it is mostly thin and discontinuous (Wells, 1989). Based on analysis of fossilised spore and pollen assemblages (palynology), the Aramac Coal Measures are stratigraphically equivalent to the Reids Dome beds in the central and south-western Bowen Basin, and are thus the oldest coals in the Galilee Basin. These are commonly referred to as Group I coals in the terminology of Queensland's Permian coal resources (Mutton, 2003). The Aramac Coal Measures are an interbedded sedimentary sequence of sandstone (about 49%), siltstone and mudstone (40%), and coal (about 11%) (Wells, 1989). Scott et al. (1995) suggested that the lower parts of the Aramac Coal Measures are predominantly sandstone with only minor coal and mudstone, whereas the upper part consists mainly of sandstone with subordinate coal. The maximum percentage of coal known from the formation is about 20%, based on interpretation of drill cuttings and down-hole geophysical logs.

The coals in the Aramac Coal Measures are mostly grey to black, brittle and predominantly dull, although minor bright bands have been described, for example, by AGL Energy Limited (AGL) (2009) in their well completion report for CSG exploration well Glenaras 6. Based on coal sample analyses from various petroleum exploration wells, the Aramac Coal Measures contain high volatile bituminous coal with a mean reflectance ($R_{v,\,max}$) of 0.6 to 0.8%. Maximum vitrinite reflectance of 1.1% has been measured in deep coal seams from about 1700 m depth below surface (Smith, 2013). Analysis of coal sample R3382 (air dried) recovered from depth of 1111 m below surface in the Geological Survey of Queensland's Longreach 1-1B stratigraphic drill-hole reported 56.8% fixed carbon, 39.0% volatile matter, 3.4% moisture and 0.8% ash (Green et al., 1991).

The Aramac Coal Measures have a restricted areal distribution in the Galilee Basin (Figure 3), and are mainly known from petroleum exploration wells drilled in the central and western parts of the basin. The unit is not known to occur in the southern Galilee Basin, that is, south of the geological Barcaldine Ridge (Figure 5). Several interpretations have suggested that the distribution of the Aramac Coal Measures has been largely controlled by structural movements at the time of deposition, with thickest coal seams formed in fault-controlled grabens and half-grabens (Scott and Hawkins, 1992; Scott et al., 1995). The thickest stratigraphic intersections of the Aramac Coal Measures in petroleum wells have mainly occurred in the Aramac Trough and the Lovelle Depression (Figure 5). These typically range from about 100 m thick to a maximum of 271 m in

Lovelle Downs 1. An unknown thickness of this formation was removed by erosion during the Middle to Late Permian.

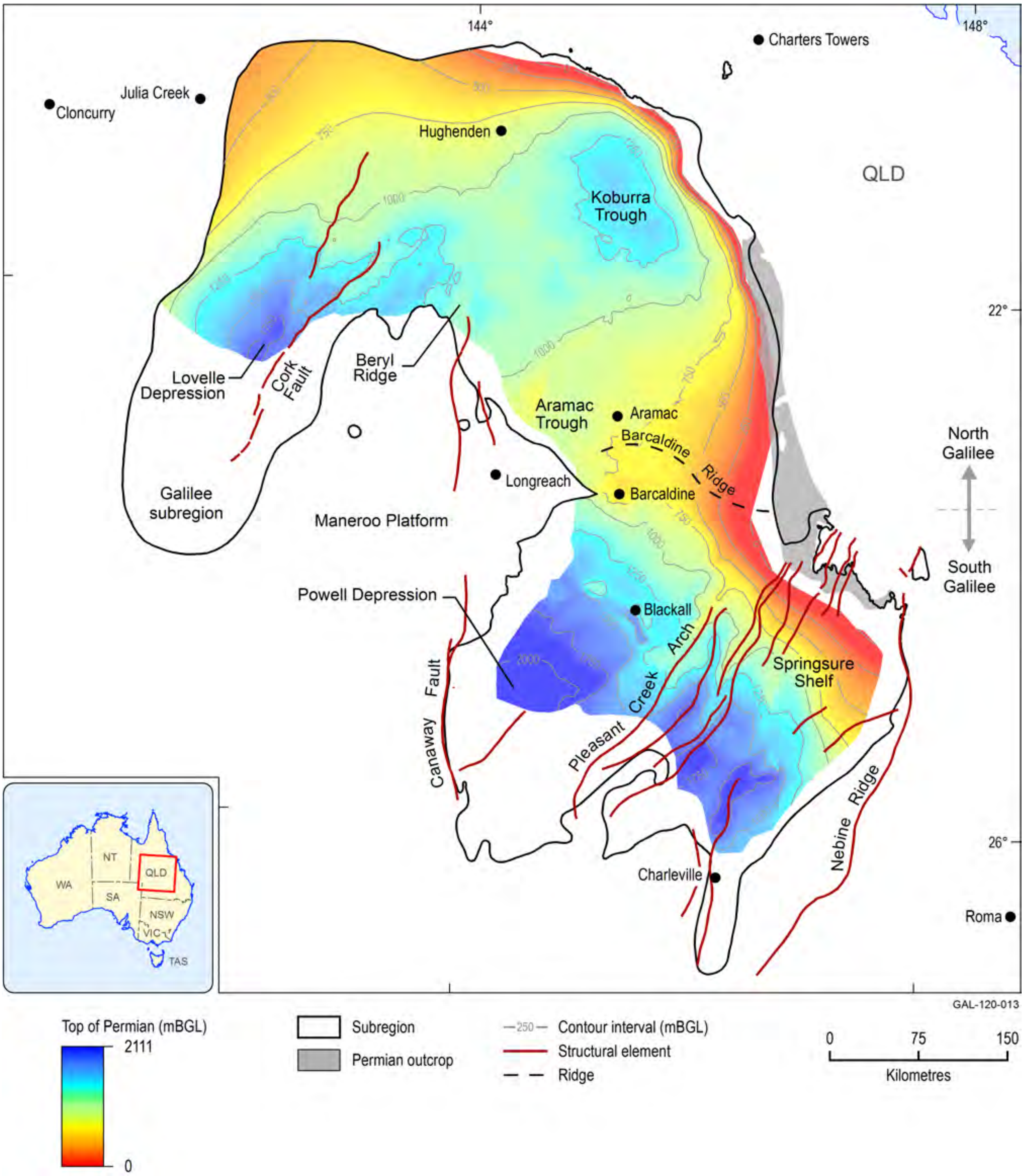



**Figure 5 Main geological structures and depositional centres in the Galilee Basin**

Source data: the top of Permian strata contours are derived from data in Bradshaw et al. (2009). Although Permian rocks exist throughout the basin, not all were shown in the mapping presented in Bradshaw et al. (2009).
mBGL – metres below ground level

The Aramac Coal Measures are buried too deeply (mostly in excess of 600 m) throughout the Galilee Basin for coal mining development to be economically viable (Durie et al., 1992). However, they have been targeted by some exploration companies for their coal seam gas (CSG) potential, usually as a combined CSG target with overlying Late Permian coal-bearing strata. For example, this exploration approach has been taken by AGL in exploration permit for petroleum (EPP) 529 in the Aramac Trough. Further information on the Joe Joe Group is provided in product 1.1 for the Galilee subregion (Evans et al., 2014).

### 1.2.1.1.2 Betts Creek beds

The thickest and most areally extensive coal-bearing units in the Galilee Basin are of Late Permian age and are equivalent to the Group IV coals of the nearby Bowen Basin (Smith, 2013). These units occur across most of the basin (Figure 3), commonly at depths of between 500 and 1000 m, with maximum depths exceeding 1500 m in the Lovelle Depression and the Powell Depression. However, close to the eastern margin of the basin, the coal-bearing Permian strata occur at relatively shallow depths beneath younger (mainly Cenozoic) sediments, and outcrop sporadically in a zone parallel to the basin margin. Along the eastern margin of the basin and into the Koburra Trough, the Late Permian coal seams are well developed and continuous (Scott and Hawkins, 1992). However, south of the Barcaldine Ridge, Late Permian coals are poorly developed, and typically occur as thin and discontinuous seams (evident in Figures 15 and 16 of product 1.1 for the Galilee subregion (Evans et al., 2014)). Consequently, the southern Galilee Basin is unlikely to be an area of future mining for Permian coal deposits.

In the northern, western and north-eastern parts of the basin (including the Lovelle Depression and the Koburra Trough, Figure 5) the main Late Permian coal-bearing unit is known as the Betts Creek beds. However, in the central-east and south of the basin, especially in areas south of the Barcaldine Ridge such as the Powell Depression, the stratigraphic equivalents of the Betts Creek beds are the coal-poor Peawaddy Formation and the Black Alley Shale, and the coal-bearing Colinlea Sandstone and Bandanna Formation (Figure 4, and discussed further below). These equivalents are also known from the south-western Bowen Basin, which is interpreted to link across the Springsure Shelf to the Galilee Basin (Smith, 2013). According to McKellar and Henderson (2013), the Betts Creek beds do not occur in areas of the Galilee Basin that overlie the Drummond Basin. In these areas, Bowen Basin equivalents are present.

The Betts Creek beds are a mixed sedimentary sequence comprising lithic sandstone, conglomerate, mudstone, carbonaceous shale, coal, pebbly mudstone, and minor tuff (GA and ASC, 2014). In some parts of the basin the Betts Creek beds form an almost continuous sequence of relatively uniform thickness and contain coal seams that dip regionally at low angles (generally less than 5°) towards the west and south-west (Smith, 2013). However, in other areas the thickness of the Betts Creek beds varies considerably (from 50 to 390 m) due to irregular basement topography at the time of deposition (Wells, 1989).

The Late Permian coals in the Galilee Basin are mostly low rank, sub-bituminous A type coals (based on the American Society for Testing and Materials (ASTM) classification, see Appendix A.1) although, in places, there are also some high volatile bituminous C type coals. Vitrinite reflectance of the Betts Creek beds coals usually ranges from 0.4 to 0.6% ($R_{v,\,max}$), and most are generally dull and relatively high in mineral matter (up to 25%). They are typically low sulfur and high ash content, and are regarded as non-coking coals, suitable for thermal uses such as generating steam for electrical power plants (Wells, 1989; Huleatt, 1991). The maceral compositions of individual coal seams are variable, for example, some plies are relatively high in inertinite, whereas others have elevated liptinite (I'Anson, 2013). In general, Galilee Basin coals are lower in vitrinite and duller than their Bowen Basin equivalents (APLNG, 2011).

Scott et al. (1995) suggested that a typical proximate coal analysis (air-dried) for the high volatile bituminous C type coals of Betts Creek beds that occur in the eastern Koburra Trough is about 46% fixed carbon, 30% volatile matter, 9% moisture and 15% ash.

#### 1.2.1.1.3 Colinlea Sandstone

The Late Permian Colinlea Sandstone is stratigraphically equivalent to the lower to middle part of the Betts Creek beds (Figure 4), but only occurs in the eastern and south-eastern parts of the Galilee Basin (Figure 3). The formation is continuous across the Nebine Ridge into the Bowen Basin (Figure 5), where the unit is more widely recognised (Scott et al., 1995).

The Colinlea Sandstone is predominantly a fine- to medium-grained quartz-rich sandstone, with thick to medium bedding in most of the sequence, apart from near the top where thinly bedded (laminated) sandstone and minor siltstone occurs (Wells, 1989). Near the base, the formation also contains pebbly quartz sandstone that, in places, grades to conglomerate. Distinct coal layers (mostly from about 0.5 to 6.0 m thick) occur in the Colinlea Sandstone of the Galilee Basin, particularly in the central-eastern part of the basin where much of the major coal mine development is expected in coming decades. For example, at the Alpha Coal Project coal seams C, D, E and F are all interpreted to belong to the Colinlea Sandstone, whereas the A and B seams are assigned to the overlying Bandanna Formation (Hancock Prospecting, 2010). Similar nomenclature for the A to F coal seams of the Colinlea Sandstone and Bandanna Formation is also followed at several other coal deposits in the Galilee Basin; for example, Kevin's Corner and China First (see Section 1.2.3 for further details).

The C seam in the Colinlea Sandstone is one of the main coal seams planned to be mined at Alpha, and it has an average cumulative thickness of 3 m. There are three distinct plies in the C seam (C1, C2, C3) consisting of dull to dull banded coal with claystone partings (Hancock Prospecting, 2010). Ash content ranges from less than 10% in some plies, but is more commonly greater than 20%.

The D coal seam in the Colinlea Sandstone at Alpha, which consists of three main plies, is mostly 6 to 7.5 m thick (including stone bands). This equates to about 4.5 m of clean coal (Hancock Prospecting, 2010). Stone bands in the D seam are usually thicker in western parts of the Alpha deposit, and thin towards the east.

In contrast to the central-eastern basin, in the south there is only minor coal seam development within the Colinlea Sandstone. The Colinlea Sandstone thins progressively westwards across the Springsure Shelf, and does not occur in the southern, western or northern parts of the basin (Figure 3).

#### 1.2.1.1.4 Bandanna Formation

As with the Colinlea Sandstone, the Bandanna Formation is well known from the Denison Trough in the Bowen Basin where it is mined at several locations. It also extends across the Nebine Ridge into the Galilee Basin where it is considered an equivalent of the upper part of the Betts Creek beds (Wells, 1989; Scott et al., 1995). The Bandanna Formation is stratigraphically separated from the Colinlea Sandstone by the coal-poor Peawaddy Formation and the Black Alley Shale (Figure 4). The Bandanna Formation has a wider areal distribution in the subsurface of the Galilee Basin than the underlying Colinlea Sandstone (Figure 3). For example, it is the only Permian coal-bearing formation known to occur in the Powell Depression (in south-west of the Galilee Basin), where it occurs at depths of over 1500 m and contains poorly developed coal seams (Scott et al., 1995).

Coals of the Bandanna Formation range from sub-bituminous to high volatile bituminous, and have vitrinite reflectance ($R_{v\,max}$) from 0.45 to 0.90% (I'Anson, 2013). This is similar to the rank of coals from the equivalent Betts Creek beds.

As for the other Late Permian coal-bearing formations, the extent of coal development in the Bandanna Formation is related to the overall thickness of the unit. The thickest coal seams occur in areas where the host formation is also relatively thick (Scott et al., 1995). In the central-eastern part of the Galilee Basin the Bandanna Formation contains two significant seams of Group IV coals, known as seams A and B. These are planned to be mined at several of the projects currently under development, including Alpha, Kevin's Corner, South Galilee and China First. Exploration and appraisal around the China First Coal Project has provided useful information on the coal seams of the Bandanna Formation (Waratah Coal, 2011). The A seam is typically one metre thick, with a maximum thickness of about two metres in the west of the project area. It is usually poorly developed and contains many carbonaceous shale and mudstone partings (Waratah Coal, 2011). In contrast, the B seam is the thickest coal seam recognised at this site and is commonly up to five metres thick. Banding is common throughout, especially in the upper three metres, and typically comprises tuffaceous carbonaceous mudstone (Waratah Coal, 2011).

In the South Galilee Coal Project the main coal resource is interpreted to occur within the D1 and D2 seams of the Bandanna Formation. The coal is high volatile, sub-bituminous and mostly dull, with abundant bright bands throughout (AMCI, 2012). There are three main coal plies in these seams which vary in thickness from 0.5 to 4.5 m. Ash content is variable but is commonly high (up to about 40% on air dried basis) (AMCI, 2012).

The Bandanna Formation is the uppermost Late Permian unit in the central-eastern and southern (e.g. Springsure Shelf) parts of the Galilee Basin. It is commonly sub-divided into two units, these being a lower shale-dominated unit and an overlying heterogeneous unit consisting of interbedded calcareous sandstone, sandy limestone, carbonaceous shale and coal (Wells, 1989). The Bandanna Formation is unconformably overlain by the Triassic Rewan Formation in much of the basin, and elsewhere by the Triassic Dunda beds and Clematis Sandstone (Figure 4). The coal seams have a relatively consistent thickness and disposition throughout most of the basin. The Late Permian Bandanna Formation coal measures dip about 3 to 5° west and no major fault offsets are known.

#### 1.2.1.1.5 Winton Formation

Within the Galilee subregion, large tonnage, low rank coal seams at relatively shallow depth (below surface) occur in the Winton Formation of the Eromanga Basin. These were deposited in the Late Cretaceous (Cenomanian stage), approximately 100 million years ago (Figure 4), and are thus considerably younger than the more extensive Permian coals. The Winton Formation rests unconformably on the older Mackunda Formation of the Eromanga Basin, with the unit's upper erosional surface overlain by Cenozoic sediments of the geological Lake Eyre Basin (Radke et al., 2012). These relationships are further described in product 1.1 for the Galilee subregion (Evans et al., 2014).

The Winton Formation has a maximum thickness of 1100 m (northern Patchawarra Trough in the south-west of the basin) and forms the uppermost part of the Rolling Downs Group (Figure 4). Throughout most of the Central Eromanga Depression formation thickness varies from 400 to 1000 m (Radke et al., 2012). The Winton Formation is a heterogeneous package of sedimentary rocks that include lithic and feldspathic sandstone, mudstone, siltstone, coal, minor conglomerate and layers of volcanic-derived detrital material (GA and ASC, 2014).

At a local-scale, significant resources of low rank coal (lignite to sub-bituminous coal) are known to occur. The coal varies from brown to black and is commonly interbedded with carbonaceous mudstone. There are two such large-scale resources within the Galilee subregion (the Inverness and Blackall deposits) as well as one to the south of the subregion boundary (South Blackall – not further considered in this report as it is not within the Galilee subregion). Considerable exploration effort is focused on similar deposits (in other nearby parts of the subregion) to assess their potential for future large-scale open-cut mining. These are further reported in Section 1.2.3.

The coals hosted in the Winton Formation commonly occur at less than 50 to 100 m below surface and form laterally extensive seams with low angle dips and minimal folding or faulting. Consequently, they may form large-tonnage deposits with low in situ strip ratios, with cumulative coal thicknesses of up to 10 to 12 m, in places (EER, 2014). These coals typically have raw ash content of 12 to 20% and generally low sulfur (Table 3). However, moisture content is typically much higher than in the older Permian coals of the Galilee Basin, and commonly exceeds 20%. These elevated moisture levels make the Cretaceous coals of the Galilee subregion less marketable as an export product.

Minor coal seams also occur in several other formations within the Eromanga Basin. These include the Mackunda Formation and the Birkhead Formation (Figure 4). Within the Galilee subregion, coals in these formations are not known to constitute economically viable resources.

**Table 3 Typical composition of sub-bituminous coal in the Winton Formation in the Galilee subregion**

| Location | Volatiles (%) | Fixed carbon (%) | Ash (%) | Sulfur (%) | Specific energy (MJ/kg) |
|---|---|---|---|---|---|
| Augathella 1968 | 29.7% | 32.9% | 12.0% | 0.4% | 15.5 to 18.2 |
| Blackall 1974 | 29.7% | 43.9% | 12.9% | 0.3% | 20.8 |

Source data: Resolve Coal (2012)
MJ/kg – megajoules/kilogram

### *1.2.1.2 Coal seam gas*

The main geological formations targeted for coal seam gas (CSG) resources in the Galilee Basin are the Aramac Coal Measures in the Joe Joe Group, and the Betts Creek beds (and their equivalent Late Permian coal-bearing strata). The Aramac Coal Measures are too deeply buried throughout the Galilee Basin to be economically viable for mining, although they have been a secondary CSG target for several companies in the western and central parts of the basin. Throughout most of the

Galilee Basin, the coals of the Betts Creek beds are regarded as the main CSG play, and these are being actively targeted by the main CSG explorers in the basin, such as AGL, Comet Ridge Limited (Comet Ridge) and Blue Energy Limited (Blue Energy) (see Section 1.2.3.2 for further details). The younger Cretaceous coals of the overlying Eromanga Basin are relatively thermally immature and are unlikely to have produced sufficient gas to enable economic CSG production. Only a few exploration wells have targeted these younger coals for CSG, and results have also generally been poor.

Previous studies of CSG resources and coal and gas properties in the Galilee Basin mostly relate to particular exploration tenements and wells. For example, Blue Energy's well completion report for the Ballyneety 1 exploration well mentions that coals intersected in their tenement typically have moderate gas content (2.5 to 3.5 $m^3$/t), low thermal maturity ($R_{v,\ max}$ of 0.45 to 0.60%) and are predominantly composed of inertinite, which makes for poor cleat systems (Blue Energy, 2010). Drilling in EPP 744, by Comet Ridge, has shown that the Aramac Coal Measures do not occur in their tenement (known as the Gunn Project, see Section 1.2.3.4 for further details), and that CSG potential is restricted to the Betts Creek beds. Results from seven exploration wells in the Gunn Project area by Comet Ridge have shown that there are five coal seams in the Betts Creek beds. These occur at depths of 700 to 1000 m below surface, and contain CSG with a mean gas content of over 4 $m^3$/t, and cumulative coal thickness varying from 16 to 24 m (Comet Ridge, 2013).

At a regional scale, I'Anson (2013) investigated coal and CSG properties from the main coal-bearing units in the Galilee Basin using data from more than 30 exploration wells drilled across the basin. This study focused on the basin's main depositional centre of the Koburra Trough. Significant findings from this work included:

- CSG within the Aramac Coal Measures and the Betts Creek beds is compositionally similar, with both formations having a consistent range of gas parameters.
- Average gas content generally ranges from less than 1 to about 6 $m^3$/t, and is mostly less than 5 $m^3$/t (Figure 6). This is generally less than that of similar age coals in the nearby Bowen Basin.
- The highest gas concentrations form a distinctive north-easterly trending zone across the Koburra Trough, although there is no clear relationship between gas concentration and depth.
- Galilee Basin coals are typically under-saturated with respect to gas, with typical raw gas saturation levels of around 30%, although there is a wide range (from about 5 to 75%).
- The composition of gas is typically greater than 90% methane (i.e. a 'dry' gas), with lesser amounts of carbon dioxide and ethane (Figure 7).
- Maximum gas holding capacity of coals (known as the Langmuir Volume) typically ranges from 10 to 30 $m^3$/t (dry ash-free basis).
- Gas isotopic compositions indicate that CSG in the Galilee Basin has a 'mixed' source signature, consistent with mixing between gas derived predominantly from biogenic processes and some remnant thermogenic processes. Biogenic gases were produced from reduction of carbon dioxide.

- The carbon dioxide component of the gas is mostly sourced from microbial activity, rather than from a magmatic or mantle-derived source.
- Although data points are limited, there is no clear evidence of spatial trends or patterns between the distribution of methane sources and the depth and rank of coal seams.
- There is a positive correlation between gas content and vitrinite reflectance in Galilee Basin coals. However, the present gas content in the basin is not solely due to coal properties – I'Anson (2013) attributed this relationship to the burial history of the Galilee Basin.

In contrast to the nearby Bowen and Surat basins, coal seams in the Galilee Basin are commonly interbedded or in direct hydraulic contact with highly porous and permeable sandstone aquifers (APLNG, 2011). Consequently, given the typically low to very low gas saturation levels of the coals, this may create problems for de-pressurising coal seams for CSG extraction. Significant volumes of co-produced water would need to be produced to reach the critical desorption point for successful gas production, which could prove very difficult with sandstone aquifers commonly present throughout the Galilee and overlying Eromanga basins (further discussed in Section 1.2.3.2).

There is currently no publicly available regional estimate of the total CSG resource (gas-in-place) in the Galilee Basin. Published resource estimates are available for only three petroleum exploration tenements, and these are limited to contingent (2C and 3C) and prospective resources. There are currently no proved, probable or possible gas reserves known in the basin (Table 4). There are two CSG pilot appraisal studies currently in the Galilee Basin, namely the AGL-operated Glenaras Project in the south-west of EPP 529, and Comet Ridge's Gunn Project about 100 km north-west of Aramac township in EPP 744. Publically available information provided by these companies indicates that they are seeking to continue their appraisal studies and eventually aim to develop estimates for commercial gas reserves, although final investment decisions on commercial production are not likely to occur for at least eight to ten years. A brief summary of these CSG operations is in Section 1.2.3.2.

**Table 4 Published contingent and prospective coal seam gas resources in the Galilee Basin**

| CSG project | Company | Exploration tenement | Contingent resources | Prospective resources | Comments |
|---|---|---|---|---|---|
| Glenaras | AGL and Galilee Energy Ltd | EPP 529 | 2C resource of 259 PJ and 3C resource of 1090 PJ | | Announced in June 2011 |
| Gunn | Comet Ridge | EPP 744 | 2C resource of 67 PJ and 3C resource of 1870 PJ | 597 PJ | Drilling and evaluation studies planned to define reserves |
| (unnamed) | Blue Energy | EPP 813 | 2C resource of 43 PJ and 3C resource of 544 PJ | 1,142 PJ | Contingent resource data from Blue Energy (2013) |

AGL is the operator of EPP 529, but the tenement is held in 50:50 joint venture partnership with Galilee Energy Ltd. Where prospective resources have been published as a range, the mid-point is quoted here. Resource numbers are current as of May 2014. 2C and 3C refer to different classes of contingent resources as defined in the Petroleum Resources Management System of the Society of Petroleum Engineers (SPE, 2011).

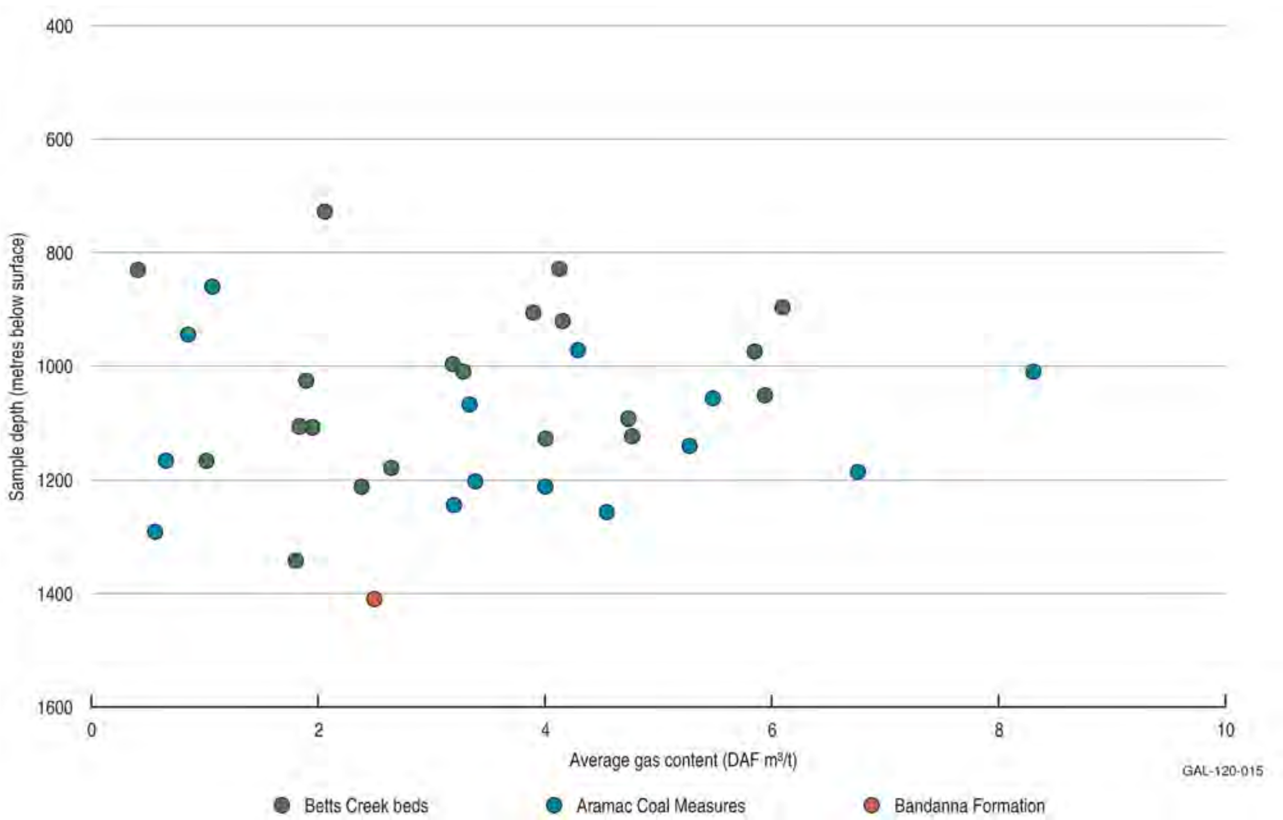



**Figure 6 Gas contents for the main coal seams of the Galilee Basin**

Source: modified from figure 4.15 in I'Anson (2013).
DAF – dry ash free

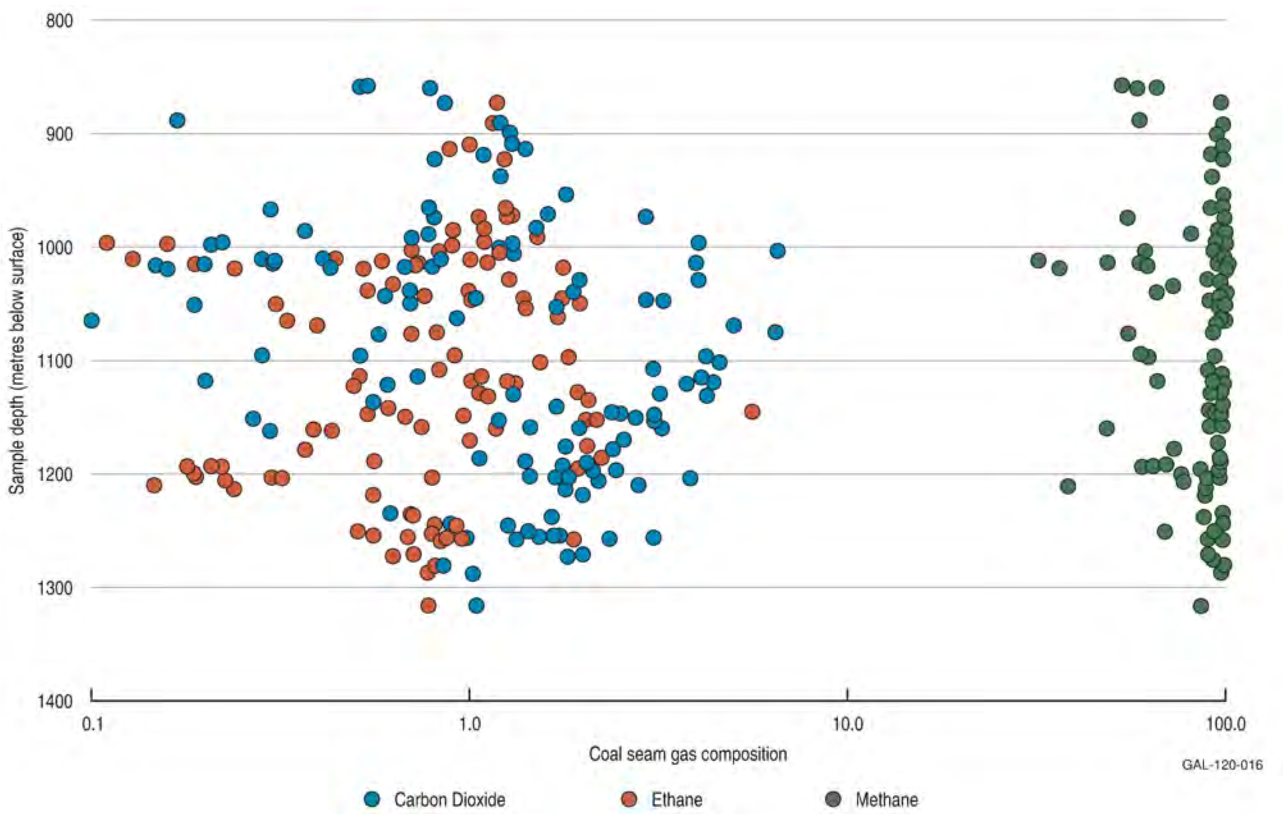



**Figure 7 Gas compositions from coal seams in the Galilee Basin**

Source: modified from figure 4.17, I'Anson (2013). Logarithmic scale used for x-axis

## *References*

AGL (2009) Well completion report Glenaras 6, Galilee Basin, Queensland. AGL Energy Limited. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D63981&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

AMCI (2012) South Galilee Coal Project environmental impact statement, Section 4, project description. American Millennium Corporation, Incorporated. Viewed 20 August 2014, <http://www.southgalilee.com.au/files/EIS/SGCP_EIS_04_Project_Description.pdf>.

APLNG (2011) Well completion report Twenty Mile Creek 1, ATP 668P, Queensland. Australia Pacific Liquefied Natural Gas. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D69913&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Blue Energy (2010) Well completion report Ballyneety 1, exploration core hole. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D64671&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Blue Energy (2013) Annual company report. Viewed 20 August 2014, <http://www.blueenergy.com.au/files/media/bul_ar_2013_web.pdf>.

Bradshaw BE, Spencer LK, Lahtinen AC, Khinder K, Ryand DJ, Colwell JB, Chirinos A and Bradshaw J (2009) Queensland Carbon Dioxide Geological Storage Atlas. Department of Employment, Economic Development and Innovation, Queensland Government.

Comet Ridge (2013) Comet Ridge's Galilee Basin extended production test project. Presentation to the Galilee Basin Coal and Energy Conference 2013. Viewed 20 August 2014, <http://www.cometridge.com.au/PDF/ASX26Nov_Galilee%20Basin%20Coal%20&%20Energy%20Conference%20Presentation.pdf>.

Durie RA, Hawkins PJ and Kukla GT (1992) The Galilee Basin coal measures: A potential methane resource? – A case study for a well planned, integrated exploration and R & D programme. In: Beamish BB and Gamson PD (eds) Symposium on coalbed methane research and developments in Australia, Townsville, 5, 81-89.

EER (2014) East Energy Resources. East Energy Resources Limited. Viewed 28 May 2014, <http://www.eastenergy.com.au/>.

EEA (1992) Well completion report Rodney Creek 1, Galilee Basin. Enron Exploration Australia. Viewed 20 August 2014,

<https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D28223&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Evans T, Tan KP, Magee J, Karim F, Sparrow A, Lewis S, Marshall S, Kellett J and Galinec V (2014) Context statement for the Galilee subregion. Product 1.1 from the Lake Eyre Basin Bioregional Assessment. Department of the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia, Australia.

GA and ASC (2014) Australian Stratigraphic Units Database. Geoscience Australia and Australian Stratigraphy Commission, Canberra. Viewed 8 May 2014, <http://www.ga.gov.au/products-services/data-applications/reference-databases/stratigraphic-units.html>.

GA and BREE (2014) Australian Energy Resource Assessment. 2nd ed. Geoscience Australia and Bureau of Resources and Energy Economics, Canberra. Viewed 4 August 2014, <http://www.ga.gov.au/corporate_data/79675/79675_AERA.pdf>.

Green PM, McKellar DC, Carmichael DC and Smith RJ (1991) Stratigraphic drilling report, GSQ Longreach 1-1B. Record 1991/20. Department of Resource Industries Queensland, Brisbane. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D40918&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Hancock Prospecting (2010) Alpha Coal Project. Environmental impact statement. Volume 2, section 4, geology. Viewed 20 August 2014, <http://www.gvkhancockcoal.com/documents/Publications/EIS/ACPEIS2010/Vol2/Section%2004%20Geology.pdf>.

Huleatt MB (1991) Handbook of Australian black coals: geology, resources, seam properties and product specifications. Bureau of Mineral Resources, Geology and Geophysics, Resource Report 7, Canberra. Viewed 20 August 2014, <http://www.ga.gov.au/corporate_data/22205/Res_Rep_07.pdf>.

I'Anson A (2013) Coal seam gas in the Galilee Basin, Queensland. Unpublished honours thesis. University of Sydney.

McKellar JL and Henderson RA (2013) Galilee Basin. In: Jell PA (ed.) Geology of Queensland. Geological Survey of Queensland, Brisbane, 196-203.

Mutton AJ (2003) Queensland coals. Physical and chemical properties. Colliery and company information (14th ed.) Department of Natural Resources and Mines, Brisbane. Viewed 20 August 2014, <http://mines.industry.qld.gov.au/assets/coal-pdf/qld_coals_2003.pdf>.

Radke BM, Kellett JR, Ransley TR and Bell JG (2012) Lexicon of the lithostratigraphic and hydrogeological units of the Great Artesian Basin and its Cenozoic cover. A technical report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment. CSIRO Water for a Healthy Country Flagship, Australia.

Resolve Coal (2012) Developing large scale coal exploration opportunities into a production focused mining company. Viewed 24 May 2014, <http://www.resolve-geo.com/website/Resolve%20Coal%20Tenements%20Presentation%2006_06_2012.pdf>

Scott SG, Beeston JW and Carr AF (1995) Galilee Basin. In: Ward CR (ed.) Geology of Australian coal basins. Geological Society of Australia, Sydney.

Scott SG and Hawkins PJ (1992) Coal geology of the northern Galilee Basin and its implications for coalseam methane investigations. In: Beamish BB and Gamson PD (eds) Symposium on coalbed methane research and developments in Australia, Townsville, 5, 85-102.

SPE (2011) Guidelines for application of the Petroleum Resources Management System. Society for Petroleum Engineers. Viewed 12 June 2014, <http://www.spe.org/industry/reserves.php>.

Smith RJ (2013) Coal. In: Jell PA (ed) Geology of Queensland. Geological Survey of Queensland, Brisbane, 689-702.

Waratah Coal (2011) Galilee Coal Project environmental impact statement. Volume 2, chapter 1, project description. Waratah Coal Pty Ltd. Viewed 20 August 2014, <http://cloud.snappages.com/7d02db4f8251a7a309f60c63fa1c911fdf2eb346/V2%20MINE_CHAP%2001_Project%20Description.pdf>.

Wells AT (1989) Stratigraphy and Permian coal measures of the Galilee Basin, Queensland. In: Harrington HJ (ed) Permian coals of Eastern Australia. Bureau of Mineral Resources Bulletin 231, Canberra.

### 1.2.2 Current activity and tenements

***Summary***

As of August 2014 there are no commercially operating coal mines or coal seam gas (CSG) production facilities within the geological Galilee Basin. Approximately 33% of the basin is covered by exploration permits for coal (EPCs), with 154 EPCs granted and eight EPC applications either wholly or partially located within the boundaries of the Galilee subregion. Most of these tenements occur within an arcuate zone that runs parallel to the basin margin, forming a contiguous block of tenements from north-west of Hughenden along the eastern basin boundary to the Springsure Shelf (south-east Galilee Basin). This zone of exploration coincides with areas in which the Late Permian coal-bearing strata are buried at relatively shallow (mineable) depths. There are 44 companies that hold title to EPCs (either directly or through subsidiary companies), with the main tenement holders being Waratah Coal Pty Ltd (Waratah Coal), Coalbank Ltd (Coalbank), Guildford Coal Ltd (Guildford Coal), Cockatoo Coal Ltd (Cockatoo Coal) and Fox Resources Ltd (Fox Resources).

In addition to the EPCs, there are 14 mining lease applications (MLAs) for proposed coal mining activities in the Galilee Basin, none of which have yet been granted. These MLAs cover the basin’s six most-advanced thermal coal development projects (Alpha, Kevin’s Corner, China First, Carmichael, South Galilee and China Stone)[1], as well as two others (Alpha North and Clyde Park). There are also six mineral development licences (MDLs) for coal projects in the Galilee subregion, and a further three currently under application. The main companies holding MLA and MDL tenements are Hancock Coal Pty Ltd (Hancock Coal), Waratah Coal, Adani Mining Ltd (Adani Mining), Macmines Austasia Pty Ltd (Macmines Austasia), and Alpha Coal Pty Ltd (Alpha Coal).

Over 54% of the Galilee Basin is covered by exploration permits for petroleum (EPPs), most of which have been awarded for coal seam gas (CSG) exploration. As of August 2014, there are 23 different EPPs that are either wholly or partially within the subregion, and these are mostly concentrated over the basin’s main depocentres such as the Koburra Trough, Aramac Trough and Lovelle Depression. A further 30 EPP applications have been lodged, although many of these will not be awarded (unsuccessful bids). There are 13 companies that hold title to petroleum exploration tenements in the Galilee Basin. The main CSG explorers are AGL Energy Ltd (AGL), Comet Ridge Ltd (Comet Ridge), Blue Energy Ltd (Blue Energy) and Galilee Energy Ltd (Galilee Energy).

Outcropping coal seams were first noted in the north-eastern geological Galilee Basin more than 100 years ago (Scott et al., 1995). However, due to its relative isolation and lack of existing infrastructure, there have never been any commercial coal mining operations or coal seam gas

[1] The China Stone Coal Project is covered by five MLAs, and the Carmichael Coal Project has three MLAs.

(CSG) production in the Galilee Basin. There is currently one petroleum production licence within the boundaries of the Galilee subregion (Petroleum Lease 65 held by Australian Gasfields Ltd for the Gilmore Gasfield), but this operation extracts gas from a conventional hydrocarbon reservoir within the Devonian aged Adavale Basin (which stratigraphically underlies the Galilee Basin). As Gilmore is not CSG-related, it is not discussed in this report.

In recent years, a number of significant new coal mining developments have been proposed on the eastern and north-eastern margins of the basin. A small-scale test pit at the Alpha Coal Project (Figure 8) successfully mined 125,000 tonnes of run-of-mine (ROM) coal in 2012, primarily to validate engineering design parameters and obtain bulk samples for analysis (Mulder, 2012). Further details of the proposed Alpha Coal Mine, and other advanced coal developments, are in section 1.2.3 of this report.

**Figure 8 Aerial view of test pit mine at Alpha Coal Project in the Galilee subregion**

Source: Mulder (2012). Image is from a public presentation and is used here with permission of GVK Resources

Coals of the Betts Creek beds were briefly mined on a trial basis by Mt Isa Mines (MIM) at Oxley Creek (near Hughenden) in the late 1940s (Carter, 1948). This followed earlier geological reconnaissance work that recognised outcropping coal seams in several creeks to the north of Hughenden, and were subsequently tested by core drilling. The trial mining operations consisted of a 30° inclined shaft sunk to a depth of about 75 m, at which point an approximately 2.5 m thick coal seam was intersected. An 80 m long drive was then dug to follow the coal seam, which was essentially flat-lying and of constant thickness along the entire length of the drive (Carter, 1948).

Coals recovered from the drive were mostly of dull appearance, with conchoidal fractures and some small seams of lustrous black coal (Carter, 1948). Analyses of coals sampled from the drive indicated relatively high ash content, and an average 1.8% sulfur. Further testing of the coal led MIM to consider the prospect uneconomic due to the inherently high ash content, and no further development work was undertaken. Carter (1948) reported that two of the surface coal dumps from the exploratory drive spontaneously combusted and burnt for almost three weeks.

### *1.2.2.1 Coal*

Relevant to the Galilee subregion, explanation of the various types of Queensland coal and CSG exploration and development tenements, and the relevant legislative acts governing them, are provided in Appendix A.2 of this report.

#### 1.2.2.1.1 Exploration permits for coal

As of 28 July 2014 there are 154 EPCs either wholly or partly covering the Galilee subregion (Figure 9), with most granted between 2008 and 2013 (inclusive). Several of these EPCs are in the process of being renewed. There are twelve pre-2008 tenements with the oldest dating to 2003 (EPC 771 held by Glencore Coal Queensland Pty Ltd (Glencore)). The size and shape of the coal exploration tenements vary considerably throughout the Galilee subregion. Most tenements occur in a contiguous arcuate band extending from the north of the basin (north-west of Hughenden) to the Springsure Shelf in the south-east (Figure 9). These EPCs are mainly within 50 to 100 km of the margins of the Galilee Basin and coincide with the zone in which the coal-bearing Late Permian rocks of the Betts Creek beds (and equivalent formations) are at mineable depth.

There is also a significant concentration of coal exploration tenements extending southwards from around Blackall in the southern part of the Galilee subregion (Figure 9). Most of these tenements are held by companies that are actively exploring for Eromanga Basin coals. These typically occur in the Cretaceous Winton Formation (Section 1.2.1.1).

In addition to the existing coal exploration tenements, at 28 July 2014 there are 8 EPC applications under assessment by the Queensland Government. There are seven applicants, of which two already hold title to tenements in the Galilee Basin (these being Coal Face Resources Pty Ltd and Endocoal Ltd). Decisions on these applications are pending.

Existing coal exploration tenements and pending applications cover about 33% of the Galilee Basin. The most current tenement data are publicly available via the interactive resource and tenure maps (IRTM) system maintained by the Queensland Department of Natural Resources and Mines (Queensland DNRM, 2014a). For the purposes of this report, tenement data were accessed from the Queensland Government on 28 July 2014.

There are 44 companies listed as the principal tenement holder of the 154 EPCs in the Galilee subregion. Of these, 15 companies hold more than three tenements. Companies with the most extensive acreage holdings are Waratah Coal (15 EPCs), Coalbank (14 EPCs through its subsidiary company Tambo Coal and Gas Pty Ltd), Guildford Coal (14 EPCs through tenements held by itself and through its 100% owned subsidiary, FTB (Qld) Pty Ltd), Fox Resources (12 EPCs), and Cockatoo Coal (11 EPCs acquired through acquisition of Blackwood Corporation in early 2014, including Blackwood's wholly owned subsidiary Matilda Coal Pty Ltd).

Further information about these companies and some of their activities is provided in the coal exploration section of this report (Section 1.2.3.1).

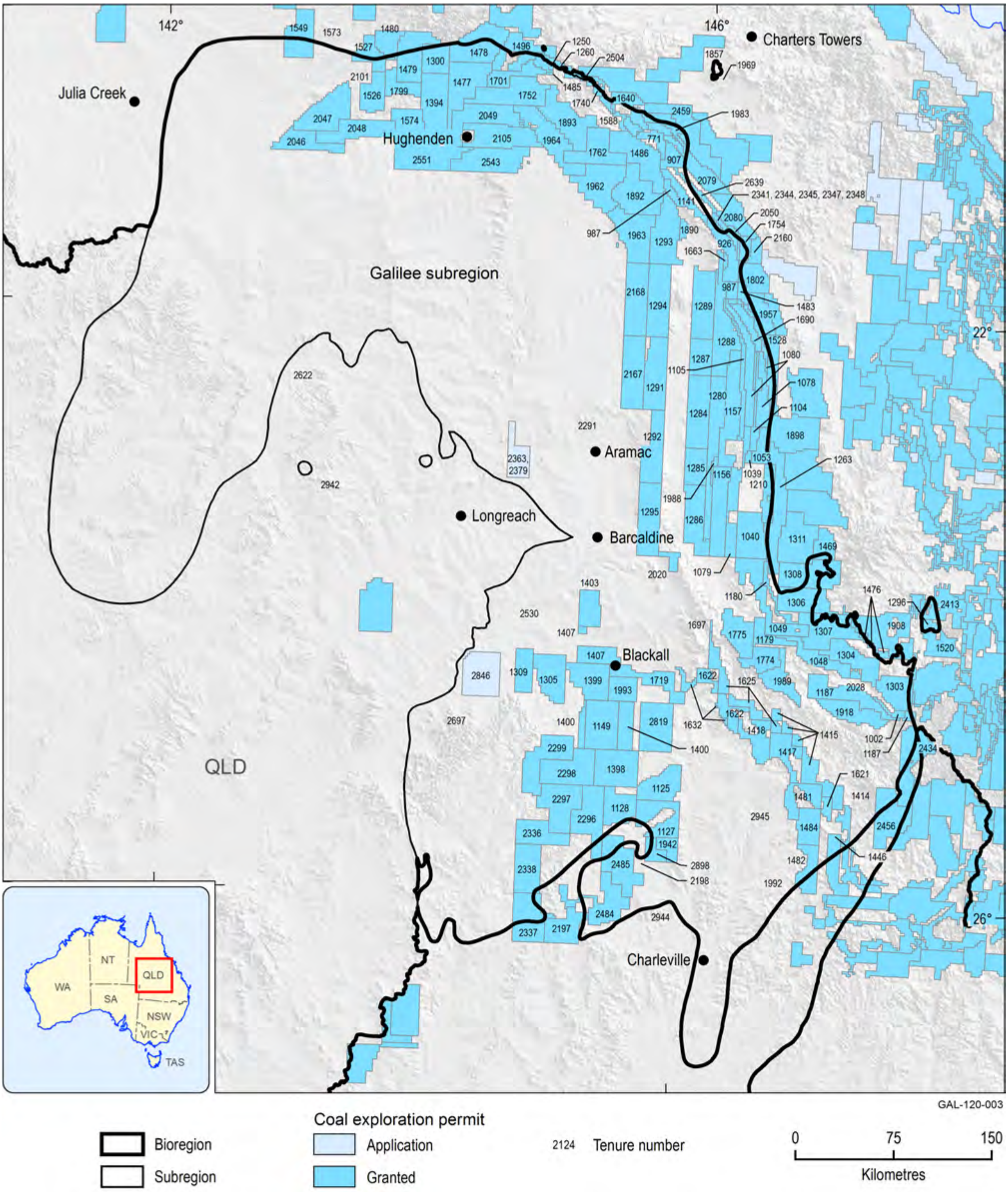



**Figure 9 Exploration permits for coal in and around the Galilee subregion, July 2014**

Source data: Queensland DNRM (2014a). Only tenements that are wholly or partly within the Galilee subregion are labelled.

### 1.2.2.1.2 Mining leases and mineral development licenses

As of 28 July 2014 there are 14 mining leases (MLs) under application in the Galilee subregion that relate to proposed coal mine developments (Figure 10 and Table 5). Mining leases for coal have yet to be granted for these applications. In addition, there are six mineral development licences (MDLs) for coal projects, and a further three MDLs that are under application (Table 6). Refer to Appendix A2 of this report for information about these different types of mining development tenements.

**Table 5 Mining lease applications for proposed coal mines in Galilee Basin, July 2014**

| Mining lease | Project name | Date lodged | Principal tenure holder | Area (ha) |
|---|---|---|---|---|
| 10369 | Clyde Park Coal Project | 18 December 2012 | Clyde Park Coal Pty Ltd | 6,741 |
| 70425 | Kevin's Corner | 18 December 2009 | Hancock Galilee Pty Ltd (Hancock Galilee) | 37,380 |
| 70426 | Alpha | 18 December 2009 | Hancock Coal | 32,423 |
| 70441 | Carmichael | 8 November 2010 | Adani Mining | 26,016 |
| 70453 | South Galilee Coal Project | 24 May 2011 | Alpha Coal | 30,822 |
| 70454 | China First Coal Project | 30 May 2011 | Waratah Coal | 75,658 |
| 70489 | North Alpha | 30 November 2012 | Waratah Coal | 104,892 |
| 70505 | Carmichael East | 9 July 2013 | Adani Mining | 16,960 |
| 70506 | Carmichael North | 9 July 2013 | Adani Mining | 1,588 |
| 70514 | Project China Stone (PCS) East | 3 February 2014 | Macmines Austasia | 4,873 |
| 70515 | Project China Stone (PCS) South | 3 February 2014 | Macmines Austasia | 4,703 |
| 70516 | Project China Stone (PCS) West | 3 February 2014 | Macmines Austasia | 4,699 |
| 70517 | Project China Stone (PCS) Central | 3 February 2014 | Macmines Austasia | 3,180 |
| 70518 | Project China Stone (PCS) North | 3 February 2014 | Macmines Austasia | 2,609 |

Source data: Queensland DNRM (2014b). Project names are as listed in the source dataset.

**Table 6 Mineral development licences for coal projects in Galilee Basin, July 2014**

| Mineral development licence | Project name | Date lodged | Date granted | Principal tenure holder | Area (ha) |
|---|---|---|---|---|---|
| 285 | Alpha West | 1 April 1998 | 11 March 2008 | Hancock Coal | 33,706 |
| 333 | Kevin's Corner | 15 June 2001 | 17 September 2007 | Hancock Galilee | 31,507 |
| 356 | Pentland | 22 April 2004 | 19 September 2006 | Glencore | 5,302 |
| 361 | West Pentland | 14 April 2005 | 20 January 2012 | Linc Energy Ltd | 2,711 |
| 455 | Galilee South | 23 May 2011 | 16 January 2012 | Waratah Coal | 7,592 |
| 464 | Blackall | 25 November 2011 | 20 July 2014 | East Energy Resources Limited | 37,675 |
| 481 | Pocky Creek | 17 September 2012 | | Waratah Coal | 3,792 |
| 485 | Laglan | 29 October 2012 | | Waratah Coal | 101,108 |
| 516 | China Stone | 4 October 2013 | | Macmines Austasia | 2,040 |

Source data: Queensland DNRM (2014c). Project names are mostly as listed in the source dataset. Mineral development licences in this table that do not have a granted date signify that the tenement is an application

The 14 mining lease applications cover the six most-advanced coal mining development projects proposed for the Galilee Basin (in terms of the statutory government approvals process); these being the Alpha, Kevin's Corner, China First, Carmichael, South Galilee, and China Stone coal projects. In some cases, there are multiple mining lease applications that cover the same project area, for example China Stone and Carmichael (Table 5). Additional to these six advanced projects, mining lease applications also exist for two less advanced (that is, not yet at environmental impact statement stage) development projects, namely North Alpha and Clyde Park. Further details about each of these proposed developments are in Section 1.2.3.1 of this report.

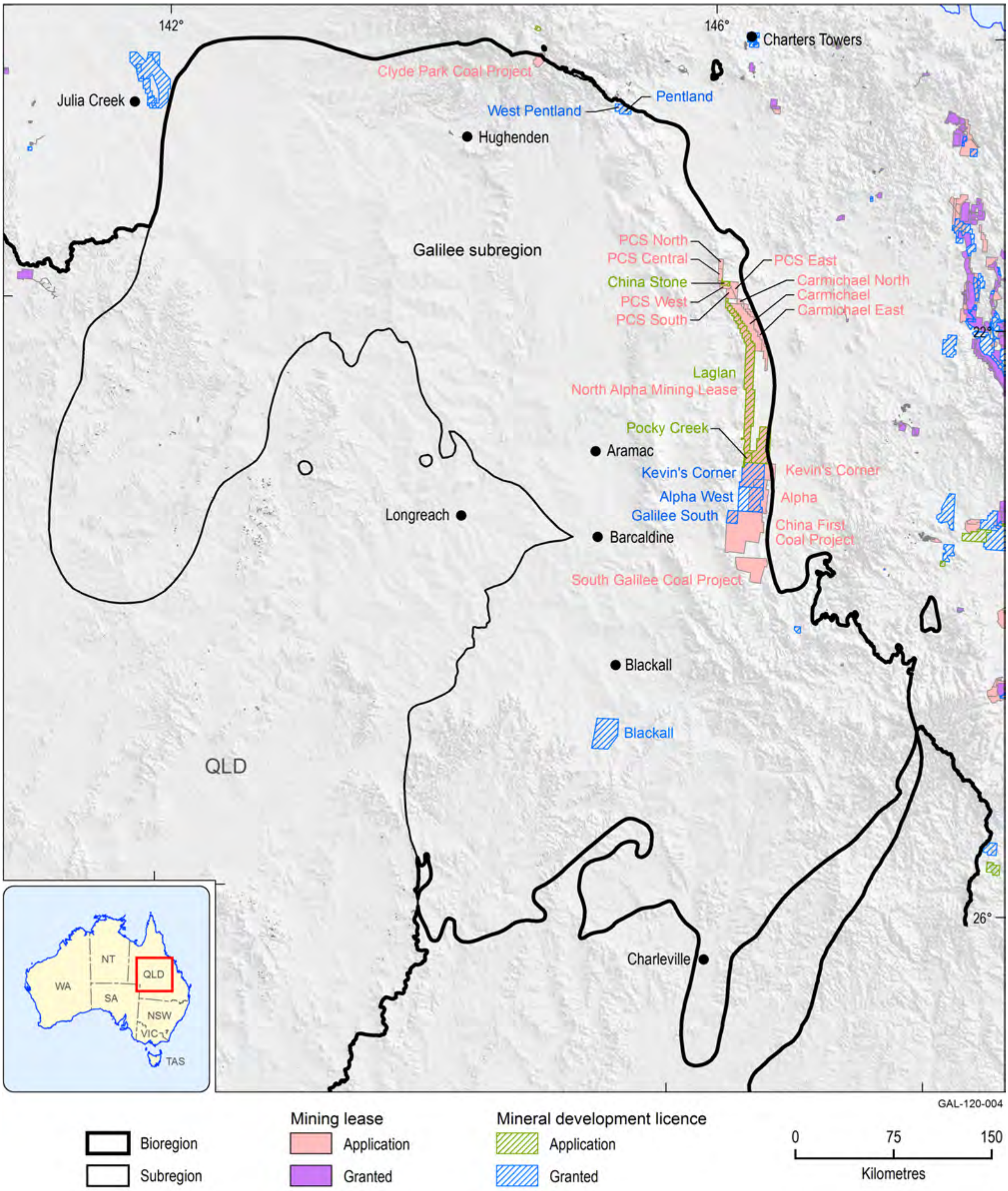



**Figure 10 Mining leases and mineral development licences in the Galilee subregion, July 2014**

Source data: Queensland DNRM (2014b and 2014c). Only mining leases and mineral development licences related to coal projects in the Galilee subregion are labelled.

### *1.2.2.2 Coal seam gas*

#### 1.2.2.2.1 Exploration permits for petroleum

As of 28 July 2014 there are 23 granted exploration permits for petroleum (EPPs) either wholly or partly within the Galilee subregion (Figure 11). These tenements are mainly concentrated around the deepest sedimentary depocentres of the Galilee Basin, namely the Lovelle Depression in the west, the Koburra Trough in the east, and in an area north of the Barcaldine Ridge around Aramac. The EPPs are held by 13 listed companies. Note that due to the different terminology used in the Queensland *Petroleum Act 1923*, petroleum tenements issued prior to the current legislation (the *Petroleum and Gas (Production and Safety) Act 2004)* are referred to as an authority to prospect for petroleum, ATP-P (rather than exploration permits for petroleum). The current terminology (EPP) is used throughout this report for consistency.

Additional to the granted EPPs there are a further 30 EPP applications either wholly or partly in the Galilee Basin (Figure 11). These were submitted in response to 'calls for tender' for these tenements, previously made by the Queensland Government. The most recent applications were lodged by Queensland Energy Resources Ltd (QER) in November 2013 (EPP applications 1179, 1180 and 1181). Of the existing 30 applications, 23 have previously been declared as unsuccessful applications. Only four applications are currently recognised as preferred tenderers by the Queensland Government. These are EPP 1093 (Seymour Energy Pty Ltd), EPP 1095 (Surat Gas Pty Ltd), and EPP 1141 and 1148 (Australian Shale Oil Resources Company Ltd). The timing of the award of these tenements is unknown.

As EPPs are awarded for both conventional and unconventional hydrocarbon exploration (conventional petroleum, CSG, shale gas, and tight gas), it is possible that not all of the EPPs in Figure 11 may be targeting CSG plays. To identify the main companies and tenements focused on CSG exploration, the listed tenement holders were cross-checked with publically available information on CSG wells drilled in the Galilee Basin. These data are available from the Queensland IRTM online system (Queensland DNRM, 2014d). As a result of this evaluation and the number of exploration wells drilled, the main companies involved in CSG exploration in the Galilee Basin in recent years are:

- AGL
- Comet Ridge
- Blue Energy
- Galilee Energy
- Origin Energy Ltd
- Exoma Energy Ltd
- Queensland Energy Resources Ltd.

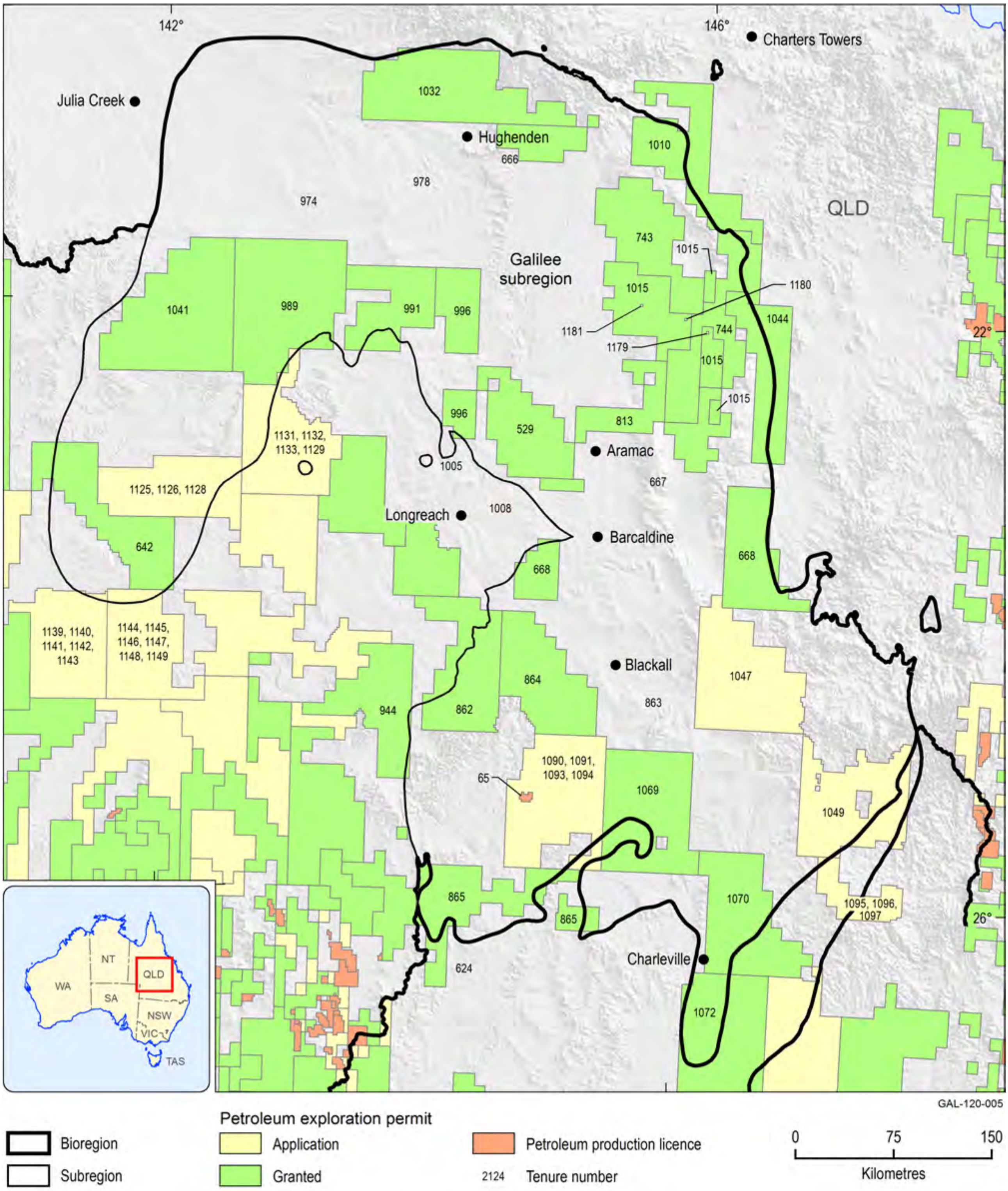



**Figure 11 Exploration permits for petroleum and production licences in and around the Galilee subregion, July 2014**

Source data: Queensland DNRM (2014d)

## *References*


Carter SR (1948) Third report on coal exploration. First phase, diamond drilling, Oxley Creek – Torrens Creek area. Second phase, shaft sinking and driving, Oxley Creek – Dingo Creek area, Hughenden district, Queensland. Unpublished report held by Geological Survey of Queensland as CR 127. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D127&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Mulder P (2012) GVK Coal Projects. Presentation to the Galilee Basin Coal and Energy Conference, November 2012. Viewed 7 October 2014, <http://www.slideshare.net/informaoz/paul-mulder>.

Queensland DNRM (2014a) Current exploration permits coal (EPC). Digital dataset, current as of 28 July 2014. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 28 July 2014, <http://www.mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>.

Queensland DNRM (2014b) Mining leases. Digital dataset, current as of 28 July 2014. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 28 July 2014, <http://www.mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>.

Queensland DNRM (2014c) Mineral development licences. Digital dataset, current as of 28 July 2014. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 28 July 2014, <http://www.mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>.

Queensland DNRM (2014d) Current exploration permits petroleum (EPP). Digital dataset, current as of 28 July 2014. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 28 July 2014, <http://www.mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>.

Scott SG, Beeston JW, and Carr AF (1995) Galilee Basin. In: Ward CR (ed.) Geology of Australian coal basins. Geological Society of Australia, Sydney.

## 1.2.3 Proposals and exploration


### *Summary*

Development proposals are well-advanced for six large scale thermal coal mining operations, spread-out across a 200 km long north-trending corridor close to the eastern margin of the geological Galilee Basin. Most of these will involve a staged combination of multiple open-cut pits and underground longwall mines and, at full production, each project expects to extract between 15 and 60 Mt of raw coal per year. Four proposals have recently received conditional approval to proceed to the construction phase following Queensland and Australian Government assessment of the environmental impact statement (EIS) documentation. These are the GVK Hancock Coal operations at the Alpha and Kevin's Corner deposits, Waratah Coal Pty Ltd's (Waratah Coal's) China First project near Alpha township, and Adani Mining Pty Ltd's (Adani Mining's) Carmichael development in the north-east of the basin, which has the potential to become Australia's largest coal mine when fully operational. Additionally, the proposed open-cut and underground developments at South Galilee and China Stone are currently within the EIS approvals system.

A further eight proposed large coal mining developments, most with current mining lease applications or mineral development licences, occur in the eastern and northern Galilee subregion. These are the Alpha North, Clyde Park, Alpha West, Carmichael East, West Pentland, Pentland, Degulla and Hyde Park coal projects. In addition, East Energy Resources Limited's (EER's) Blackall deposit in the southern part of the Galilee subregion is the most advanced proposal for mining of lower rank coals hosted in the Cretaceous Winton Formation (Eromanga Basin). All of these proposals are at various stages of planning, such as initial concept design and pre-feasibility studies. The companies seeking to develop these sites are yet to submit an EIS, although information available for several projects suggests that at least some may seek statutory approval in the future.

Future coal exploration activity is expected to continue in the most prospective regions of the Galilee Basin, although at reduced levels from those experienced between 2008 and 2013. However, several companies have recently identified upside exploration potential in the basin with new resource announcements. These include an approximate 1100 Mt thermal coal resource at Hughenden (Guildford Coal Limited (Guildford Coal)), a 364 Mt inferred resource at Yellow Jacket (Cuesta Coal Limited (Cuesta)), and a 322 Mt maiden inferred resource at South Pentland (Cockatoo Coal Limited (Cockatoo Coal)). Significant coal discoveries have also been made in the Eromanga Basin within the Galilee subregion, including the 1300 Mt inferred resource at Coalbank Limited's (Coalbank's) Inverness deposit.

The development of a coal seam gas (CSG) production industry in the Galilee Basin is significantly less-advanced than for coal. Evaluation and testing of initial exploration wells has thus far led to three separate contingent (2C and 3C) CSG resource announcements. However, CSG reserves have yet to be defined. The most advanced project is operated by an AGL Energy Ltd (AGL) – Galilee Energy Ltd (Galilee Energy) joint venture, and is known as the Galilee Gas Project. Focused on the Glenaras site, a 259 petajoule (PJ) 2C gas resource has been defined.

At Glenaras, a five-well pilot has been operating since 2009, and successful gas flows have proven that CSG production is technically feasible in the basin. Other CSG production testing has been undertaken at the Gunn Project site to the east of Glenaras. The petroleum exploration tenements that include the Gunn site are operated by Comet Ridge Limited (Comet Ridge), which has identified a 2C gas resource of 67 PJ and 3C resource of 1870 PJ. Both the Glenaras and Gunn CSG operations require a significant amount of further testing and appraisal before investment decisions on the economic viability of establishing full-scale production can be confidently made. Current indications from industry representatives suggest that any future commercial CSG operations in the Galilee Basin are likely to be at least a decade (or more) away.

### *1.2.3.1 Coal*

The geological Galilee Basin contains extensive world-class resources of predominantly high-volatile, low sulfur thermal coal. Development plans are well-advanced for six major black coal deposits on the eastern margin of the basin (Figure 12). Because of their large size these operations are projected to achieve significant economies of scale.

Although the Galilee Basin is currently a major focus of coal exploration and possible future development, most of this activity has taken place post-2008. In 2003, Mutton reviewed the physical and chemical properties of all known Queensland coal deposits. As part of this review only three coal deposits were described from the Galilee Basin, these being Alpha, Kevin's Corner and Pentland (all first identified in the 1970s). This indicates that, a little over ten years ago, the overall size of the coal resources in the Galilee Basin was poorly understood. The total resource inventory quoted by Mutton (2003) for the Galilee Basin amounted to only 1678 Mt of raw coal available for open-cut mining (measured and indicated resources), and 530 Mt of raw coal available for underground mining.

In a little over a decade the estimated coal resources of the Galilee Basin (i.e. the 23,248 Mt of identified resources quoted in GA and BREE, 2014) have grown over ten times the tonnage quoted by Mutton (2003). This large increase in relatively short time reflects the boom in greenfield exploration that has occurred since the mid-2000s (closely aligned to significant increases in global coal prices), and the successful delineation of at least seven thermal coal deposits containing in excess of one billion tonnes of identified resources (reported in accordance with the industry standard guidelines of the Joint Ore Reserves Committee (JORC) Code).

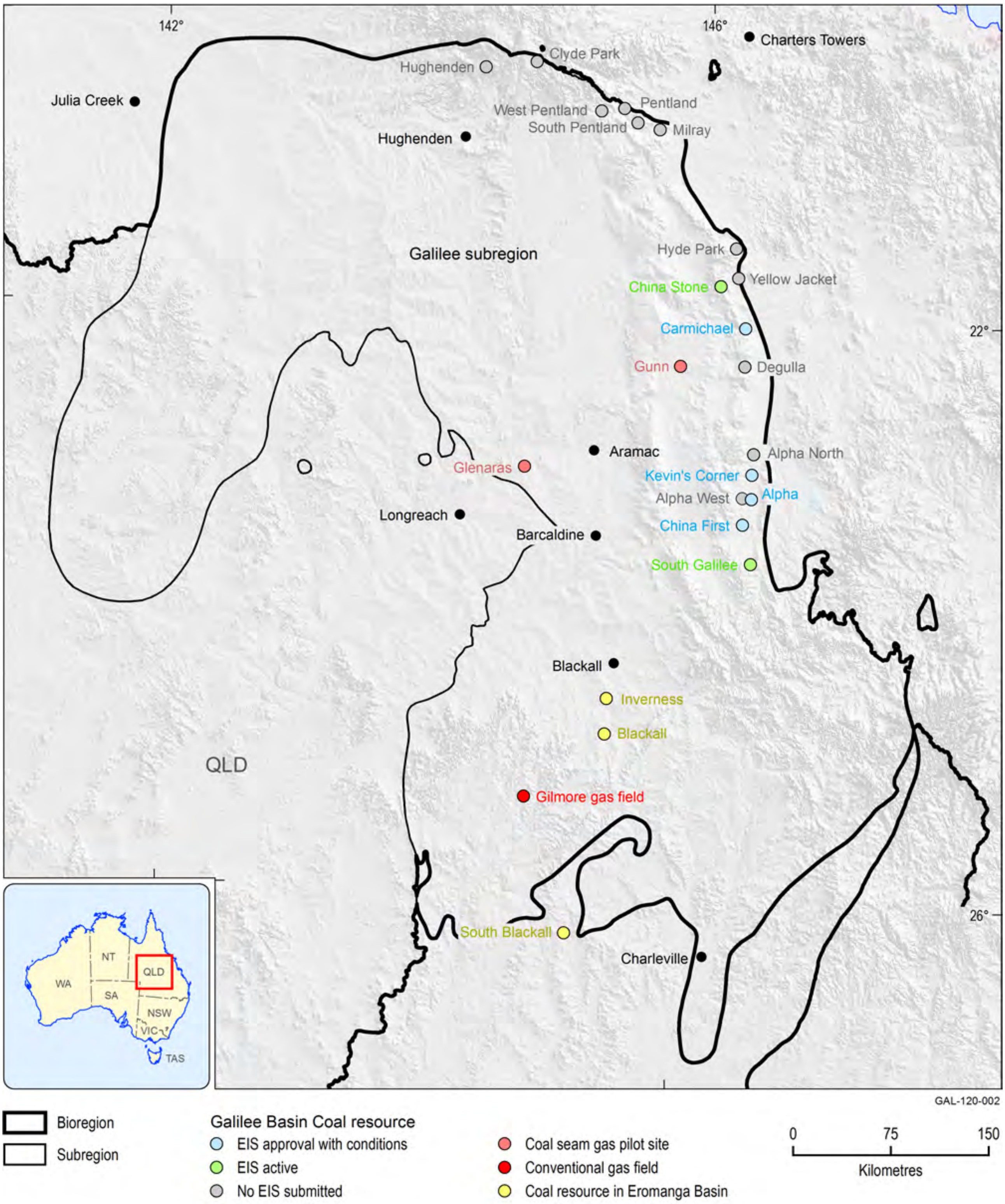



**Figure 12 Status of coal and coal seam gas resource projects in the Galilee subregion**

EIS – environmental impact statement

The six most advanced coal development projects in the Galilee Basin are covered by various mineral development licences (MDLs) and mining lease applications (MLAs) (as outlined in Section 1.2.2, with details of tenement types in Appendix A2 of this report). Environmental impact statements (EIS) have been submitted and assessed for most of these projects (Figure 12). The EIS assessment was required as these proposed coal developments have the potential to cause significant environmental impacts. Thus, they have been declared 'coordinated projects' by the Queensland Coordinator-General under the *State Development and Public Works Organisation Act 1971*. Other Queensland legislative acts that may relate to assessing environmental impacts of development projects include the *Environmental Protection Act 1994*, and the *Sustainable Planning Act 2009*. Further information about the process of assessing coordinated projects in Queensland is available from Queensland Government (DSDIP, 2014a).

There are four coal mining development projects in the Galilee subregion that have recently been granted approval by the Queensland Government (subject to various conditions) to begin the initial stages of mining construction and development prior to starting commercial operations. Listed in order of approval (Figure 12), these coal projects are:

- Alpha
- Kevin's Corner
- China First
- Carmichael.

There are two other proposed coal development projects that are currently within the EIS approvals system and pending assessment outcomes:

- China Stone
- South Galilee.

In addition to the statutory requirements under Queensland legislation, these proposed developments have also been declared 'controlled actions' under relevant Australian Government law (specifically, the *Environment Protection and Biodiversity Conservation Act 1999*). This requires that they are also assessed for their potential impacts on Matters of National Environmental Significance (MNES). As of August 2014, the Alpha, Kevin's Corner, China First and Carmichael coal projects have all been approved with conditions by the Australian Government under the EPBC Act. However, to permit mine construction operations to commence, these developments also require the granting of a mining lease from the Queensland Government (under the *Mineral Resources Act 1989*), as well as the award of an environmental authority (EA) under the Queensland *Environmental Protection Act 1994*. The EA is required as the coal mining and associated activities are regarded as environmentally relevant activities (ERA). The EA administering authority for resource-related activities in Queensland is the Department of Environmental and Heritage Protection (EHP).

A summary of the proposed developments and resource characteristics at each of the operations at EIS stage (as listed above) is included within this section, mostly obtained from relevant information provided by development companies in their EIS and related documentation. This provides a general overview of the developments that are likely to be carried out at each of these sites in the future (at least according to current plans).

As well as the six most-advanced coal mining developments, there are another two MLAs for coal projects in the Galilee Basin that are not yet at EIS stage:

- Alpha North
- Clyde Park.

The timing of any future EIS assessment of these two projects is currently unknown. However, brief summaries are also presented in this section for these two resource projects to provide an indication of the style of development that may occur in the future. These details have mostly been taken from publically available information from company websites, and various reports and statements presented to the Australian Securities Exchange (ASX).

There are several coal projects in the Galilee Basin covered by MDLs (but not yet MLAs), and these can be considered as potential sites for future coal mining development. However, these are at a less-advanced state than MLA projects, and decisions to proceed with each of these will depend upon the outcomes of further resource assessment and preliminary mine feasibility studies. The potential coal project developments in the Galilee Basin with MDLs, but which are not yet at the stage of submitting a MLAs are:

- Alpha West
- Carmichael East
- Pentland
- West Pentland
- Blackall.

Brief summaries of the coal resources and potential developments for the relevant MDL projects, as well as other potential developments at the Degulla and Hyde Park coal projects (though not yet at MDL or MLA stage), are also provided in this report section. The details of these potential developments are mostly taken from publically available information from company websites, and reports and statements presented to the ASX. The likelihood and timing of possible EIS submission is not currently known for these projects.

**Note on mining and coal seam gas related water**

The information provided in this report section about each proposed mining or CSG development focuses mainly on the details relating to their coal and gas resources and relevant features of planned mining development and associated infrastructure. The details of water management and monitoring associated with these developments, such as mine dewatering volumes or expected annual water usage rates, are not included within this report. Instead, this information is reported in later products for the Galilee subregion.

#### 1.2.3.1.1 Alpha Coal Project

The Alpha Coal Project is perhaps the best known and most extensively delineated coal deposit in the Galilee Basin. The project is being developed in partnership between GVK Coal Developers Pty Ltd (GVK) (79% ownership), a major Indian-based infrastructure company, and Hancock Prospecting Pty Ltd (Hancock Prospecting) (21% ownership) through its wholly owned subsidiary, Hancock Coal Pty Ltd (Hancock Coal). The project area lies about 50 km north-north-west of the township of Alpha, and 130 km south-west of Clermont in central Queensland (Figure 12). It occurs near the central-eastern boundary of the Galilee Basin close to several other large scale coal resources such as Kevin's Corner, Alpha West and China First. Development will occur in the area of mining lease application (MLA) 70426, which overlies exploration permit for coal (EPC) 1210, mineral development licence (MDL) 285 and part of MDL 333.

Stratigraphically, six coal seams have been delineated in the Alpha mine host sequence, namely the A (uppermost), B, C, D, E and F (lowermost) seams (Figure 13). These seams are in the Late Permian Bandanna Formation (seams A and B), and the underlying Colinlea Sandstone (seams C to F). The seams dip consistently at a low angle westwards (mostly <1°), and thickness varies in multiple directions from less than one metre (e.g. sub-crop of seam C) to about eight metres thick (seam B). There is minimal folding or faulting of the coal-bearing strata in the project area, such that most coal seams are geologically consistent throughout the mining lease. For example, Hancock Prospecting (2010) indicated that coal seams in the project area can be correlated with similar seams intersected in drillholes over 100 km away to the west.

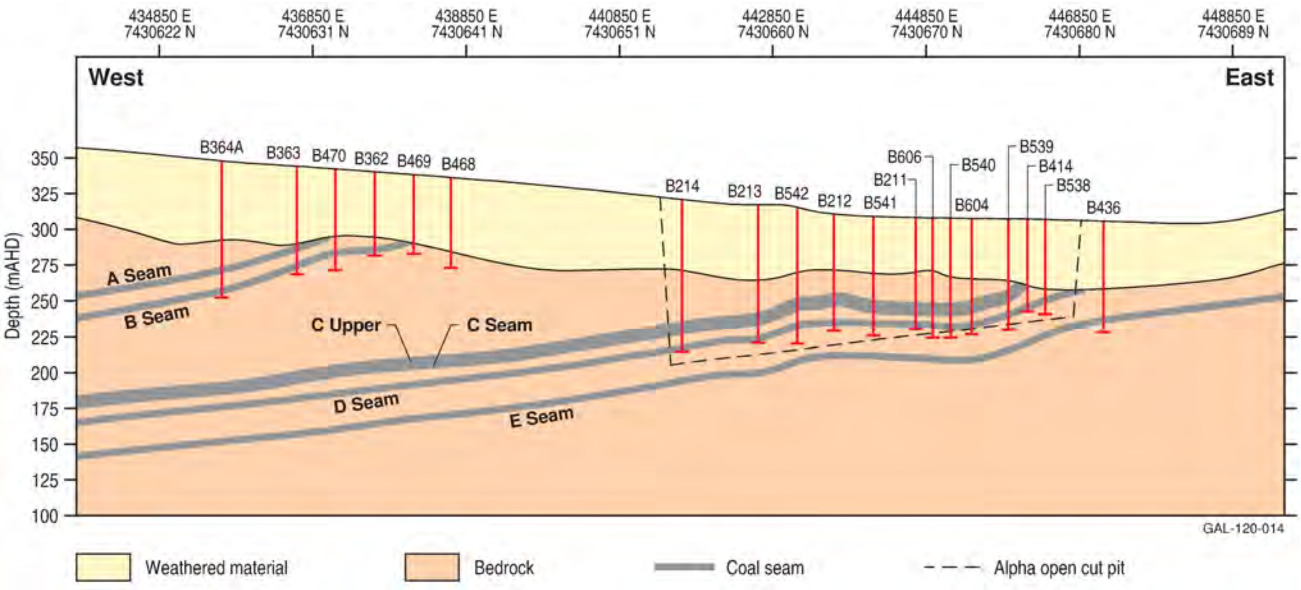



**Figure 13 Geological cross-section (west to east) through central part of Alpha Coal Project in the Galilee subregion**

Source: modified from Hancock Prospecting (2010). The lowest coal seam (seam F) is not shown. Labelled coal exploration bores shown as red lines.

In general, the coal resources at Alpha are high volatile (30 to 35%) bituminous with variable ash content, typically 8 to 35%, and low sulfur. The coal has been shown to have a high propensity for spontaneous combustion, requiring significant attention during mine operations to ensure effective monitoring and management (Hancock Prospecting, 2010).

The Permian coal-bearing strata in the area of MLA 70426 are overlain by a variable thickness of geologically younger Cenozoic sediments, including sand, fine gravel and minor clay (Hancock Prospecting, 2010). These range from over 60 m thick in some areas to less than 20 m thick in the north of the lease. In the far western part of the mining lease there is remnant sub-crop of Triassic Rewan Formation siltstone and sandstone, although this does not occur over the proposed mining area.

Proposed development at the Alpha Coal Project has been designed around six large scale open-cut pits. These will trend northwards as development progresses, and eventually cover a continuous strike-length of about 24 km across the centre of MLA 70426. Mining will initially target the C and D seams of the Colinlea Sandstone, which have a combined measured plus indicated coal resource of nearly 1.8 billion tonnes (Gt), reported in accordance with the JORC Code (Table 7). These seams are the only ones at Alpha Coal Project currently considered economically viable for extraction via open-cut mining. Seams A and B in the Bandanna Formation sequence have a restricted spatial distribution and only minor tonnages of these occur within the far western part of the project area lease (Figure 13). A nominal tonnage from the B seam contributes to the overall coal resource at Alpha, as shown in Table 6 (Hancock Prospecting, 2010).

Annual production rates are expected to be 30 million tonnes (Mt) of thermal black coal for delivery to export markets (Hancock Prospecting, 2011). This will result from mining 38 Mt of run of mine (ROM) coal every year. The expected life-of-mine is 30 years, although delineation of additional resources in the future could extend mining life. This may include future development of underground mining operations to target deeper seams that are presently considered uneconomic for open-cut.

**Table 7 Alpha Coal Project resources in the Galilee subregion**

| JORC Code resource category | B seam tonnage (Mt) | C seam tonnage (Mt) | D seam tonnage (Mt) | Total resource (Mt) |
|---|---|---|---|---|
| Measured | | 240 | 581 | 821 |
| Indicated | | 250 | 450 | 700 |
| Inferred | 40 | 70 | 190 | 300 |
| Total | 40 | 560 | 1221 | 1821 |

Source: Hancock Prospecting (2010). Resources current as of July 2010. The A seam is not part of the Alpha coal resource as it is not significantly developed within the mining area, occurring inconsistently in the far west of MLA 70426.
JORC – Joint Ore Reserves Committee

Mining operations at Alpha Coal Project will require six conventional draglines and truck and shovel equipment to remove and haul the overburden from the pit area (Hancock Prospecting, 2011). Draglines will also be used to remove interburden where required. Two in-pit crushing and conveying (IPCC) systems will be used to haul overburden to the stockpile. The overburden will initially be stockpiled in designated out-of-pit areas, before it is later used to backfill the open-cut pits. Coal will be loaded with either front-end loader or excavator, with a fleet of over 40 bottom-dump coal trucks to haul coal to the ROM facilities. All mined coal will pass through the ROM, where it will be initially sized (reduced) before further processing occurs at the coal handling and preparation plant (CHPP).

To support mining and processing there will be significant investment in new infrastructure within the area of the mine footprint, expected to affect about 20,680 hectares (Hancock Prospecting, 2011). Construction of the mine and associated infrastructure is estimated to take 48 months. The main infrastructure associated with the Alpha Coal Project will include:

- coal handling and preparation plant (CHPP)
- run of mine (ROM) pads

- quarry and borrow pits
- tailings storage facility (TSF)
- light industrial area (LIA) for mine support
- mine infrastructure area (MIA)
- various dams, roads, water and wastewater systems
- accommodation village.

In addition to these mine-site requirements, the development proposal for the Alpha Coal Project also includes a new 495 km long railway corridor linking the mine-site with the Port of Abbott Point near Bowen. This railway is expected to be a privately owned and operated standard gauge line, with a non-electrified single track (Hancock Prospecting, 2011). The eventual export capacity of the rail line is expected to be 60 Mt/year over a 30 year operating life. Rail facilities will include two balloon loops, nine passing loops, maintenance sidings, and a marshalling yard. The rail link will be used to transport washed product coal from Alpha and the nearby Kevin's Corner coal mine (and potentially from other mining operations in the Galilee Basin) to the port loading facilities at Abbott Point for export to market. Further development of the port facilities at Abbott Point will also be required to handle the expected increase in export volumes from Alpha and the other coal development projects expected to come online in the Galilee Basin over the next decade.

The Alpha Coal Project received regulatory approval from the Queensland Coordinator-General in May 2012 (Queensland Coordinator-General, 2012), subject to various conditions designed to mitigate and manage potential adverse environmental impacts. The Australian Government also provided approval with conditions for the development in August 2012 under the EPBC Act. In September 2013 action was launched by several groups in the Queensland Land Court against the project. In April 2014 the court released its non-binding recommendations to the Queensland Government, and indicated that if the mine is to proceed, it should be subject to additional conditions concerning groundwater monitoring, licenses and compensation. As of August 2014, the start of construction at Alpha mine was awaiting the final approvals needed under relevant Queensland legislation. These relate to the granting of the proposed Alpha mining lease (ML 70426, which is currently under application), and the award of an environmental authority (EA) under the Queensland *Environmental Protection Act 1994*. The EA is required for Alpha as the coal mining activities are regarded as an environmentally relevant activity (ERA).

If the ML and EA processes are successful, then construction of mine-site and associated infrastructure at Alpha may commence thereafter. Depending on the start date, construction of the proposed Alpha development may be completed in 2016 or 2017 (Hancock Prospecting, 2011). Initial coal production is expected in 2017, ramping up to full-scale operations between 2017 and 2020.

### 1.2.3.1.2 Kevin's Corner Coal Project

The Kevin's Corner Coal Project is being developed by Hancock Galilee Pty Ltd (Hancock Galilee), a wholly owned subsidiary of GVK. The Kevin's Corner site is adjacent and just to the north of the proposed Alpha coal mine (Figure 12). Mining lease application (MLA) 70425 covers the proposed Kevin's Corner site, within existing Hancock Prospecting tenement boundaries of EPC 1210 and MDL 333. Construction of the entire operation, with an expected capital outlay of $4.2 billion, is expected to take about four years, although initial coal production is planned to occur after two years of construction (currently estimated to be in 2017) (Hancock Galilee, 2011). The mine is expected to progress to full production capacity over five to seven years, and will operate for at least 30 years. The peak annual production rate of product coal is expected to be at least 27 Mt, although the mine will have a maximum 30 Mt/year capacity (Hancock Galilee, 2012).

The thermal coal resources at Kevin's Corner are contiguous with those to the south at Alpha, and have been well defined by extensive drilling and detailed resource modelling and characterisation. A significant 4.3 billion tonne (Gt) coal resource is delineated (reported in accordance with the JORC Code), which includes almost half a billion tonnes of reserve category coal (Hancock Galilee, 2011). The resource is high moisture, high volatile, low to medium rank coal with low sulfur content. Similar to Alpha, there are six Late Permian coal seams at Kevin's Corner, with the upper seams in the Bandanna Formation (A and B), and the lower four seams part of the Colinlea Sandstone (Mutton, 2003).

The Late Permian strata at Kevin's Corner are overlain by a variably thick cover of Cenozoic sediments, averaging about 40 m. The Cenozoic cover, which includes sand, gravel and clay, is thickest in the central and eastern parts of the mining lease, and thins towards the topographically high areas to the west. In the far west of the site fine-grained Triassic rocks of the Rewan Group overlie the Permian coal-bearing strata. The north-striking coal seams are of relatively consistent thickness across the MLA and dip gently to the west (1 to 2°) with no major (regional scale) faults. Mining operations will primarily target the D seam due to its relatively low ash content, which makes it the most economically attractive (export quality) coal within the MLA. A lesser amount of run of mine (ROM) coal will be extracted from the overlying A, B and C seams, although the total combined tonnage of these three seams is likely to be less than 10% of all raw coal mined at Kevin's Corner (Hancock Galilee, 2011). A summarised stratigraphic column for the Kevin's Corner Coal Project is in Table 8.

Although adjacent to the proposed Alpha coal mine, the Kevin's Corner mine has been designed as a stand-alone facility that will comprise two open-cut (the Central and Northern pits) and three underground (longwall) operations, as well as supporting infrastructure including a coal handling and processing plant (CHPP). Over the life-of-mine, approximately 75% of all ROM coal will be extracted from the longwall mines, and 25% from the open-cuts. Initial operations will focus on open-cut mining the shallower coal seams in the east of the lease, commencing in sub-crop areas and progressing westwards (down-dip). The open-cut pits will be developed over a strike-length of 6.5 km; although this is expected to reduce to about 4 km over-time (Hancock Galilee, 2012). Overburden will be stripped using conventional excavator, truck-shovel and dragline equipment, and hauled to waste dumps. As mining progresses, waste rock (and coarse coal rejects from the CHPP) will be used to backfill areas of the pit that have been mined-out. The pre-strip truck-excavator fleet will remove all of the weathered Cenozoic overburden.

**Table 8 Composite stratigraphy of the Kevin's Corner Coal Project in the Galilee subregion**

| Geological age | Lithology | Stratigraphic unit | Thickness | Comments |
|---|---|---|---|---|
| Quaternary | Sand, fine gravel and clay | Unknown | Mean of 40 m | Alluvial material |
| Neogene and Paleogene | Saprolite with remnant red mudstone and pale sandstone | Unknown | Variable, 5 to 60 m | Clay-rich, strongly weathered material |
| Triassic | Green to purplish-brown mudstone, siltstone and sandstone | Rewan Group | 175 m | Only occurs in far west of mining lease application area |
| Late Permian | Sandstone | Bandanna Formation | 30 to 50 m | |
| Late Permian | Coal seam A | Bandanna Formation | 1 to 2.5 m | Seam contains thin stone bands that thicken from south to north |
| Late Permian | Sandstone, siltstone and mudstone | Bandanna Formation | 10 m | |
| Late Permian | Coal seam B | Bandanna Formation | 6 to 8 m | Seam contains many non-coal bands, comprising 15 to 30% of total seam |
| Late Permian | Siltstone and mudstone | Bandanna Formation | 60 to 70 m | |
| Late Permian | Coal seam C - upper | Colinlea Sandstone | 2 to 5 m | Inferior quality coal |
| Late Permian | Coal seam C - lower | Colinlea Sandstone | 3 to 4 m | Coal quality superior to C upper seam |
| Late Permian | Siltstone and sandstone | Colinlea Sandstone | 2 to 20 m | |
| Late Permian | Coal seam D | Colinlea Sandstone | 4.5 to 6 m | Stony bands occur, seam thickens to west, upper section splits off main seam towards north-west |
| Late Permian | Sandstone | Colinlea Sandstone | 30 m | |
| Late Permian | Coal seam E | Colinlea Sandstone | 0.5 m | |
| Late Permian | Sandstone | Colinlea Sandstone | 15 to 20 m | |
| Late Permian | Coal seam F | Colinlea Sandstone | 1 to 3 m | |
| Late Permian | Sandstone | Colinlea Sandstone | Unknown | |
| Early Permian | Labile and quartz-bearing sandstone | Unknown | Not penetrated to base | Transition to rocks of the underlying Joe Joe Group |

Source data: Hancock Galilee (2011)

Three independent underground longwall mines are proposed at Kevin's Corner. Mining will progress towards the west, with individual longwall panels retreating from north to south (Hancock Galilee, 2012). Each underground operation is designed to have its own access point for coal removal (via conveyor), servicing and ventilation. The Northern Underground mine will be developed first, as it has the shallowest access point and shortest initial panel length. The Central and Southern underground mines will then be sequentially developed. The mine plan has been designed so that maximum underground capacity of about 28 Mt of ROM coal per year will be achieved about seven years after work begins on the first underground drift (Hancock Galilee, 2012).

Apart from the main open-cut and underground mining operations, the Kevin's Corner development will also include:

- coal handling and preparation plant (CHPP)
- rail loop (for loading) and spur (to connect to the main Alpha Coal Project railway) to allow coal to be transported to the export shipping facility at Abbott Point
- accommodation village to house the mostly fly-in/fly-out workforce
- airport, including a runway 2500 m long
- light industrial area (LIA), will be located along the mine access road near to rail, power and water supplies and the site airport. The LIA will house vehicle workshops, warehouse facilities and buildings for mine security, administration and environmental management
- mine infrastructure area (MIA); including all facilities directly associated with mine operations such as control points, vehicle parking, servicing and maintenance workshops and vehicle wash-down areas.

The Queensland Coordinator-General (CG) declared the Kevin's Corner Coal Project to be a 'coordinated project' in September 2009. This required preparation of EIS documentation for submission to the CG, as well as for public consultation. The project was also referred to the Australian Government, and declared a 'controlled action' under the EPBC Act. Following a period of review, consultation, and the preparation of a Supplementary EIS, it was determined by the Queensland CG in May 2013 that the Kevin's Corner Coal Project could proceed subject to conditions. Approval for the development to proceed was also granted by the Australian Government under the EPBC Act in November 2013. As of August 2014, construction of the Kevin's Corner mine-site and associated infrastructure requires granting of the mining lease application (MLA 70425) from the Queensland Government, as well as approval of the development's environmental authority (EA) under the *Environmental Protection Act 1994*.

#### 1.2.3.1.3 China First Coal Project

Waratah Coal proposes to develop a large scale greenfield coal mining operation in the Galilee Basin called the China First Coal Project (previously known as the Galilee Coal Project – Northern Export Facility). Waratah Coal is a privately owned Australian coal exploration and development company seeking to mine coal resources in the Galilee Basin for export to markets in China. In addition to the proposed open-cut and underground mining operations and supporting infrastructure (Figure 14) the project also includes building a new 453 km long rail network to link the mine with the coal export facility at Abbott Point. The estimated capital expenditure for this combined development is $6.5 billion, with $4 billion for the mine and $2.5 billion for the railway (Waratah Coal, 2011). The mine-site will be built about 30 km north-west of the town of Alpha, and 120 km east of Barcaldine (Figure 12), close to the eastern boundary of the Galilee Basin.

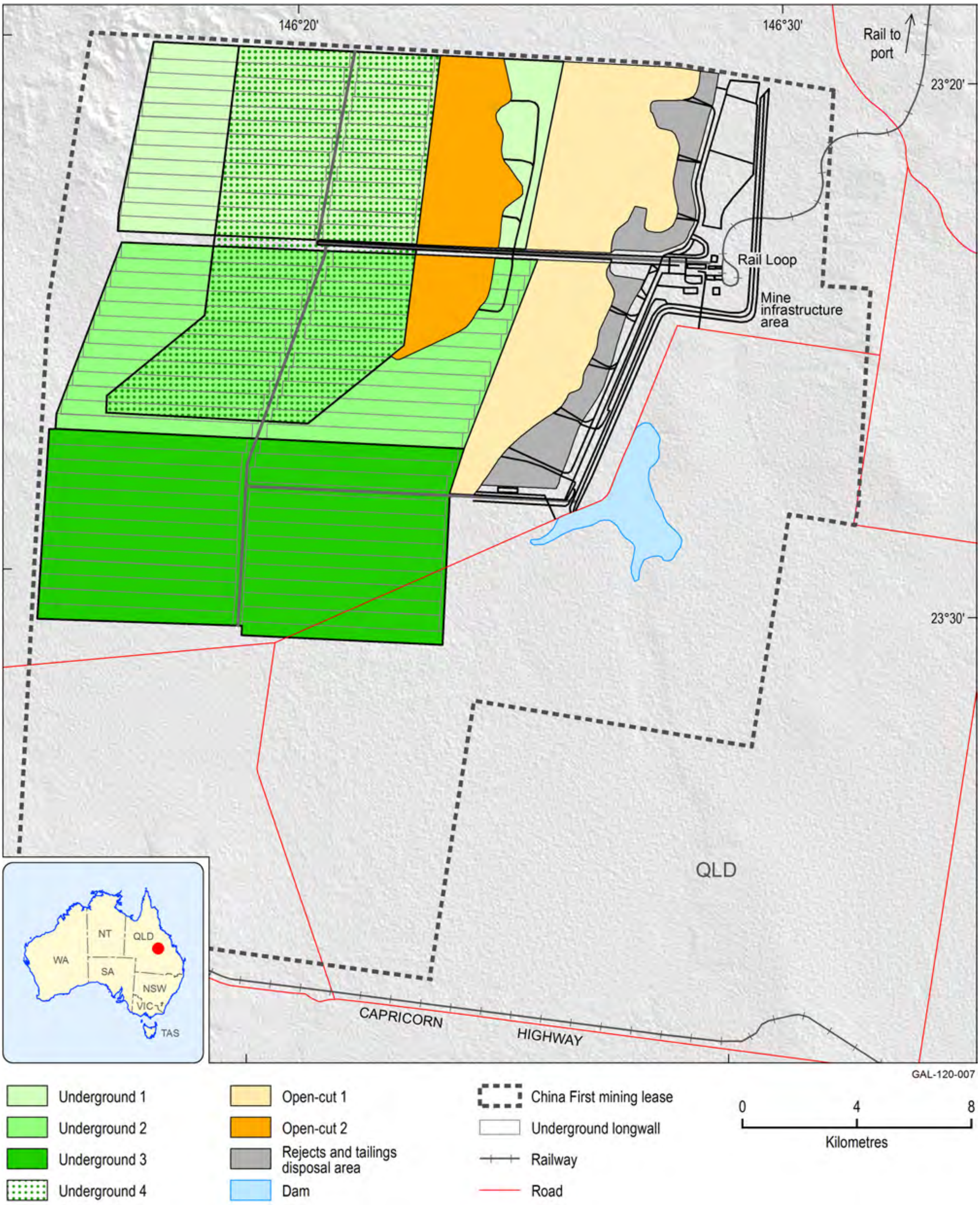



**Figure 14 Concept design for China First Coal Project in the Galilee subregion**

Source data: derived from Figure 2.2 in Queensland Coordinator-General (2013). Figure shows proposed layout of open-cut pits, underground longwalls and associated mine infrastructure.

The China First Coal Project aims to mine approximately 1.4 Gt of raw coal within an area covered by mining lease application (MLA) 70454. This lease occurs within existing Waratah Coal exploration tenements, EPC 1040 and EPC 1079. The mine design is based around a 25 to 30 year life that includes two open-cut pits, each with a northern and southern mining area (Figure 14).

The pits are expected to operate at peak annual production rates of 10 Mt. In addition, four underground longwall operations are planned to produce up to nine Mt per year of raw coal. Once all components of the mining operation are at peak capacity, the total annual production rate will be 56 Mt of run of mine (ROM) coal, which equates to 40 Mt of saleable processed coal for export (Waratah Coal, 2013a). The ROM coal will be washed and processed in one of two coal handling and processing plants (CHPP) that will be built on-site in the mine infrastructure area.

The identified resources at China First Coal Project amount to 3.68 Gt of high volatile sub-bituminous coal (resources have been estimated by a Competent Person as defined by the JORC Code) (Waratah Coal, 2011). They are perhydrous coals (>6% hydrogen) with low ash and sulfur contents, and are suitable as a thermal coal product, for example, to use in coal-fired power stations. Typical of the central-eastern margin of the Galilee Basin, the coal resources at China First Coal Project are hosted in the Late Permian rocks of the Bandanna Formation and the Colinlea Sandstone. Previous exploration work has identified six main coal seams, sequentially named from A (uppermost) through to F (lowermost) as per the standard naming convention of Late Permian coals in the Galilee Basin (Scott et al., 1995). The seams have good lateral continuity throughout the tenement and dip at low angles (1 to 2°) towards the west. No significant structural disruption of the main coal seams has been identified in the area.

According to Waratah Coal (2011), key features of the coal seams in the China First Coal Project area are:

- A seam – typically only 1 m thick, the A seam occurs in the west of the MLA due to the regional dip of the strata and geometry of subcropping areas. The A seam is commonly poorly developed and contains significant mudstone partings. Thus, the A seam is not an important component of the overall coal resource at China First Coal Project.
- B seam – this is the thickest overall seam in the lease area, usually at least 5 m thick. Mudstone bands are common throughout the upper 3 m, which tends to degrade this part of the seam and influence overall ash content. The basal 2 to 2.8 m section is commonly a distinctive clean section with dull and bright banding throughout.
- C seam – averaging 2 m thick, the C seam is generally clean of bands, although there is an increase in non-coal weakness planes (known as penny bands) near the top of the seam. Overlying the C seam is a further 2 m of thinly banded stony coal and mudstone, although this part is not considered economic.
- D seam – is divided into an upper (DU) and lower (DL) seam, and generally comprises the highest quality coal at China First. The DU seam is 10 to 15 m below the C seam and has a relatively consistent thickness of about 2 m. The DU seam is sharply defined at both the base and roof, and is mostly clean apart from some thin stone bands in the mid-section. The DL seam has two splits (DL1 and DL2), separated by a carbonaceous mudstone. The DL1 split varies from 0.7 to 0.9 m thick, whereas DL2 varies from 1.6 to 2.1 m thick. DL coal is mostly clean and consists of relatively equal parts bright and dull bands.
- E and F seams – both seams are about 1 m thick, and are currently not economically viable to extract due to their erratic nature (tending to split and degrade) and occurrence in areas of thick overburden. The E seam occurs at depths of 10 to 20 m below the DL Seam, and the F seam is a further 20 m lower.

Within the project area the coal seams are overlain by Cenozoic overburden, typically 95 to 125 m thick. These sediments are generally thinner in the north-west of the MLA (commonly 20 m or less) and thickest in the south (around 100 m thick), and consist of a mixed package of sand, gravel and clay. In the eastern part of the project area the Cenozoic sediments are in direct unconformable contact with the Permian strata. In contrast, the distinctive green-grey Triassic siltstone and mudstone of the Rewan Group occurs below the Cenozoic sediments in the west of the MLA, overlying older Permian rocks (Waratah Coal, 2011). Where present, the stratigraphic contact between rocks of the Rewan Group and the underlying Permian units is 20 to 40 m above the uppermost coal seam (A seam). Development of the open-cut operations will thus require stripping of a significant amount of waste rock overburden.

The open-cut operations will use a combination of conventional mining techniques such as walking draglines to remove overburden, and a truck and shovel fleet for coal recovery and partings removal from pits (Waratah Coal, 2013a). To improve productivity and allow greater flexibility when stripping overburden, large electric rope shovels will be used to load in-pit overburden conveyors.

The four longwall mines will access the underground coal resource at depths of 120 m below ground surface, with three longwalls targeting the C and D coal seams and one mining the B seam. Conventional longwall operations will use a coal shearer to cut coal away from the face, and a face conveyor running the length of the development face to carry the coal onto a belt conveyor system that transports coal out of the underground workings. Longwall blocks are expected to be up to 7 km long, and will have a 450 m wide operating face. Extraction heights at each face are likely to vary depending on individual seam characteristics, mostly between 1.8 to 2.5 m.

The China First Coal Project will have two purpose-built coal handling and preparation plants (CHPP) in the east of the MLA near the initial open-cut pits (Figure 14). These plants will have a raw washing capacity of 28 Mt/year. The overall product yield is estimated at 72% following washing. The CHPP will operate using conventional wet beneficiation processes that are widely used in the Australian coal industry (Waratah Coal, 2013a). Tailings from the CHPP will be stored in the nearby tailings storage facility, using either traditional co-disposal system or filter press system (requiring greater capital investment).

Other components of the mining operations will include:

- raw coal stockpiles
- haul roads from open-cut pits to crushing and stockpile facilities
- overland conveyors to transport raw coal to the CHPP
- product coal stockpiles for storage prior to train loading
- train load-out facilities
- stockpiles for topsoil and initial overburden waste rock (once surface operations have progressed, waste rock will be used to infill areas of pits that are mined-out)
- various water management structures such as dams, levees, creek diversions, drainage channels and sediment traps

- mine industrial area (MIA) for a variety of mine support activities, e.g. workshops, maintenance areas, fuel storage, and administration buildings
- workers accommodation village (adjacent to mining lease) to accommodate the bulk of the expected 2,000-strong operational workforce, most of which will use fly-in/fly-out rosters.

The development of a dedicated railway is an important component of the China First Coal Project. Waratah Coal proposes to build a new 453 km long rail network to link the mine with the coal export facility at Abbott Point (Waratah Coal, 2011). The rail system has been designed to support 25,000 tonne payload trains using a modern, heavy haulage standard gauge line. The initial annual transport capacity will be 60 Mt, although Waratah has sought approval for the railway to eventually cater for 400 Mt of coal transport per year. This indicates that additional rail contracts may be sought in the future from other proposed developments in the Galilee Basin. The rail design will include six passing loops and will have a mean easement width of about 50 m, with a maximum width of 184 m in areas where cross-slope cuttings are needed (Waratah Coal, 2013a).

The China First Coal Project proposal, comprising the mine and rail components, received conditional approval to proceed to development from the Queensland Coordinator-General in August 2013. Subsequent approval under the EPBC Act was granted by the Australian Government in December 2013. The approval is subject to a range of development and operating conditions, particularly around potential impacts to groundwater resources in the Great Artesian Basin and the reduction of ecological integrity and conservation value associated with land clearing and open-cut mining in the Bimblebox Nature Reserve.

Information recently released by the Queensland Government indicates that mining of the China First Coal Project may start in 2017. This suggests that construction activities may begin in 2015 or 2016, although this will depend on the timing of granting for the project's proposed mining lease (MLA 70454) and environmental authority (EA), and ongoing assessment of the economic viability of the project (for example, in light of changes to coal prices and overall market conditions). However, the Queensland Government's preference for the rail corridor proposed by GVK-Hancock to service the southern Galilee Basin (as well as the Adani Mining rail proposal for the central Galilee Basin) (Queensland Government, 2012), indicates that it is currently uncertain if Waratah Coal's proposed rail network (as outlined above for the China First Coal Project) will be developed as originally specified.

#### 1.2.3.1.4 Carmichael Coal Mine and Rail Project

Adani Mining is the proponent of the Carmichael Coal Mine and Rail Project in the north-eastern Galilee Basin, about 160 km north-west of the town of Clermont (Figure 12). The Carmichael Project proposes the development of a large scale thermal coal mine on mining lease application (MLA) 70441, which incorporates EPC 1690 (Adani Mining) and some parts of neighbouring EPC 1080 (Waratah Coal). The site is also covered by MLA 70505 (Carmichael East) and MLA 70506 (Carmichael North). Adani Mining has received consent from Waratah to lodge MLA 70441 as it includes parts of Waratah's EPC 1080 (Adani Mining, 2013). Considerable mining-related infrastructure and coal processing and handling facilities are proposed for MLA 70441 and in nearby areas off-site. Capital investment for the life of operation is estimated at $16 billion, with the integrated coal and rail project expected to have an operational life of 60 years. A 90 year mine life was originally planned in the EIS documentation (Adani Mining, 2012), but was subsequently revised to 60 years in the Supplementary EIS (Adani Mining, 2013).

The total coal resource at Carmichael is estimated at 10.15 Gt (reported in accordance with the JORC Code). This includes 1.16 Gt of measured resource, 3.24 Gt of indicated resource and 5.74 Gt of inferred resource (Adani Mining, 2012). The black coal deposits at Carmichael are of Late Permian age, similar to the other advanced coal projects in the central-eastern Galilee Basin such as Alpha and China First. Previous exploration and feasibility studies have shown that the coal deposit underlies almost the entire area of EPC 1690 (Adani Mining, 2013).

There are five main coal seams in the project area. These have a mean thickness of 28 m and a maximum cumulative thickness of 50 m. Consistent with the widely accepted coal nomenclature for the Galilee Basin; the coal seams are designated as A-B, C, D, E and F (Table 9).

**Table 9 Composite stratigraphy of the Carmichael Coal Project in the Galilee subregion**

| Geological age | Lithology | Stratigraphy | Thickness |
|---|---|---|---|
| Cenozoic | Clay and mudstone | | 40 to 100 m |
| Triassic | Mudstone and siltstone | Rewan Group | |
| Late Permian | Sandstone | Bandanna Formation | |
| Late Permian | A-B coal seam | Bandanna Formation | 12 to 18 m – resource seam |
| Late Permian | Sandstone and siltstone | Bandanna Formation | 10 m |
| Late Permian | B coal seam splits | Bandanna Formation | 1 to 2 m |
| Late Permian | Siltstone and mudstone | Bandanna Formation | 60 to 70 m |
| Late Permian | C coal seam (carbonaceous) | Bandanna Formation | 3 to 4 m |
| Late Permian | Siltstone and sandstone | Colinlea Sandstone | 2 to 20 m |
| Late Permian | D1 coal seam | Colinlea Sandstone | 4 to 6 m – resource seam |
| Late Permian | Sandstone | Colinlea Sandstone | 5 to 30 m |
| Late Permian | D2/D3 coal seam | Colinlea Sandstone | 8 to 10 m – resource seam |
| Late Permian | Siltstone and mudstone | Colinlea Sandstone | 10 to 20 m |
| Late Permian | E coal seam | Colinlea Sandstone | 1 to 3 m – resource seam |
| Late Permian | Sandstone and siltstone | Colinlea Sandstone | 5 to 10 m |
| Late Permian | F coal seams | Colinlea Sandstone | 1 to 5 m – resource seam |
| Early Permian | Sandstone | Joe Joe Group | |

Source data: Adani Mining (2012)

The A-B and C seams are interpreted to belong to the Bandanna Formation, whereas the lower three seams are in the Colinlea Sandstone. The current coal resource estimate does not include the C seam due to high ash content and heterogeneous thickness (inferior raw coal). The coal seams are known to sub-crop along the eastern boundary of the project area, and dip gently to the west at relatively low angles (2 to 6°) (Adani Mining, 2012). There are four main easterly trending geological faults that cross-cut the coal seams and off-set their continuity, with vertical displacement of between 20 and 40 m.

As reported for other Galilee Basin coal deposits, overburden at Carmichael includes poorly consolidated to unconsolidated Cenozoic sediments such as sand, gravel and clay (Table 9). These have a mean thickness of 74 m, but may be over 100 m thick in some places. In the west of the project area the coal seams are overlain by up to 400 m of weathered Triassic rocks, comprising the Dunda beds and the predominantly fine-grained Rewan Group (Adani Mining, 2012). Interburden between coal seams includes some sections of predominantly sandstone and siltstone, with other sections consisting mostly of finer-grained rocks such as mudstone. These are also of variable thickness, with some being less than ten m thick (e.g. the strata separating seams E and F), and others over 60 m thick (between the B and C seams).

Even by world standards, the proposed Carmichael mine will be a massive development and, if it reaches its expected full production capacity by about mid-2020, it will be Australia's largest coal mine (Adani Mining, 2013). The proposed maximum annual production rate of 60 Mt will be sourced from a combined open-cut and underground mining operation (Figure 15). The project has been designed to achieve this production objective within approximately the first ten years of operation, and aims to maintain a steady annual production rate for the following 15 years (Adani Mining, 2013). Annual production rates from the open-cut operations alone are expected to remain steady at around 40 Mt for over 25 years (from about 2024 to 2050). Underground mining, which will operate concurrently with open-cut mining, is expected to last for about 40 years, starting around 2020 and finishing in 2060 (Adani Mining, 2013).

Key components of the proposed Carmichael mine and its on-site infrastructure include:

- open-cut mining operations will be progressively developed across six separate pits, and will aim to produce 40 Mt of coal per year. Simultaneous mining operations will occur in up to six pits at a time, and the total strike-length of open-cut pits is likely to exceed 30 km (Figure 15)
- three independent underground longwall mines will operate concurrently with the open-cut operations. These will mine two seams over a 45 km north to south area, with 300 m longwall panels, an expected panel length of 5000 m and an extraction face three to five metres high
- mine infrastructure area (MIA), which includes a rail balloon loop
- coal handling and processing plant (CHPP) with maximum processing capacity of 74.5 Mt of raw coal per year
- out of pit waste rock dumps – the expected volume of overburden and interburden to be removed for mining is estimated at over 13 billion bank cubic metres (bcm). Where possible, waste rock will be permanently stored in mined open-cut voids
- mine water management dams.

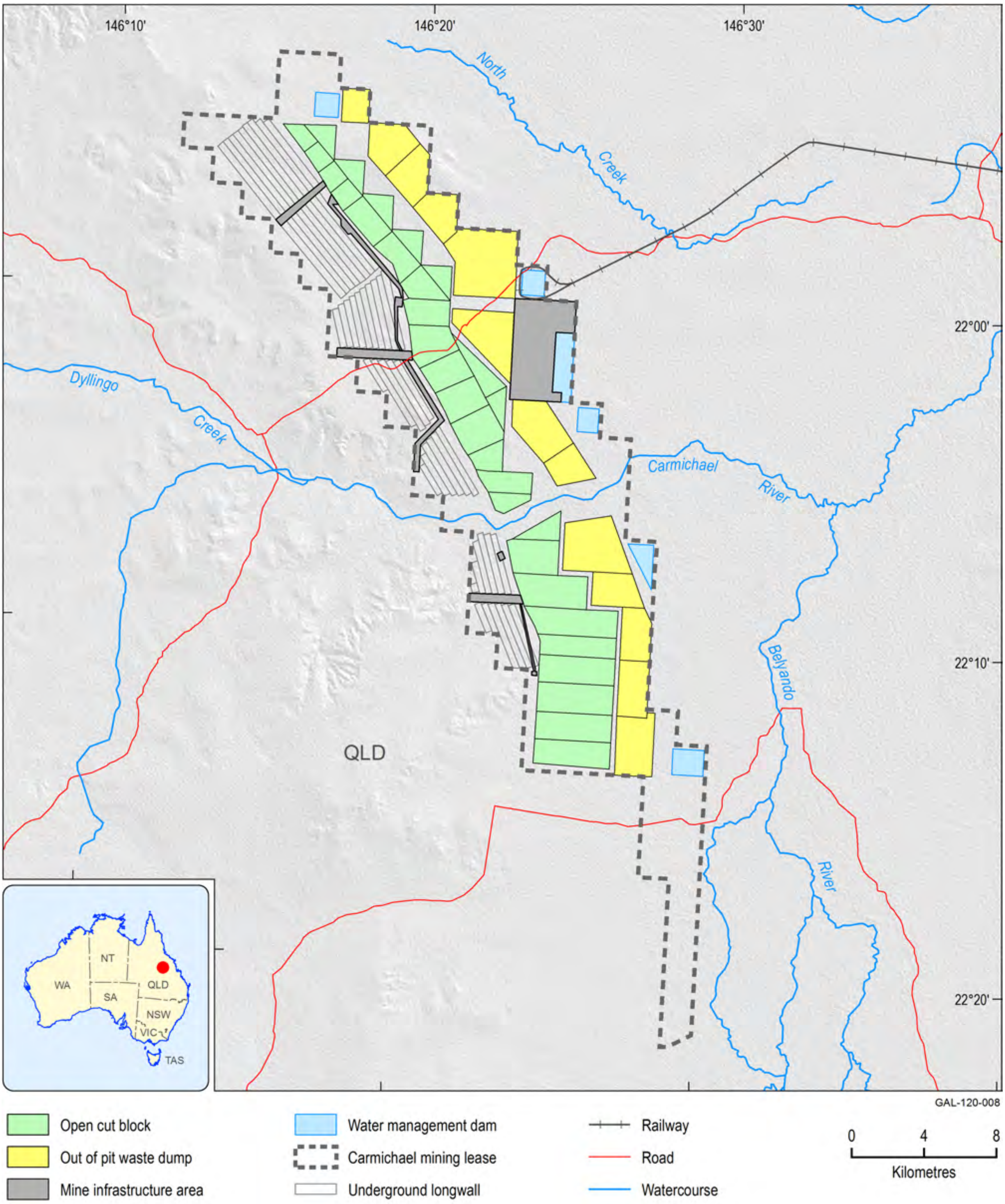



**Figure 15 Carmichael mine plan and associated infrastructure areas in the Galilee subregion**

Source data: derived from Figure 2.2 in Queensland Coordinator-General (2014)

Adani Mining (2013) indicated that the overall mine concept and infrastructure components are unlikely to change from the plans outlined in the Supplementary EIS, although further refinement of planned mining operations may occur based on updated geological exploration and geotechnical data.

Off-site infrastructure that may be developed to support the mining operations includes quarry pits, a workers accommodation village and associated facilities, a heavy industrial area and a new airport with a 3000 metre long airstrip. Adani Mining proposes for the bulk of the 3500-strong operational workforce to access the site via a fly-in/fly-out roster (Adani Mining, 2012). Water supply infrastructure is also required for extraction, storage and delivery of up to 12.5 GL/year.

The large scale of the mining operations at Carmichael requires a significant investment in equipment and plant. Open-cut operations propose to mainly use conventional truck and shovel equipment for stripping overburden and extracting coal, probably in combination with bucket wheel excavators, draglines and continuous haulage systems (Adani Mining, 2013, although exact mining details were not yet finalised in the Supplementary EIS). The three underground longwall mines will require standard equipment such as hydraulic shields for roof support, coal shearers to cut the coal from the working face, and conveyor systems to transport coal to the surface ROM pads (Adani Mining, 2013).

The west to east flowing Carmichael River transects the central part of the proposed mining area. A 51 hectare exclusion zone has been proposed to provide a protected corridor around the Carmichael River (Figure 15). This corridor has a minimum width of 500 m either side of the centre of the river to minimise impacts to the river and associated riparian zone.

All coal mined at Carmichael is expected to be transported via privately owned railway connecting to existing rail infrastructure near Moranbah in the Bowen Basin (the Goonyella and Newlands rail system) (Adani Mining, 2012). Coal will then be shipped to international markets (mainly India) via the coal export terminal at either Abbott Point or Hay Point. The development of this 189 km long greenfield rail link forms part of the integrated Carmichael development project. The rail system may consist of sections with dual gauge and narrow gauge tracks, as well as reception and departure lines at each end, and an 18.7 km long balloon loop loading line (Queensland Coordinator-General, 2014).

In May 2014 the Carmichael Project obtained conditional approval to proceed (Queensland Coordinator-General, 2014). In late July 2014, environmental approval was also received from the Australian Government under the EPBC Act. As of August 2014, the remaining stages in the overall pre-mining approval process are granting of the current mining lease applications that cover the proposed Carmichael development, and issuing of an environmental authority (EA) to conduct mining related activities. If the ML and EA are granted, construction of the first open-cut pit is planned to commence in 2015 (based on the schedules in Adani Mining, 2012), with the first underground workings starting around 2018 or 2019. Mining operations will initially begin in the northern sector of the lease, with the southern part to be developed in later stages. If construction goes to schedule, first coal production is expected from open-cut pits in 2016, and from longwall operations in about 2020.

Activities associated with construction, maintenance, rehabilitation and decommissioning of mine operations and infrastructure may occur as needed throughout the operational life of the project. Final decommissioning and rehabilitation is scheduled to start in 2071 (Queensland Coordinator-General, 2014).

#### 1.2.3.1.5 South Galilee Coal Project

The South Galilee Coal Project (SGCP) is a proposed open-cut and underground mining operation approximately 12 km south-west of Alpha township and 170 km west of Emerald (Figure 12). It is the southern-most and smallest of the six major coal projects for which development plans are currently well advanced, along the central-eastern boundary of the Galilee Basin. The SGCP is a joint venture initiative between AMCI Pty Ltd (Alpha) and Alpha Coal Pty Ltd (Alpha Coal), a subsidiary of Bandanna Energy Ltd. Alpha Coal Management Pty Ltd (Alpha Coal Management) are the designated manager of, and agent for, the South Galilee Coal Project joint venture. The coal resource at South Galilee has been defined through various exploration programmes undertaken on two coal exploration tenements held by Alpha Coal, namely EPC 1049 and EPC 1180. The development of the mine-site is expected to occur on mining lease application (MLA) 70453. Estimated capital expenditure for the SGCP is $4.2 billion (Alpha Coal, 2012).

If approved, the SGCP is expected to have a mine life of 33 years and may produce over 450 Mt of run of mine (ROM) coal (Alpha Coal Management, 2014). This could yield approximately 400 Mt of product coal over the life of operations, which would likely be exported to international thermal coal markets (Alpha Coal, 2012). Further exploration being undertaken within the project area may delineate new resources that could be added to the resource base in the future, thereby extending the operational life of the mine.

Coal resources targeted for possible extraction at the SGCP are hosted in the Late Permian Bandanna Formation. The main coal seams are designated D1 and D2, and contain a total resource of over 1.1 Gt (Table 10), reported in accordance with the JORC Code. The seams consist of three plies with a variable thickness between 0.5 and 4.5 m, and have ash content from 7.5 to 41% (Alpha Coal, 2012). The coal is high volatile sub-bituminous and generally has a dull appearance, although bright banding is relatively common.

Similar to other coal deposits in this part of the Galilee Basin, the coal-bearing Permian strata at SGCP are overlain by unconsolidated Cenozoic sediments such as sand, gravel and silt. These vary from 3 to 52 m thick across MLA 70453, and have a mean thickness of 21 m (Alpha Coal, 2012). Consequently, a significant volume of Cenozoic overburden would have to be removed from proposed open-cut mine areas before the target coal seams could be extracted. There are also overlying Triassic rocks in the western part of the SGCP, where higher land surface elevation occurs in the area of the Great Dividing Range. However, if the SGCP is approved, these rocks would not need to be removed as they do not occur in the open-cut mining area.

**Table 10 Coal resource in D coal seam at South Galilee Coal Project**

| Coal seam | Measured resource | Indicated resource | Inferred resource | Total |
|---|---|---|---|---|
| D1 | 50.4 Mt | 105.8 Mt | 555 Mt | 711.2 Mt |
| D2 | 116.3 Mt | 100.5 Mt | 251 Mt | 467.8 Mt |
| Total | 166.7 Mt | 206.3 Mt | 806 Mt | 1,179.0 Mt |

Source data: Alpha Coal (2012). Resources have been estimated by a Competent Person as defined in the JORC Code.

In their initial EIS submission (October 2012) the SGCP proponents indicated that mining would take place in three main stages using a combination of open-cut and underground methods (Alpha Coal, 2012). However, following EIS lodgement, the proponents recognised that there was considerable uncertainty of timing in the delivery of external (third-party) infrastructure (such as power, water and transport networks), which the SGCP development depended upon (Alpha Coal Management, 2014). Consequently, a revised approach was conceived to overcome this timing uncertainty, with the addition of a stand-alone initial development stage termed the Epsilon Mine (which is intended to precede the main mine development stages one to three as outlined in the EIS). Epsilon is proposed as a small-scale open-cut mine, sited within part of the larger pit area described in the EIS. If approved, it will target good quality coal with a low stripping ratio, identified by the proponents as a 'sweet spot' in the overall coal resource (Alpha Coal Management, 2014).

The components of the proposed Epsilon Mine at SGCP are outlined in the Additional Environmental Impact Statement (AEIS) submitted in early 2014 (Alpha Coal Management, 2014). The main features proposed for Epsilon are:

- truck and shovel open-cut mining operations capable of supporting 3 Mt/year for 13 years of operation
- no external water supply will be required, as a density separation process (dry process) is proposed to beneficiate the raw coal on-site. Existing surface water storages coupled with proposed new groundwater sources are expected to provide sufficient water supply
- on-site power supply to be used
- coal to be transported to the existing port facility at Gladstone, using existing railway networks, such as the QR railway between Alpha and Emerald, and the Aurizon Blackwater railway onto Gladstone port
- mine decommissioning to occur during operation of Stage 1 of the SGCP.

The overall impacts of the revised Epsilon stage for the SGCP are that there will be a longer ramp up period to the full mine production schedule (as proposed in the EIS). This will reduce the areal extent of mining and also help mitigate some environmental impacts, such as reducing disturbance of creek beds within the mining lease (Alpha Coal Management, 2014).

Construction of the mine and associated infrastructure may commence following granting of all required environmental approvals and awarding of the mining lease. However, as of August 2014, the actual timing of construction is unknown. Initial mining operations may be expected to commence after about two years of construction activity, and could progressively ramp-up over the subsequent construction stages to the peak production capacity of about 20 Mt/year expected in 2028 and 2029 (Alpha Coal Management, 2014). According to the development schedule in the AEIS, annual production rates after 2030 are expected to stabilise at around 17 Mt/year.

The original three stage development sequence (as per the EIS) was planned over the initial ten years of construction and mining operations (Table 11). However, many initial construction activities proposed for Stage 1 are expected to now begin during the Epsilon development phase, including some of the major civil and capital works components including some aspects of mine-site infrastructure (e.g. coal handling and preparation plant, CHPP), the workers accommodation camp (SGCP proposes a fly-in/fly-out workforce via the Alpha airport), and the rail spur to link to the existing east to west railway line (Alpha Coal Management, 2014). The subsequent stages of construction would mainly focus on extending the open-cut mining area and developing the underground operations, as well as additional infrastructure to support the full-scale operations.

**Table 11 Planned stages in development of South Galilee Coal Project**

| | Initial stage – Epsilon Mine | Stage 1 | Stage 2 | Stage 3 |
|---|---|---|---|---|
| Approximate provisional start date for mining | 2017 | 2020 | 2023 | 2028 |
| Product coal tonnage | 3 Mt/year | Up to 5 Mt/year | Up to 10 Mt/year | Up to 20 Mt/year |
| Mining method | Open-cut mine | Open-cut mine | Open-cut and #1 longwall underground mine | Open-cut and #1 and #2 longwall underground mine |

Source data: Alpha Coal (2012) and Alpha Coal Management (2014). The start date for each stage is preceded by approximately two years of construction activities. The schedule presented here is based on the anticipated maximum level of production, and the actual schedule that occurs will be influenced by other factors such as final mine planning and design, geological knowledge, economic conditions and access to third-party infrastructure.

Four open-cut mining pits are eventually planned for development at SGCP, with a combined footprint of about 14 km along strike. According to Alpha Coal (2012), open-cut mining operations (if approved) will involve several major activities:

- clearing – prior to mining, vegetation would have to be cleared and topsoil removed and stockpiled for later rehabilitation use
- drilling and blasting – some drilling and blasting of overburden material may be required prior to excavation, especially in the lower part of the Permian strata which are considered overburden (above the top mineable coal seams)
- overburden removal – initial excavation of the box cut to allow dragline access may use a power shovel. The dragline would then be mainly used to dig overburden and dump it to the spoil pile
- overburden and interburden placement – some initial waste rock may be used to build flood prevention barriers, with the remainder placed in waste rock heaps. The development proposal indicates that most of the overburden excavated by dragline would be placed in spoil piles in previously dug mining strips. Some waste rock with potential to generate acid forming material may require selective handling
- coal mining – a fleet of shovels and haul trucks is proposed to mine and transport the coal to the ROM prior to processing at the CHPP. If approved, mining would be done using conventional strip mining techniques. Multiple mining areas are planned for concurrent operations in both D1 and D2 coal seams.

Underground mining operations using the longwall method may focus on deeper seams buried down-dip to the west of the open-cut operations. If approved, the underground operations are expected to commence during Stage 2 of the mine development. Access to underground operations may occur from the southern-most open-cut via a box cut. Operations initially targeting the D1 coal seam may be followed by mining of the D2 seam (Alpha Coal, 2012). Seven underground headings have been designed to access the D1 seam from the box cut. The longwall mining panels are designed to be 350 m wide and up to 5000 m long, with a minimum depth below surface of 140 m (Alpha Coal, 2012). As the longwall progresses, a series of pillars would be left in-place to support the overlying strata and protect personnel, machinery and roadways.

The SGCP development plan indicates that two run of mine (ROM) coal heaps would be used to dump coal mined from the open-cuts (stages one to three). There may also be a separate underground ROM coal dump in the box cut area. Conveyors are planned to transport coal from the ROM heaps to the sizing facilities, in preparation for delivery to the raw coal pile near the CHPP. The CHPP is designed to operate on a 24/7 schedule, with a feed capacity of 2000 tonnes of coal per hour. There may be four product coal stockpiles linked by conveyor to the train load-out facility for proposed transport to Abbott Point coal terminal.

Exploration work in the SGCP area has shown no major indications of CSG in the target seams of the Bandanna Formation (Alpha Coal, 2012). This suggests that underground mine ventilation would be adequately handled by the initial combination of underground roadways and mining drifts into each seam, followed by later installation of dual return shafts (each six m wide). There may be multiple ventilation fans installed to provide the required level of mine flow ventilation.

In late 2012 then EIS for the SGCP (Alpha Coal, 2012) was prepared for public consultation and submitted for assessment to the office of the Queensland Coordinator-General. Additional information about the project was subsequently requested by the Coordinator-General, and the AEIS was submitted by the proponent in early 2014. The Coordinator-General's evaluation stage commenced for the SGCP on 1 July 2014. The SGCP has also been referred for approval to the Australian Government, and was declared a 'controlled action' under the EPBC Act in June 2010. Consequently, the SGCP has yet to be approved.

Despite the addition of the initial Epsilon mine stage, the full-scale development of the SGCP will ultimately depend upon access to external (third-party) infrastructure currently planned for the wider Galilee development region. In particular, access to the proposed new railway linking the south Galilee mining region to Abbott Point, the Galilee Basin Transmission Project (proposed by Powerlink Queensland), and secured port loading capacity at the expanded Abbott Point coal terminal are integral to the successful long-term development of the SGCP (Alpha Coal, 2012).

#### 1.2.3.1.6 China Stone Coal Project

Macmines Austasia Pty Ltd (Macmines Austasia) has proposed to develop the China Stone Coal Project within the southern block of EPC 987 in the northern Galilee Basin (Figure 12). This has been planned as a large scale greenfield operation using both open-cut and underground mining techniques, with an expected 40 year mine life. The site covers about 20,000 hectares and is some 170 km south of Charters Towers, and 190 km north-west of Moranbah in central Queensland. The northern lease boundary of the proposed Carmichael Coal Mine (operated by Adani Mining) lies three kilometres to the south of the China Stone Coal Project.

Of the six most advanced major coal mines proposed thus far for the Galilee Basin, the China Stone Coal Project is the least progressed in terms of required government approvals. An initial advice statement (IAS) was submitted to the state government in 2012 (Macmines Austasia, 2012), and the Queensland Coordinator-General released the Terms of Reference for the project EIS in early 2013. Macmines Austasia is currently in the process of preparing the EIS documentation, but has yet to make its submission. Approval from the Australian Government under the EPBC Act may also be required prior to development, although a referral has yet to be made.

The approximate limit of subcropping coal measures in the south of EPC 987 was ascertained by stratigraphic drilling undertaken by the Queensland Government in 1977. Based on this early work, significant coal exploration drilling and sampling programmes undertaken by Macmines Austasia in 2008 and 2010 led to the delineation of the initial coal resource. As of June 2011, coal resources at the proposed China Stone mine included 286 Mt of indicated resource and 3500 Mt of inferred resource (these resources have been estimated by a Competent Person as defined by the JORC Code). However, additional resources totalling about 9.8 Gt (upper estimate of exploration target) could occur across the entire lease area (Macmines Austasia, 2011). The coal is sub-bituminous, medium rank B, typical of the Late Permian coals in the Galilee Basin.

Although there is only limited information publicly available about the coal resources at China Stone Project, the proximity to the Carmichael mine and the likely strike continuity of the target seams suggests that the resource target probably has similar characteristics. Thus, the main coal resources at the proposed China Stone mine are likely to be hosted in the Late Permian strata of the Bandanna Formation and Colinlea Sandstone. According to Macmines Austasia (2011), the coal seams underlying EPC 987 have a predicted cumulative thickness of about 30 m. These seams occur over a 20 km long strike-length and dip gently to the west about 3 to 5°. There are no major fault off-sets known in the lease area. Also similar to Carmichael, poorly consolidated and variably weathered Cenozoic sediments cover the Permian rocks, with a total thickness of 20 to 100 m.

The initial mine concept plan indicates that open-cut mining operations may be developed in an elongated north-trending orientation that runs parallel with the strike of the target coal seams. This pit design shows a 13 km long main axis, targeting coal from the areas of the lease where overburden is relatively thin, progressing from east to west (down-dip). Stripping of the overburden may involve several draglines in combination with conventional truck and shovel operations (Macmines Austasia, 2012). If the development is approved, proposed full-scale production rates would require multiple mining pits to be concurrently active, with coal probably mined using excavators and rope shovels. Haul trucks and conveyors are expected to be used in combination to transport raw coal to the run of mine (ROM) heaps.

Underground mining activities may occur below the northern and southern ends of the open-cut mine. These longwall operations would likely target the deeper seams down-dip to the west of the pits. Up to four longwalls may operate concurrently once full production begins (Macmines Austasia, 2012). The suitability of the top-coal caving method is also being assessed for upper seams away from the open-cut areas.

Development plans indicate that most of the mine surface infrastructure may be sited in the eastern part of the tenement. This would include the coal handling and processing plant (CHPP), mine infrastructure area (MIA), tailings storage facility (TSF), power station, rail loop and train loading area, accommodation village and airstrip.

If approved, the China Stone Coal Project is expected to have peak ROM coal production rates of about 60 Mt/year. Washing and processing of raw coal on-site is expected to produce 45 Mt of export quality thermal coal. According to the IAS, mine construction may begin in 2015 with the first open-cut coal production in 2017 and longwall production scheduled for 2019 (Macmines Austasia, 2012). The anticipated dates are dependent upon timing of all necessary environmental approvals from the Queensland and Australian governments. If approved, final rehabilitation and decommissioning would occur following the cessation of mining operations.

A number of potential options for rail connections from the proposed China Stone mine to the preferred coal export facility at Abbott Point are currently being investigated. The most likely of these involves connecting the southern part of the mine-site to the proposed east to west rail corridor that the Queensland Government has declared will connect many of the Galilee Basin mines with the existing rail network that services the Bowen Basin near Moranbah (Macmines Austasia, 2012).

#### 1.2.3.1.7 Alpha North Coal Project

Waratah Coal has defined significant thermal coal resources within their EPC tenements 1039, 1053 and 1079 immediately north of the proposed Kevin's Corner coal mine (Figure 12). In September 2012 Waratah lodged mineral development licences (MDLs) 481 (Pocky Creek) and 485 (Laglan) over the most prospective area of these tenements, and subsequently followed that in November 2012 with mining lease application (MLA) 70489. This area, known as the Alpha North Coal Project, contains about 3.5 Gt of high quality thermal coal (reported in accordance with the JORC Code) which could be developed into another large scale Galilee Basin mining operation at some future stage (Waratah Coal, 2014a).

Although the China First Coal Project is clearly the most advanced development of Waratah Coal's Galilee Basin assets, preliminary concept plans for an integrated mining operation at North Alpha, along with associated infrastructure, are available at Waratah Coal (2014a). These plans indicate that, if fully constructed, the North Alpha Coal Project may consist of two open-cut mines, four underground longwall mines, coal handling and preparation plants, and associated mining infrastructure. A staged development process may occur, initially producing coal from the open-cut mines, before the more productive underground operations were commissioned. At peak annual production, about 56 Mt of run-of-mine (ROM) coal may be mined, leading to 40 Mt/year of product coal for export (Waratah Coal, 2013b). A rail spur would also be built (subject to approvals) to connect the Alpha North mine with the proposed railway development linking the China First mine with the coal export port of Abbot Point.

Waratah Coal is seeking a joint venture partner to share the investment risk for the proposed Alpha North Coal Project. Consequently, the timing of the approvals process of Alpha North Coal Project, such as notifying the Queensland Coordinator-General and preparing documentation for an EIS submission is currently unknown.

#### 1.2.3.1.8 Clyde Park Coal Project

Clyde Park Coal Pty Ltd (Clyde Park Coal) holds mining lease application (MLA) 10369 at the edge of the north-eastern Galilee Basin (Figure 12). This MLA, which was lodged in December 2012, hosts the proposed Clyde Park Coal Project (formerly known as White Mountain) within contiguous EPC tenements 1250 and 1260. The site is about 70 km north-west of the town of

Pentland, and close to the existing Mount Isa to Townsville railway. Clyde Park Coal is 64.4% owned by Guildford Coal, with most of the remaining shares held by Tiaro Coal Ltd.

Previous exploration work at Clyde Park has delineated a 728 Mt thermal coal resource in EPC 1260, comprising 51 Mt of indicated resource and 677 Mt of inferred resource (Guildford Coal, 2013). Additionally, an initial exploration target of 40 to 815 Mt of similar thermal coal has been defined in neighbouring EPC 1250 (Guildford Coal, 2013). These resources are hosted in the Late Permian Betts Creek beds, and appear to be consistent with other coal deposits known from the north-eastern Galilee Basin, such as those at South Pentland (Cockatoo Coal) and Hughenden (Guildford Coal). Based upon initial test results from exploration, the Clyde Park Coal Project is considered to have good potential for producing export quality thermal coal with moderate ash and low sulfur contents. Further information on the Clyde Park Coal Project is available at Guilford Coal (2014a).

At around the same time as the mining lease application was lodged an initial advice statement (IAS) concerning the proposed development of Clyde Park Coal Project was made to the Queensland Coordinator-General. This was the first step in the required statutory approvals process, leading to submission of an EIS. However, the IAS was subsequently withdrawn by Guildford Coal in July 2013 prior to lodging an EIS, as further consideration of mining options meant that the original details provided in the IAS were out-dated. At the time of writing, the future plans and timing for regulatory approval of the Clyde Park Coal Project are unknown, although the MLA is still pending.

In December 2012, Guildford Coal signed a memorandum of understanding with infrastructure company Asciano Ltd (Guildford Coal, 2013). This aimed to develop an integrated ‘pit to port’ solution for future mines that may be developed in the north and north-eastern Galilee Basin, including the portfolio of coal assets which Guildford has a stake in within the region including the Hughenden, Clyde Park and Pentland projects.

#### 1.2.3.1.9 Alpha West Coal Project

The Alpha West coal deposit occurs immediately west of the proposed Alpha thermal coal mine development near the eastern edge of the central Galilee Basin. Similar to Alpha Coal Project, the 1.8 billion tonnes of identified high quality thermal coal resource at the Alpha West coal deposit are owned by Hancock Coal, a joint venture between GVK (79%) and Hancock Prospecting (21%). Mineral development licence (MDL) 285 covers the Alpha West resource, and an initial concept study for future mining operations was completed in 2012 (Mulder, 2013).

The concept plan indicates that Alpha West could be developed as a large underground mining complex that would target the same coal seams planned to be mined up-dip (to the east) from open-cut pits at Alpha mine. Multiple longwall operations are likely to be the optimal mining method, producing 16 to 24 Mt/year for export markets (the actual amount will depend on the number of longwall mines developed). Depending upon approvals applications and the timing of construction, current planning by Hancock Coal is for initial mining to begin in 2018. A 30 year (or longer) mine life is expected (Mulder, 2013).

Development of the Alpha West Coal Project will depend on access to rail and port infrastructure set to be developed by the GVK Hancock joint venture for the Alpha mine.

### 1.2.3.1.10 Carmichael East Coal Project

The Carmichael East coal deposit is about 180 km west of Clermont (Figure 12), and sits within the Waratah Coal mining lease application (MLA) 70489 (Alpha North). This project area, which is immediately north of Waratah Coal's Alpha North Coal Project, also coincides with EPC 1079 and 1080, and MDL 485 (at Laglan). Waratah Coal has indicated that the thermal coal resources at Carmichael East are of high quality, and that an initial exploration resource target of approximately 9 billion tonnes may exist (Waratah Coal, 2014b). However, there are no resource estimates by a Competent Person (as defined in the JORC Code) currently available in the public domain. The resources are likely to be extracted by underground longwall operations commencing at a rate of about 9 Mt/year. Any future development would likely rely on access to infrastructure (including rail load-out facilities) at the nearby North Alpha Coal Mine.

Detailed publically available information relating to the Carmichael East Coal Project is scarce (Waratah Coal, 2014b). Although there may be significant potential for future large scale underground operations, the coal resources at Carmichael East require a significant amount of further geological investigation and feasibility assessment before they can be developed into a commercially operating mine.

### 1.2.3.1.11 West Pentland Coal Project

New Emerald Coal Ltd (NEC), a wholly owned subsidiary of Linc Energy Ltd (Linc Energy), holds an advanced thermal coal project[1] 7 km south-west of the town of Pentland in the north-eastern Galilee Basin (Figure 12). Mineral development licence (MDL) 361 was granted to Linc Energy in January 2012, and covers about 25 km2 of EPC 526. The Flinders Highway intersects MDL 361 in the south-west corner of the deposit. Based on previous exploration drilling and development of a geological and coal resource model (Xenith, 2013), the West Pentland deposit currently has a thermal coal resource of 266 Mt, comprising 176 Mt of indicated resource and 90 Mt of inferred resource (reported in accordance with the JORC Code). A mine concept study completed by Xenith (2013) indicated that a new coal mining facility in MDL 361 could produce three to four Mt/year of unwashed thermal coal.

The coal resources at the West Pentland deposit are hosted in the Late Permian Betts Creek beds. Two separate coal-bearing units are recognised, the Pentland Upper and Pentland Lower units (Xenith, 2013). The upper coal unit contains significant shale, and has high raw ash content which makes it currently uneconomic to mine. In contrast, the Pentland Lower unit contains multiple seams of moderate ash, low rank thermal coal that make it suitable for mining of export quality product. For modelling purposes, five coal seams (designated PL1, PL2, PL4, PL6 and PL8) and three parting stone bands (PL3, PL, PL7) are defined (Xenith, 2013). Cumulative coal thickness ranges from about 5 m in the shallowest zone, up to 35 m in the central zone of the deposit.

[1] For the purposes of this report, NEC's Pentland Coal Project is hereafter termed 'West Pentland' to distinguish it from the adjacent Glencore Pentland coal deposit in MDL 356 which lies immediately east of West Pentland.

Further drilling and evaluation of coal seams in MDL 361 has the potential to increase the identified resource in several areas (Xenith, 2013). NEC are considering development plans for the coal resource at MDL 361, and could potentially commence an EIS and begin pre-feasibility studies in the near to medium future (although there is currently no definitive date for lodging an EIS).

### 1.2.3.1.12 Pentland Coal Project

Mineral development licence (MDL) 356, granted in September 2006, is currently held by Glencore Coal Queensland Pty Ltd (Glencore) (Section 1.2.2). This MDL covers about 50 km2 and sits immediately to the east of NEC's West Pentland lease. In 2012 the maiden measured resource of 65 Mt, indicated resource of 15 Mt and inferred resource of 20 Mt was announced for Pentland (GA and BREE, 2013), presumably hosted in the Late Permian Betts Creek beds. However, there is scant information publically available to provide more detail about this coal resource. The tenement was formerly part of Xstrata Coal Pty Limited's (Xstrata's) asset portfolio, prior to the merger between Xstrata and Glencore in 2013. Given recent uncertainty about the future of a number of former Xstrata projects, the timing for development of the coal resources at the Pentland site is unknown.

### 1.2.3.1.13 Degulla Coal Project

Vale Coal Exploration Pty Ltd (Vale) is the current owner of the Degulla coal deposit, situated in the eastern Galilee Basin between the Carmichael and Alpha North Projects (Figure 12). Publicly available information about coal resources at Degulla is scarce (for example, the total resource as estimated by a Competent Person as defined by the JORC Code is currently unavailable); although a large tonnage deposit is known to occur. For example, Price (2011) quoted Vale sources as suggesting that (if developed) production at Degulla would likely range from 20 to 40 Mt/year, and would seek to export coal via Abbott Point. This indicates that the total resource tonnage at Degulla is probably comparable in size to at least the South Galilee Coal Project, and may exceed one billion tonnes of raw coal. However, media reports in mid-2013 indicated that Vale were attempting to sell the Degulla Coal Project, following several cost-cutting measures and asset write downs across their suite of Australian coal operations (The Australian, 2013). The status of this sale attempt, and any further exploration or appraisal work at Degulla in more recent times, is currently unknown.

### 1.2.3.1.14 Hyde Park Coal Project

Resolve Coal Pty Ltd (Resolve Coal) has identified an approximately 1.7 billion tonne thermal coal resource at their Hyde Park Coal Project, near the north-eastern margin of the Galilee Basin (Figure 12). This consists of 364 Mt of indicated resources and 1330 Mt of inferred resources (reported in accordance with the JORC Code) (Resolve Coal, 2014). Although Resolve Coal have yet to apply for a mineral development licence or mining lease, an overview of the Hyde Park Coal Project is warranted here due to the significant amount of geological and resource analysis undertaken by Resolve Coal. This has included a completed mine concept study, with follow-on work now started on pre-feasibility (due third quarter of 2014) and baseline environmental studies (Resolve Coal, 2009). These are likely precursor stages to a MDL or MLA, and signify the potential for future work on an EIS given that Resolve Coal have previously indicated their plans to submit an Initial Advice Statement (IAS) to the Queensland Government (Resolve Coal, 2013).

The Hyde Park Coal Project (HPCP) occurs on EPC 1754 (Bulli Creek) and EPC 2050 (Row Creek), approximately 140 km south of Charters Towers (Figure 12). These exploration tenements are 100% owned and operated by Resolve Coal, and cover an area of 236 km2. The HPCP is close to the major new coal developments planned at China Stone and Carmichael, and this has led Resolve Coal to recently sign an agreement with Adani Mining to provide 10 Mt/year input to the planned rail link between the Carmichael mine and their loading facilities at the Port of Abbott Point (Resolve Coal, 2013). Resolve Coal is also negotiating with Macmines Austasia (China Stone Coal Project) on potential for joint infrastructure planning.

The coal seams at HPCP occur in the Late Permian Betts Creek beds of the Galilee Basin. Six coal seams (A to F), most with multiple plies, have been identified across the south-western part of Resolve Coal’s tenements. A cumulative coal thickness of about 38 m across all seams has been recovered from some exploration drillholes, with the main target coal seams (C and D) about 12 m thick in places (Resolve Coal, 2013). The strike continuity of the coal seams is greater than 18 km (north-striking), with seams dipping at low angles towards the west (Resolve Coal, 2013). The coal resource generally has a low overburden ratio, suggesting that future mining operations will be open-cut. Initial concept planning suggests the potential for at least a 30 year mine life producing ten Mt/year of high quality thermal coal for export markets.

The current resource at Hyde Park (reported in accordance with the JORC Code) is 364 Mt of indicated resource, and 1330 Mt of inferred resource (Resolve Coal, 2013). Additionally, Resolve Coal has significant exploration targets across their two tenements, estimated at a further 50 to 150 Mt in the south, and zero to 1 Gt in the north (Resolve Coal, 2013). Coal washability and yield analyses have shown that the HPCP resources are high energy, export quality coals, with coal wash yields of 70 to 80% (or more).

### 1.2.3.1.15 Blackall Coal Project

East Energy Resources Limited (EER) is a coal exploration and development company focused on the Mesozoic coal resources of the Eromanga Basin, Queensland. Currently, EERs main focus is the Blackall Coal Project about 25 km south of the town of Blackall (Figure 12). The Blackall Coal Project consists of three main coal resource areas within three coal exploration tenements (EPC 1149, EPC 1398 and EPC 1399). As of September 2014, the total resource across the entire project area is estimated in accordance with the JORC Code as 3.44 billion tonnes of thermal quality coal (EER, 2014).

In November 2011 EER applied for MDL 464 to undertake more detailed resource characterisation studies for the Blackall deposit, and this was granted by the Queensland Government in July 2014 (EER, 2013). In contrast to other coal projects with MLA or MDL holdings in the Galilee subregion, the coals of the Blackall Project are hosted within the Late Cretaceous strata of the Winton Formation. This unit is significantly younger than the Late Permian rocks which contain the more well-known and regionally extensive coal resources of the eastern and northern Galilee Basin.

Initial exploration programmes undertaken by EER identified six main intervals of sub-bituminous coal within EPC 1149 (designated as seams 1 to 6). Most of these seams have several upper and lower plies, with the thickest being seams 2, 3 Lower (3L), and 4 Upper (EER, 2014). The coals have average raw ash content of 22% and moisture levels ranging from 18 to 22% (air dried basis). The initial resource evaluation area has a strike-length of about 95 km and a mean width of 6 km, with current resources in EPC 1149 totalling 1.74 billion tonnes (resources estimated by a Competent Person as defined by the JORC Code). This comprises of 627.5 Mt of indicated resource, and 1113 Mt of inferred resource (EER, 2014).

In May 2013 EER purchased Idalia Coal, which increased the size of their tenement holding within the Blackall region through acquisition of EPC 1398 and 1399 to the immediate south and north of EPC 1149, respectively. This acquisition initially added a further 440 Mt of inferred resource of similar quality coal to the EER portfolio, as well as a significant regional exploration target (EER, 2013). Further investigative work commissioned by EER in 2013, including a 68 hole drilling program, resulted in an upgraded coal resource for EPC 1399 totalling 1504 Mt of inferred resource reported in accordance with the JORC Code (EER, 2014). The current exploration target at Blackall across EPC 1398 and EPC 1399 is estimated at 2.0 to 2.5 billion tonnes of coal (EER, 2014).

Previous work commissioned by EER examined potential options for future development of the large scale sub-bituminous coal resources on their Blackall tenements. The final report stated that the coal quality is suitable for thermal energy use, and the volume and architecture of coal-bearing strata are amenable to large scale open-cut mining (EER, 2013). With further brownfield exploration aimed at increasing the resource size, there is potential to develop a 30 year mine life, with staged production schedules eventually ramping up to full capacity of about 20 Mt/year of washed coal product. Potential market options identified included supplying a local power station (which would need to be built), coal for sale to domestic or export markets, coal gasification, and gas to liquids conversion.

Given the large tonnage of the current resource identified at Blackall Coal Project and further resource definition drilling planned in the future (EER, 2014), there may be potential for EER to consider future mining operations at Blackall. Several independent studies have now been undertaken to better understand the geology, resources, mining options, infrastructure requirements and financial considerations of developing the Blackall Coal Project (EER, 2013). However, at this stage, the timing and details of such developments are unknown, and will depend on factors such as securing access to infrastructure and signing sales contracts for the coal resources.

### 1.2.3.1.16 Regional coal exploration in Galilee Basin

Renewed interest in the coal resources of the Galilee Basin led to an upsurge in grassroots exploration programmes from around the mid-2000s. This is reflected in the significant number of EPCs granted, either wholly or partly, within the Galilee subregion during this time (refer to Section 1.2.2). In recent years there have been many coal exploration programmes active in the Galilee Basin, led by diverse exploration and development companies. Analysis of the number and size of EPC tenements in the Galilee Basin indicates that the main exploration portfolios are currently held by:

- Waratah Coal – currently controls the greatest number of EPC tenements of any single entity in the Galilee Basin (14 EPC tenements), with efforts mostly focused around their major coal resource discoveries at the China First, Alpha North and Carmichael East projects.

- Guildford Coal – the main publically listed Australian company exploring in the Galilee Basin, Guildford Coal are focused on their Hughenden, Pentland and Clyde Park prospects in the northern Galilee subregion (Figure 16). The total identified resource across all of Guildford's Galilee tenements is nearly 2 billion tonnes, as reported in accordance with the JORC Code (Guildford Coal, 2013). In late September 2014, Guildford Coal was advised of a conditional off-market takeover bid by Sino Construction Ltd (Guildford Coal, 2014b).
- Cockatoo Coal – the takeover of Blackwood Corporation Ltd (Blackwood Corporation) by Cockatoo Coal in early 2014 means that they now own the former Blackwood Galilee Basin tenements at South Pentland, North Hughenden and Carmichael North. The current main focus of Cockatoo Coal seems to be on expanding their existing Baralaba Coal Mine operation in the Bowen Basin (Cockatoo Coal, 2013). However, further exploration and appraisal efforts by Cockatoo Coal in the Galilee Basin continue to build upon the previous efforts of Blackwood Corporation. For example, in September 2014 Cockatoo Coal announced a resource upgrade at South Pentland, with a total identified resource of 445 Mt comprising 94 Mt of indicated resource and 351 Mt inferred resource (Cockatoo Coal, 2014).
- Coalbank – focused mainly on exploring for the lower rank coals of the Jurassic and Cretaceous Eromanga Basin, Coalbank (mostly through their wholly owned subsidiary, Tambo Coal and Gas Pty Ltd) controls significant tenement position stretching south-east from Blackall to the Galilee subregion boundary (and beyond into the part of the Eromanga Basin that occurs outside of the Galilee subregion).
- Fox Resources Ltd (Fox Resources) – following recent acquisition of tenement holdings from Cliffs Australia Coal Pty Ltd, Fox Resources control 11 EPCs in the south-eastern Galilee Basin. Available information indicates that Fox Resources are mainly focused on negotiating with potential joint venture partners to fund further exploration of these coal tenements (Fox Resources, 2014).

A summary of some important exploration results reported by various companies in the Galilee Basin in recent times is in Table 11 (not including the deposits which are previously listed in the proposals section).

As well as greenfield exploration programmes, some of the main development companies in the Galilee Basin are working on further delineating the extent of their known coal resources, with a view towards better understanding the dimensions and quality of these coal deposits and potentially increasing the size of their total resources. For example, Waratah Coal is undertaking additional exploration work around the China First Coal Project to potentially delineate additional coal resources (Waratah Coal, 2013a).

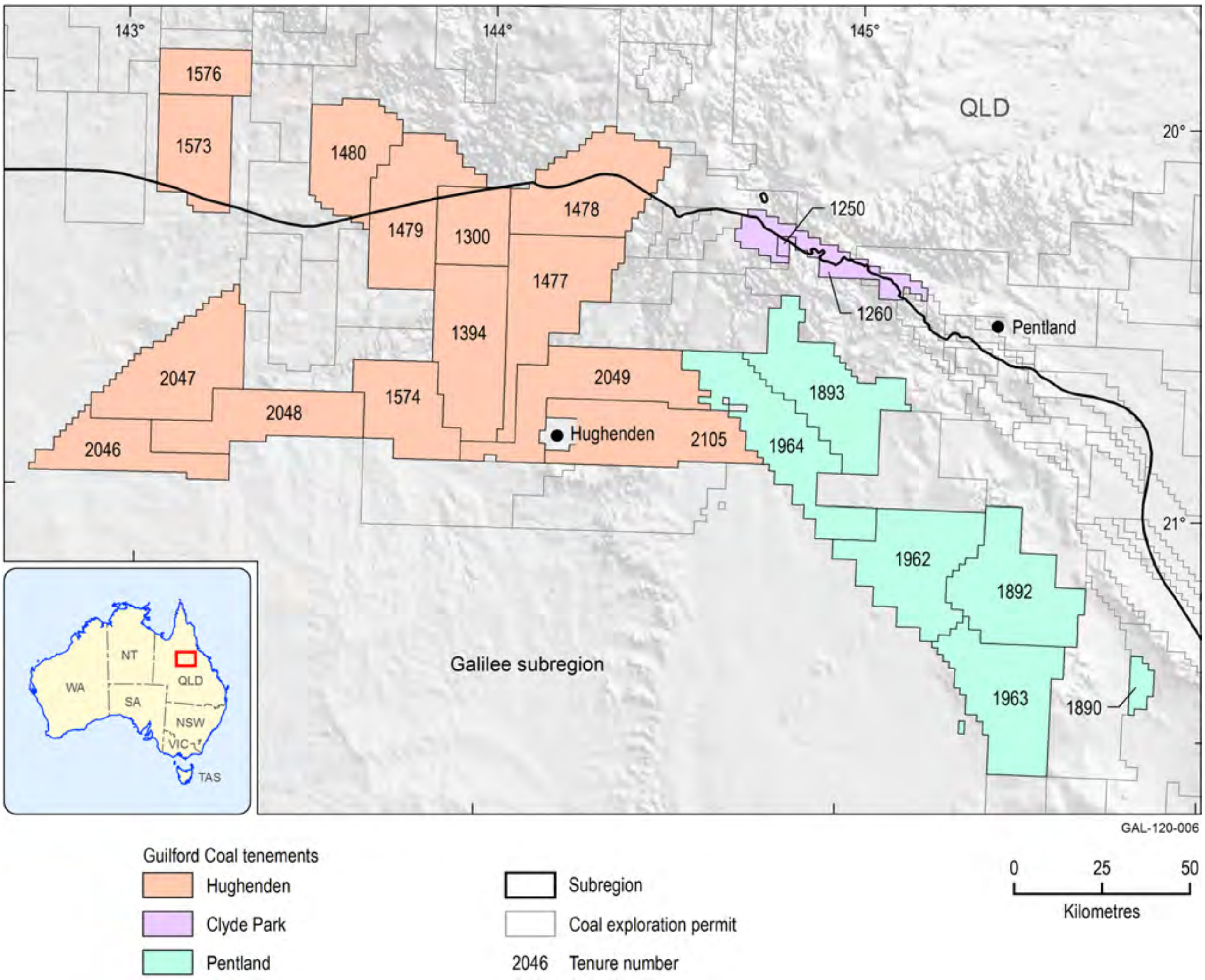



**Figure 16 Galilee Basin exploration tenements for Guildford Coal in the northern Galilee subregion**

Source data: Queensland DNRM (2014a). The regional project names of Hughenden, Clyde Park and Pentland for tenement collections are those used by Guildford Coal.

The Galilee Basin has clearly been the focus of major exploration investment in recent times, leading to many economically significant greenfield coal discoveries. However, despite these exploration successes, the enormous size of the basin (about 250,000 km2) and the numerous exploration tenements which support considerable ongoing exploration activities suggest that the known resource base of the Galilee Basin may continue to grow. Although it is uncertain if new discoveries will rival the large size of many of the current mining proposals, the basin's relatively modest exploration maturity suggests that further coal resource discoveries are possible. Consequently, the current resource base known for the Galilee Basin may not reflect the actual in situ coal resource tonnage. It is possible that other coal resource developments (such as arising from initial exploration prospects or perhaps those not yet discovered) may be developed over the coming 10 to 20 years (or even further into the future) in the Galilee Basin.

**Table 12 Recent coal resource discoveries in Galilee Basin**

| Project name | Principal company | Exploration tenements | Target stratigraphy | Identified resources | Current status | Comments |
|---|---|---|---|---|---|---|
| Hughenden | Guildford Coal | EPC 1477, EPC 1478 | Late Permian Betts Creek beds. The Jurassic Blantyre beds of the Injune Creek Group in Eromanga Basin are also considered a potential exploration target, but there are no identified resources at present | 133 Mt indicated resource and 1076 Mt inferred resource of thermal coal (Guildford Coal, 2013) | Further drilling of the inferred resource is planned to better delineate the deposit and improve geological confidence of the resource | The Hughenden Project consists of numerous EPC tenements that together relate to the total exploration target resource. The inferred resource at Hughenden is within EPC 1477 and EPC 1478. A larger exploration target of between 285 to 2830 Mt of thermal coal is defined across the other tenement holdings.<br>The Hughenden resource is suitable for underground mining (350 to 600 m below surface) (Guildford Coal, 2013). |
| South Pentland | Cockatoo Coal (following takeover of Blackwood Corporation in early 2014) | EPC 1486, EPC 1762 | Betts Creek beds | Export quality thermal coal, with 445 Mt identified resource comprising 94 Mt indicated and 351 Mt inferred (Cockatoo Coal, 2014) | Blackwood Corporation was undertaking a mine concept plan at South Pentland prior to takeover | Located 54 km south of Pentland. There is a tenement exploration target of over 3 billion tonnes (Blackwood Corporation, 2013). |
| Yellow Jacket | Cuesta Coal | EPC 1802 | Late Permian Betts Creek beds (suspected, although the successful drillholes occur east of the existing known extent of the Permian Galilee Basin) | Thermal coal 364 Mt inferred resource (Cuesta, 2013) | Further exploration and resource evaluation work including geological modelling and coal sample analyses | The initial exploration success requires further evaluation prior to potential mine concept planning. Cuesta also holds other exploration tenements within the eastern Galilee subregion. |

| Project name | Principal company | Exploration tenements | Target stratigraphy | Identified resources | Current status | Comments |
|---|---|---|---|---|---|---|
| Inverness | Coalbank | EPC 1993, EPC 1719 | Cretaceous Winton Formation | Sub-bituminous coal consisting of 1300 Mt inferred resource, of which 825 Mt is at depth of less than 50 m below surface (Coalbank, 2013) | Initial mine concept study area about 13 km long by 5 km wide selected for further evaluation based on review of geological model. Further drilling programmes required to improve understanding of resource and provide input to next stage of modelling | Located south of Blackall, the Inverness deposit occurs in the western part of EPC 1993. |

The exploration projects listed here are those within the Galilee subregion that have been identified as having a coal resource compliant with the Joint Ore Reserves Committee (JORC) Code. EPC is exploration permit for coal

#### 1.2.3.1.17 Galilee Basin State Development Area

To facilitate the development of infrastructure required for the Galilee Basin coal mines, the Queensland Government declared the Galilee Basin State Development Area (GBSDA) in June 2014 (DSDIP, 2014b). According to the Queensland Government, the GBSDA will assist in properly planning and coordinating the development of the coal mines and associated infrastructure in the Galilee Basin, including the six most advanced coal mining projects currently planned. The GBSDA seeks to lower upfront development costs to help stimulate development of the coal resources in the southern and central basin (DSDIP, 2013).

As part of the GBSDA, the Queensland Government has announced their preferred options for the rail corridors proposed by various companies as part of integrated mine-rail-port developments in the Galilee Basin. These are:

- An approximately 500 m wide east–west corridor to extend the existing QR rail network from near Moranbah to the central Galilee Basin, and provide links to coal ports at Abbott Point, Dalrymple Bay and Dudgeon Point. This is consistent with the rail network extension proposed by Adani Mining to service the Carmichael coal mine (Section 1.2.3.1.4), and would also likely be used by the proposed China Stone coal mine (and any others within the central Galilee Basin that may be developed in the future).
- An approximately 500 m wide north–south rail corridor consistent with the rail alignment proposed by GVK Hancock (1.2.3.1.1) to link proposed mines in the southern Galilee Basin (such as Alpha and Kevin’s Corner) to the coal port at Abbott Point.

Given the preference of the GBSDA to favour development of these two rail lines, the future of other proposed rail networks previously outlined in this section (such as that proposed by Waratah Coal for the China First Coal Mine) is currently uncertain.

Further information about the Galilee Basin State Development Area and the proposed framework for infrastructure options including rail, roads, water, ports and power is available from the Queensland Government (DSDIP, 2014b).

### *1.2.3.2 Coal seam gas*

There are currently no coal seam gas (CSG) development proposals seeking to progress beyond initial pilot well testing and appraisal to full-scale commercial production. Details of the CSG pilot testing and exploration focus in the Galilee Basin are in Section 1.2.3.2.2.

#### 1.2.3.2.1 History of coal seam gas exploration

The Galilee Basin was first explored for conventional hydrocarbons during the late 1950s and 1960s. This work involved regional seismic surveying and drilling of over 40 exploration wells, many to depths of about 3000 or 4000 m. However, results were generally not encouraging as most wells reported no hydrocarbons. An exception, well Lake Galilee 1 drilled in 1964 resulted in recovery of minor oil (uneconomic quantities) from a conventional sandstone reservoir. As a result of the overall poor exploration success, hydrocarbon exploration stalled in the 1970s with only ten wells drilled. There was some renewed interest in the 1980s (about 25 new wells) although, as before, exploration results were generally poor.

Since the early 1990s the main focus of hydrocarbon exploration in the Galilee Basin has been on the potential for CSG resources. This began with the pioneering work of Enron Exploration Australia Pty Ltd (EEA), when drilling of the Fleetwood, Splitters Creek and Rodney Creek wells targeted the Betts Creek beds and the Aramac Coal Measures at depths greater than 1000 m (Blue Energy, 2010). The Rodney Creek 1 well encountered a significant thickness of net coal (35 m), with moderate to good natural permeability (2 to 35 millidarcies). During drill-stem testing both gas and water naturally flowed, indicating in situ fractured coal and relatively high level of gas saturation (EEA, 1992). This initial exploration effort provided evidence that CSG could be extracted from the coal-bearing Permian Galilee Basin, although this did not lead to an immediate substantial increase in further drilling or CSG-focused exploration.

### 1.2.3.2.2 Current coal seam gas exploration and testing

The most recent phase of CSG exploration in the Galilee Basin started around 2007, spurred by renewed interest in CSG due to production successes in the nearby Surat and Bowen basins. Recognition of extensive and laterally continuous coal seams across much of the Galilee Basin, commonly with multiple stacked seams of over 20 m cumulative coal thickness, led many explorers to initially hail the basin as a potential major CSG province. Since 2008 there have been over 60 new CSG exploration wells drilled in the basin, and significant interest was shown through work programmes initiated by major petroleum companies including AGL and Origin Energy (through the Australia Pacific Liquefied Natural Gas (APLNG) joint venture). Many junior exploration companies have also been actively involved in the Galilee Basin, with prospective and contingent CSG resources recently announced by both Comet Ridge and Blue Energy Limited (Blue Energy) (see Table 3 in Section 1.2.1).

As of August 2014, the most advanced CSG exploration projects in the Galilee Basin (all with reported 2C and/or 3C contingent resources) are:

- Galilee Gas Project – a joint venture between AGL (operators) and Galilee Energy in exploration permit for petroleum (EPP) 529
- Gunn CSG Project – owned and operated by Comet Ridge in EPP 744
- Blue Energy's CSG exploration project in EPP 813.

Other exploration work for CSG in the Galilee Basin has also recently been undertaken by:

- Queensland Energy Resources (QER) – current holders of four EPPs in the Galilee Basin (EPP 1010, EPP 1015, EPP 1032, and EPP 1044), QER have recently drilled several exploration wells for CSG in parts of the northern and eastern basin. These include the Ophir 3 well (December 2012) and the Solomon 3 well (January 2013), which reported successful coal intersections in the Betts Creek beds, with coal seams containing moderate gas contents and relatively low natural permeability.
- Pangaea Resources – focused in the north-western Galilee Basin around the Lovelle Depression, Pangaea Resources hold adjacent tenements EPP 989 and EPP 1041. Recent work has involved reprocessing 1400 km of two dimensional seismic data and drilling six exploration wells to assess unconventional hydrocarbon potential of the Permian coal measures, as well as the shales of the Cretaceous Toolebuc Formation (Pangaea Resources, 2014).

***Galilee Gas Project***

The most advanced CSG project currently in the Galilee Basin occurs in EPP 529, and is a 50:50 joint venture operation between AGL (JV operators) and Galilee Energy Ltd. Known as the Galilee Gas Project, the main focus of activity is centred about 100 km north-east of Longreach (Figure 12), where exploration work has so far established a 259 PJ (2C) contingent CSG gas resource. This petroleum tenement was first granted to EEA in the early 1990s, and work since that time has involved expenditure of over $50 million (AGL, 2013) including:

- acquisition of nearly 550 line km of two dimensional seismic reflection data
- drilling ten exploration wells, including seven cored wells
- establishing a five well production pilot test operation, known as the Glenaras production pilot
- constructing a large holding dam for co-produced water from the Glenaras pilot wells, capable of holding about 300 ML
- drilling groundwater monitoring bores to evaluate the potential drawdown effects of CSG production on other aquifers in the Glenaras area, for example, monitoring bore Gowing 1 monitors the confined aquifer pressure in the overlying Hutton Sandstone aquifer (Figure 17)
- establishing related infrastructure including a small onsite camp.

An initial CSG pilot site with multiple wells was established in the early 2000s at Rodney Creek, about 5 km north-east of Glenaras, by Galilee Energy. The pilot site at Rodney Creek was based upon the earlier work of EEA, and targeted coal seams in both the Betts Creek beds and the underlying Aramac Coal Measures. However, despite drilling several wells and intersecting prospective coal seams, the pilot wells at Rodney Creek were largely unsuccessful and failed to produce commercial quantities of CSG. This was interpreted as due to fracture stimulation of the coals unintentionally penetrating into overlying aquifers, resulting in insufficient drawdown of the CSG reservoirs to reach desorption pressures (AGL, 2009). At the end of the test period these wells were plugged and abandoned.

Learning from the problems that beset the Rodney Creek pilot, AGL successfully established a five well production test site at Glenaras (Figure 17). Production test wells Glenaras 2 to Glenaras 6 were drilled in 2009, with a combination of hydraulic fracturing and under-reaming methods used to stimulate production. This development strategy helped to avoid the extensive fracturing of overlying aquifers that had earlier led to problems at Rodney Creek. The Glenaras wells were sited based on analysis of existing well and seismic data, and were drilled to intersect the Betts Creek beds and evaluate the gas and water flow potential of the main coal seams (AGL, 2009).

In October 2011 AGL reported the first successful gas flow from the Glenaras pilot site (from Glenaras 6 well), with a steady flow rate of 54 thousand standard cubic feet (Mscf) per day for four days, prior to maintenance shut-down (Alpha Securities, 2011). Successful gas flows from the Betts Creek beds at the Glenaras pilot site have proven the technical requirements for an operating CSG production field in the Galilee Basin. However, a commercial decision on the long-term viability of CSG production facilities at Glenaras is unlikely for at least eight to ten years, and will depend on both technical and commercial considerations (John Ross, AGL, 2014, pers. comm.). This reflects that further pilot testing of the target coal seams and evaluation of the economic implications of development is considered essential by AGL and Galilee Energy for Glenaras to be a successful CSG production site. Ongoing testing, monitoring and evaluation work is planned to continue at Glenaras in the interim, in-line with AGL's currently approved operational timeframes and approvals.

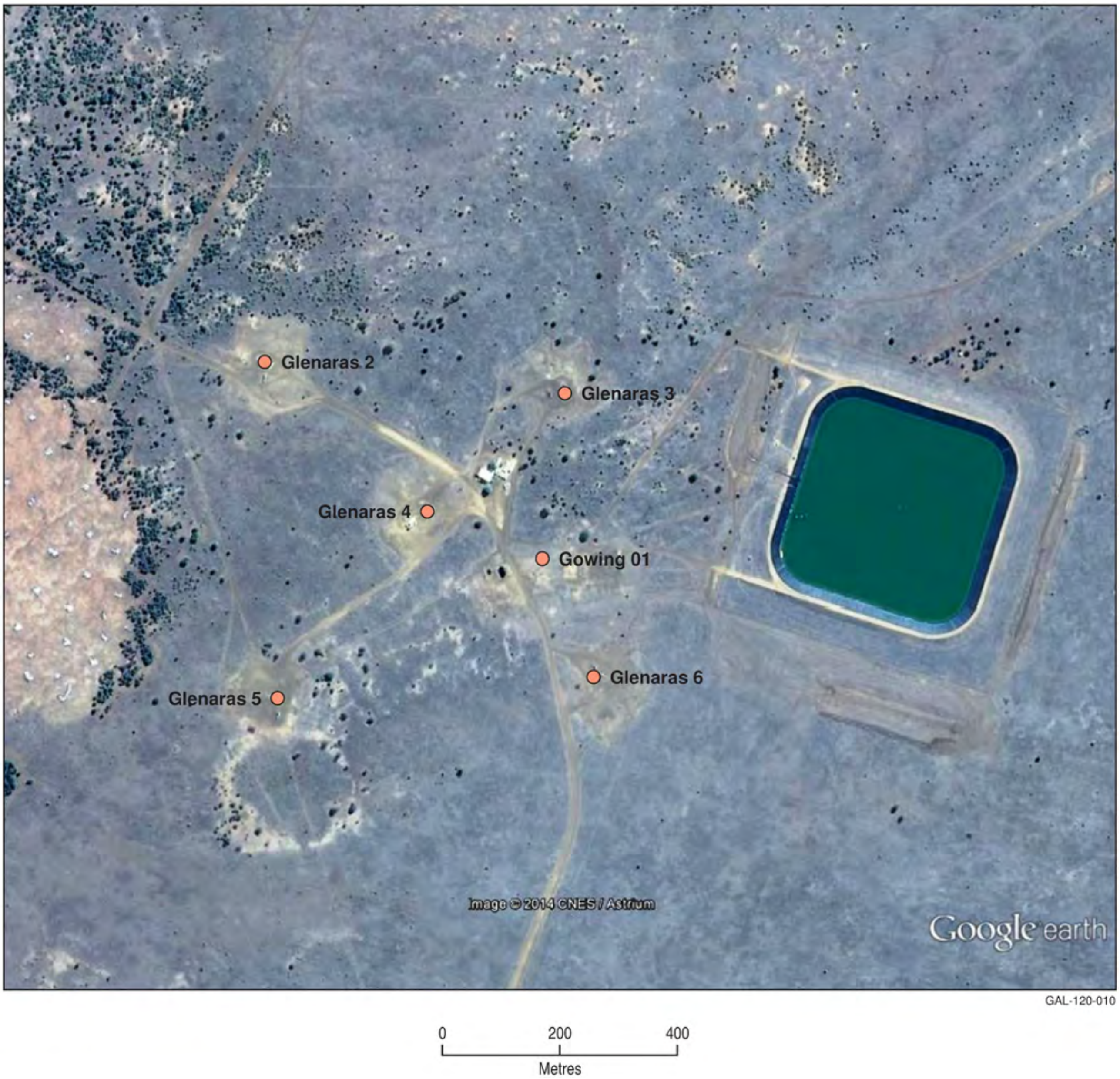



**Figure 17 Glenaras and Gowing wells with the 300 megalitre holding dam at the Glenaras pilot production site**

Source: Google (2013). This figure is not covered by a Creative Commons Attribution licence. Map data © 2014 Google, CNES/Astrium. Well locations are sourced from Queensland DNRM (2014c).

### *Gunn Coal Seam Gas Project*

Comet Ridge currently holds two petroleum exploration tenements in the eastern Galilee Basin (EPP 734 and EPP 744), north-east of Aramac. CSG exploration across this area since 2009 has targeted the Betts Creek beds, and involved drilling eight wells and completing over 250 km of two dimensional seismic reflection surveys (Comet Ridge, 2013a). Results from this work identified the Gunn Project area in the south-west of EPP 744 as being the most prospective for CSG (Figure 12), and also led Comet Ridge to farm-in to neighbouring EPP 1015 (held by Queensland Energy Resources) in 2012 to create a continuous acreage area to the east of Gunn (Figure 18).

Within the Gunn Project area drilling has identified five discrete coal seams at depths ranging from 700 to 1000 metres below surface (Comet Ridge, 2013b). These are interpreted as part of the Betts Creek beds. Net cumulative coal thickness in most wells is greater than 16 m, with some wells containing up to 24 m of total coal. These coals have good permeability, and gas contents mostly greater than 4 $m^3$/t (Comet Ridge, 2013a). Based on their initial understanding of the geology and CSG resources at Gunn, Comet Ridge (2013a) estimated that recoverable gas occurs over an area of 1865 km2 within their tenement and adjacent farm-in area.

In November 2012 Comet Ridge completed the Gunn 2 well to use for an extended production test, with the aims of: establishing connectivity with the coal seams, producing water from the coals, and obtaining water samples for further analysis (Comet Ridge, 2013a). A 4 m thick section of the C1 seam in the Betts Creek beds was isolated to connect the well with the target coals and allow for inflow of formation water (Comet Ridge, 2013a). Continuous pumping for over a month in early 2013 showed that the water rate progressively increased before stabilising at 400 barrels of water per day. Water quality was good, and analysis of pressure data indicated that a greater flow capacity was possible over the 4 m perforated interval (in this case, the flow rate had stabilised as the pump had reached its operational limits). Future operations at Gunn will aim to establish a pilot production scheme to convert the current resources to a CSG reserve (Comet Ridge, 2013a). In addition, a new appraisal well (Harrington 1) was spudded (i.e. drilling began) in mid-May 2014 approximately 24 km to the north-east of Gunn 2 (in EPP 1015), to further evaluate the CSG potential of the Betts Creek beds in this area. The Harrington 1 well was cased and suspended in June 2014 after reaching a total depth of 1042 m and intersecting 19 m of net coal (Comet Ridge, 2014). Comet Ridge reported that gas was observed bubbling from the core when it was brought to surface.

Comet Ridge considers that the Galilee Basin continues to hold the greatest upside potential within their existing exploration portfolio (Comet Ridge, 2013b). Preliminary consideration of potential commercial options (all of which would require building new pipelines and associated infrastructure) for gas supplies extracted from the Gunn Project area includes:

- supplying gas (e.g. to use in gas-fired power stations) to the various coal mines slated for development in the east of the Galilee Basin
- supplying gas for manufacturing of liquefied natural gas (LNG) at the Gladstone processing facility
- input to the domestic or industrial gas supply network.

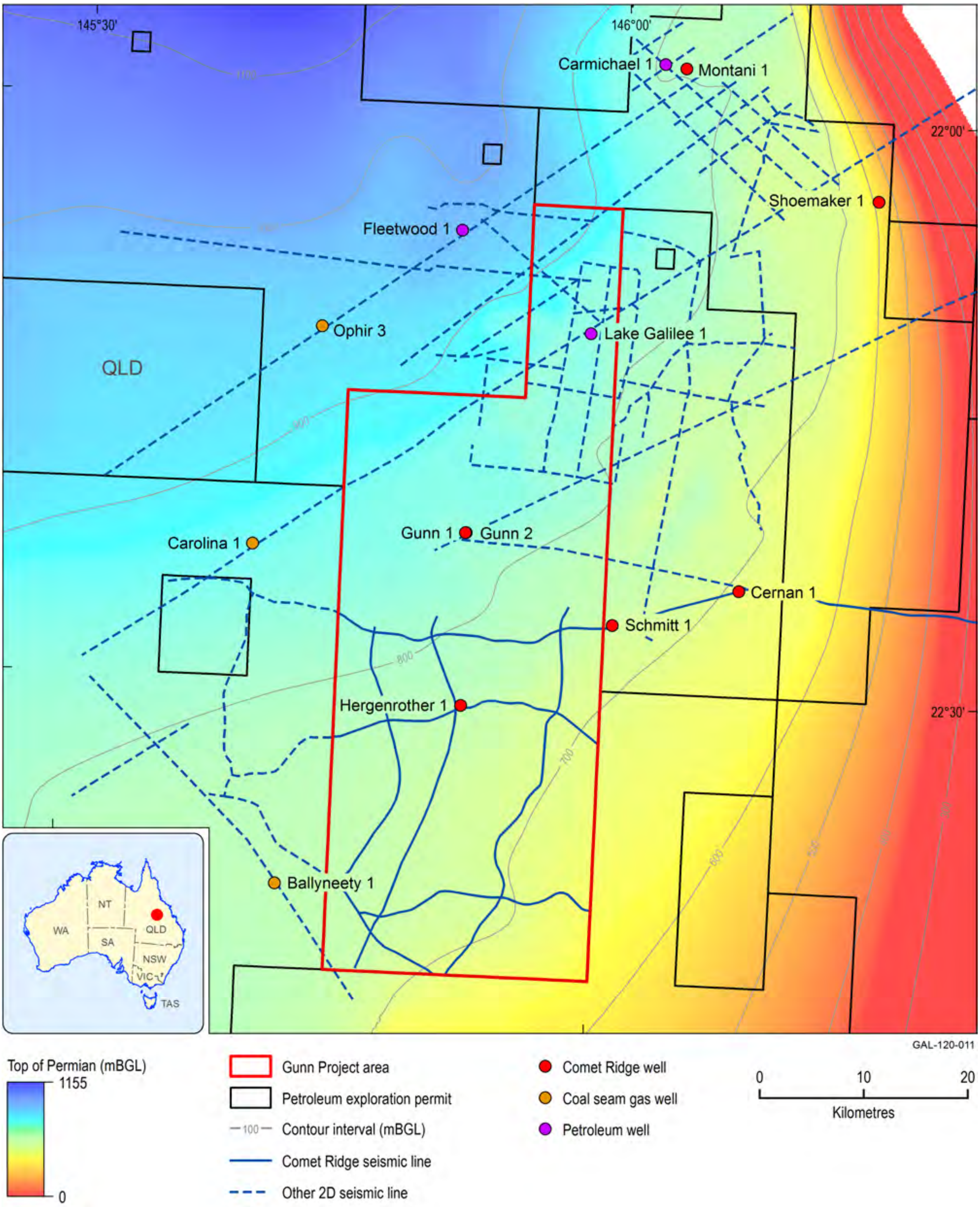



**Figure 18 Gunn Coal Seam Gas Project area in Galilee Basin**

Source data: Top of Permian data after Bradshaw et al. (2009), seismic lines from Comet Ridge (2013a), exploration permits for petroleum from Queensland DNRM (2014a) and well locations from Queensland DNRM (2014b).

### *Exploration permit for petroleum 813 – Blue Energy*

Petroleum exploration and development company Blue Energy hold EPP 813 in the central Galilee Basin, adjoining the prospective Comet Ridge tenements to the east and the Galilee Gas Project to the west. Initial results from the Carolina 1 well in 2008 led to an expanded programme of drilling four exploration wells in 2009 and 2010, and this work has resulted in an estimated 554 PJ contingent resource (3C) and a 1142 PJ prospective resource (Alpha Securities, 2011). Net coal intersections are thickest in the western part of the tenement (such as the 26.7 m total coal intersected in well Kanaka 1), as the basal Aramac Coal Measures do not occur in the eastern parts of the tenement. Analyses of coal samples have shown moderate gas contents of 3 to 6 $m^3$/t (DAF).

Blue Energy reported that the drilling of most of their exploration wells in EPP 813 proved difficult due to water-saturated sandstone aquifers that are in direct hydraulic contact with the target coal seams (Blue Energy, 2009). This meant that very large volumes of water were produced during the drilling process, severely hampering drilling efficiency. The permeability of target coal seams was also shown to be relatively low (0.5 to 5 md), and Blue Energy has suggested that horizontal drilling along coal seams would be the most productive well completion technique for future CSG operations (Blue Energy, 2013).

Alpha Securities (2011) undertook a commercial review of Blue Energy and suggested that, to further add to the CSG resource in EPP 813, Blue Energy should undertake a new phase of exploration well drilling. This should involve new coring to expand the gas resource base, and assist in locating a preferred site for future pilot production testing. Furthermore, Blue Energy (2009) have readily acknowledged the existing challenges of establishing commercial CSG flow rates in the Galilee Basin, and suggested that the most prospective areas may be where coals have been additionally ‘charged’ by a conventional petroleum system. The likelihood of identifying such areas (if they exist) is unknown.

The timing and scope of future work in EPP 813 is unclear, as most of Blue Energy’s recent focus appears to be on their CSG plays in the Bowen Basin (Blue Energy, 2013). They also hold significant tenement position in other proven and potentially productive unconventional hydrocarbon basins in eastern and central Australia, such as the Cooper, Surat, Maryborough and Carpentaria basins.

***Concluding comments on coal seam gas potential in Galilee Basin***

In contrast to successful CSG production pilots for AGL and Comet Ridge, several companies have recently decided to slow or discontinue their CSG exploration work and relinquish tenements in the Galilee Basin. Notable among these is Exoma Energy Limited (Exoma Energy) who (in JV partnership with the China National Offshore Oil Corporation (CNOOC) Galilee Gas Company Pty Ltd) undertook an extensive exploration campaign involving drilling and sampling of 19 exploration wells across multiple tenements in the northern and central Galilee Basin (Exoma Energy, 2013). In their 2013 annual company report Exoma Energy recognised that the geological conditions in their tenements were unlikely to favour supporting large scale CSG development. In particular, most coal seams that Exoma Energy had investigated were shown to be in direct hydraulic connection with extensive permeable sandstone aquifers (Exoma Energy, 2013). Consequently, gas content within most coal seams is relatively low (as gas has dispersed into the connected and more permeable sandstone aquifers), and unlikely to be suitable for large scale commercialisation.

In addition to the technical challenges of finding coal seams with sufficient gas content, one of the fundamental long-term challenges that confronts any commercial CSG operation in the Galilee Basin remains the lack of existing gas infrastructure to provide pipelines to market (Alpha

Securities, 2011). There may also be short- to medium-term problems in some areas in managing the overlap between resource tenements for coal mining, petroleum development, and possibly geothermal or carbon sequestration activities.

The infrastructure issues for CSG are similar to those faced by the coal mining industry in the basin, although planning for coal infrastructure development is considerably more progressed at this time. It is likely that the next decade will see continued focus on further exploration and appraisal work aimed at better understanding the geology and resource characteristics of CSG in the Galilee Basin. There is also likely to be an emphasis on converting existing contingent resources into proven and probable reserves (2P), for example, at relatively advanced testing sites such as Glenaras and Gunn. Given that much of the Galilee Basin remains relatively poorly explored for CSG to date, further exploration successes, and potentially new CSG field discoveries, remain a distinct possibility in coming years. This eventually may lead to commercial CSG production operations starting in the Galilee Basin, although the magnitude and location of any such areas (at least beyond those previously discussed in this report) is currently uncertain based on the limitations of existing data and information.

## *References*


Adani Mining (2012) Carmichael Coal Mine and Rail Project. Environmental impact statement. Viewed 20 August 2014, <http://www.adanimining.com/EIS-PDFDocs-Listing>.

Adani Mining (2013) Carmichael Coal Mine and Rail Project. Supplementary environmental impact statement. Viewed 20 August 2014, <http://www.adanimining.com/SEIS-PDFDocs-Listing>.

AGL (2009) Well completion report Glenaras 6, Galilee Basin, Queensland. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D63981&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

AGL (2013) Galilee Gas Project Agforce meeting, presentation.

Alpha Coal (2012) South Galilee Coal Project. Environmental impact statement. Viewed 20 August 2014, <http://www.southgalilee.com.au/SGCPEIS.aspx>.

Alpha Coal Management (2014) South Galilee Coal Project. Additional environmental impact statement, Volume 1. Viewed 21 August 2014, <http://eisdocs.dsdip.qld.gov.au/South%20Galilee%20Coal/AEIS/Volume%201.pdf>.

Alpha Securities (2011) Report on Blue Energy Ltd. Viewed 20 August 2014, <http://www.alphasecurities.com.au/files/research/Blue%20Energy%20%28Final%29%20-%2021%20October%202011.pdf>.

Blackwood Corporation (2013) Annual company report. Viewed 20 August 2014, <http://www.bwdcorp.com.au/images/pdfs/Blackwood%20Annual%20Report_2013.pdf>.

Blue Energy (2009) Well completion report Kanaka 1, exploration core hole. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.

tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D64629&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Blue Energy (2010) Well completion report Ballyneety 1, exploration core hole. Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D64671&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Blue Energy (2013) Annual company report. Viewed 20 August 2014, <http://www.blueenergy.com.au/files/media/bul_ar_2013_web.pdf>.

Bradshaw BE, Spencer LK, Lahtinen AC, Khinder K, Ryand DJ, Colwell JB, Chirinos A and Bradshaw J (2009) Queensland Carbon Dioxide Geological Storage Atlas. Department of Employment, Economic Development and Innovation, Queensland Government.

Coalbank (2013) Annual company report. Viewed 21 August 2014, <http://www.coalbank.com/coalbankmedia/2013_06_30_Annual_Report.pdf>.

Cockatoo Coal (2013) Annual company report. Viewed 1 August 2014, <http://www.cockatoocoal.com.au/index.cfm/investors/asx-reports1/annual-reports/>.

Cockatoo Coal (2014) JORC upgrades at South Pentland Project to 445 Mt. ASX announcement, 10 September 2014. Viewed 7 October 2014, <http://www.cockatoocoal.com.au/index.cfm/investors/asx-announcements/2014-asx-announcements/jorc-upgrades-at-south-pentland-project/>.

Comet Ridge (2013a) Comet Ridge's Galilee Basin extended production test project. Presentation to the Galilee Basin Coal and Energy Conference 2013. Viewed 20 August 2014, <http://www.cometridge.com.au/PDF/ASX26Nov_Galilee%20Basin%20Coal%20&%20Energy%20Conference%20Presentation.pdf>.

Comet Ridge (2013b) Galilee Basin projects. Viewed 29 May 2014, <http://www.cometridge.com.au/Projects_Galilee.htm>.

Comet Ridge (2014) Australian Securities Exchange announcement, Harrington 1 well intersects 19 m net coal in Galilee Basin. Viewed 20 August 2014, <http://www.cometridge.com.au/PDF/ASX13June14_Harrington%201%20well%20intersects%2019m%20net%20coal%20in%20Galilee%20Basin.pdf>.

Cuesta (2013) Quarterly activities report to Australian Securities Exchange for the period ending 31 December 2013. Viewed 21 August 2014, <http://www.cuestacoal.com.au/wp-content/uploads/2014/02/131231_Quarterly_Report_period_ending_31_December_2013_Final-for-release.pdf>.

DSDIP (2013) Galilee Basin Development Strategy. Queensland Department of State Development, Infrastructure and Planning. Viewed 7 October 2014, <http://www.dsdip.qld.gov.au/resources/plan/galilee-basin-strategy.pdf>.

DSDIP (2014a) Coordinated projects. Queensland Department of State Development, Infrastructure and Planning. Viewed 4 June 2014, <http://www.dsdip.qld.gov.au/assessments-and-approvals/coordinated-projects.html>.

DSDIP (2014b) Galilee Basin State Development Area. Queensland Department of State Development, Infrastructure and Planning. Viewed 27 August 2014, <http://www.dsdip.qld.gov.au/coordinator-general/galilee-basin-state-development-area.html>.

EER (2013) Annual company report. East Energy Resources. Viewed 20 August 2014, <http://www.eastenergy.com.au/wp-content/uploads/2011/03/East-Energy-Annual-Report-for-web.pdf>.

EER (2014) East Energy reports 3.44 billion tonnes JORC resource for Blackall Project. East Energy Resources ASX announcement, 10 July 2014. Viewed 7 October 2014, <http://www.eastenergy.com.au/wp-content/uploads/2011/03/EER-ASX-20140710-EER-announces-3-44Bt-JORC-final.pdf>.

EEA (1992) Well completion report Rodney Creek 1, Galilee Basin. Enron Exploration Australia Viewed 20 August 2014, <https://qdexguest.deedi.qld.gov.au/portal/site/qdex/template.PAGE/search/?javax.portlet.tpst=c59371e644a51ca46a5e5410866d10a0&javax.portlet.prp_c59371e644a51ca46a5e5410866d10a0=action%3DdoReportDisplay%26id%3D28223&javax.portlet.begCacheTok=com.vignette.cachetoken&javax.portlet.endCacheTok=com.vignette.cachetoken>.

Exoma Energy (2013) Annual company report. Viewed 20 August 2014, <http://www.exoma.net/irm/content/ar2013/index.html#/10/>.

Fox Resources (2014) Fox Resources coal exploration. Viewed 1 August 2014, <http://www.foxresources.com.au/coal-exploration.asp>.

GA and BREE (2013) Australia's Mineral Resource Assessment 2013. Geoscience Australia and Bureau of Resources and Energy Economics, Canberra. Viewed 20 August 2014, <http://www.ga.gov.au/data-pubs/data-and-publications-search/publications/australian-minerals-resource-assessment#heading-1>.

GA and BREE (2014) Australian Energy Resource Assessment. 2nd ed. Geoscience Australia, Canberra. Viewed 4 August 2014, <http://www.ga.gov.au/corporate_data/79675/79675_AERA.pdf>.

Google (2013) Google earth version 7.1.2.2041. Google, California.

Guildford Coal (2013) Annual company report. Viewed 20 August 2014, <http://www.guildfordcoal.com.au/wp-content/uploads/2014/05/GUF-2013-ASX-291-Annual-Report-to-Shareholders.pdf>.

Guildford Coal (2014a) Clyde Park Coal. Viewed 27 May 2014, <http://www.guildfordcoal.com.au/australian-projects/white-mountain/>.

Guildford Coal (2014b) Notice of intention of off-market takeover received. ASX announcement, 24 September 2014. Viewed 7 October 2014, <http://www.guildfordcoal.com.au/wp-content/uploads/2014/09/ASX-Announcement-Notice-of-intention-of-Off-Market-Takeover-received.pdf>.

Hancock Prospecting (2010) Alpha Coal Project. Environmental impact statement. Volume 2, section 4, geology. Viewed 20 August 2014, <http://www.gvkhancockcoal.com/documents/Publications/EIS/ACPEIS2010/Vol2/Section%2004%20Geology.pdf>.

Hancock Prospecting (2011) Alpha Coal Project. Supplementary environmental impact statement. Viewed 20 August 2014, <http://www.gvkhancockcoal.com/our-assets/alpha#alpha-coal-project-supplementary-eis-2011>.

Hancock Galilee (2011) Kevin's Corner Project. Environmental impact statement. Volume 1, section 4, geology. Viewed 20 August 2014, <http://www.gvkhancockcoal.com/documents/Publications/EIS/KevinsCornerEIS2011/Vol1/Volume%201%20Section%2004%20Geology.pdf>.

Hancock Galilee (2012) Kevin's Corner Project. Supplementary environmental impact statement. Viewed 20 August 2014, <http://www.gvkhancockcoal.com/our-assets/kevin-s-corner>.

Macmines Austasia (2011) EPC 987 – Regional geology. Viewed 22 May 2014, <http://www.macmines.com/english/cumentproject/cumentproject.asp?ID=628>.

Macmines Austasia (2012) Project China Stone. Initial advice statement. Viewed 20 August 2014, <http://www.dsdip.qld.gov.au/resources/project/china-stone-coal-project/china-stone-coal-project-ias.pdf>.

Mutton AJ (2003) Queensland coals. Physical and chemical properties. Colliery and company information (14th ed). Department of Natural Resources and Mines, Brisbane. Viewed 20 August 2014, <http://mines.industry.qld.gov.au/assets/coal-pdf/qld_coals_2003.pdf>.

Mulder P (2013) GVK Hancock's Galilee Basin Assets. Presentation to Brisbane Mining Club Forum. Viewed 20 August 2014, <http://www.brisbaneminingclub.com.au/event_archive_pdfs/2013/BMC%20Paul%20Mulder%20Presentation_290813.PDF>.

Pangaea Resources (2014) Galilee Basin. Viewed 29 May 2014, <http://www.pangaea.net.au/operating-areas/galilee-basin>.

Price B (2011) We would love control: Vale. International Longwall News. Viewed 23 June 2014, <http://www.aquilaresources.com.au/files/International%20Longwall%2024062011.pdf>.

Queensland Coordinator-General (2012) Alpha Coal Project. Coordinator-General's evaluation report on the environmental impact statement. Brisbane. 387p. Viewed 20 August 2014, <http://www.dsdip.qld.gov.au/resources/project/alpha-coal-project/alpha-coal-cg-report-final-sig.pdf>.

Queensland Coordinator-General (2013) Galilee Coal Project (Northern Export Facility). Coordinator-General's evaluation report on the environmental impact statement. Brisbane. 267p. Viewed 20 August 2014, <http://www.dsdip.qld.gov.au/resources/project/china-first-coal/galilee-coal-cg-report.pdf>.

Queensland Coordinator-General (2014) Carmichael Coal Project. Coordinator-General's evaluation report on the environmental impact statement. Brisbane. 585p. Viewed 20 August 2014, <http://www.dsdip.qld.gov.au/resources/project/carmichael/carmichael-coal-mine-and-rail-cg-report-may2014.pdf>.

Queensland DNRM (2014a) Current exploration permits coal (EPC). [Digital dataset, current as of 4 March 2014]. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 12 May 2014, <http://www.mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>.

Queensland DNRM (2014b) Current exploration permits petroleum (EPP). Digital dataset, current as of 28 July 2014. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 28 July 2014, <http://www.mines.industry.qld.gov.au/geoscience/interactive-resource-tenure-maps.htm>.

Queensland DNRM (2014c) Coal seam gas well locations – Queensland. Digital dataset, current as of 6 August 2014. Queensland Department of Natural Resources and Mines, Brisbane. Viewed 20 August 2014, <https://data.qld.gov.au/dataset/queensland-borehole-series/resource/7b813f3f-2f8f-45dc-b916-728da2cd91cd?inner_span=True>.

Queensland Government (2012) Two rail corridors defined for Galilee Basin. Media statement, Deputy Premier, Minister for State Development, Infrastructure and Planning, The Honourable Jeff Seeney. 6 June 2012. Viewed 27 August 2014, <http://statements.qld.gov.au/Statement/2012/6/6/two-rail-corridors-defined-for-galilee-basin>.

Resolve Coal (2009) Resolve exploration and mining. Viewed 28 May 2014, <http://www.resolve-geo.com>.

Resolve Coal (2014) The Hyde Park Coal Project. Viewed 30 May 2014, <http://www.hydeparkcoal.com.au/>.Scott SG, Beeston JW, and Carr AF (1995) Galilee Basin. In: Ward CR (ed.) Geology of Australian coal basins. Geological Society of Australia, Sydney.

The Australian (2013) Vale to sell Degulla mine as coal price falls. Viewed 27 May 2014, <http://www.theaustralian.com.au/business/mining-energy/vale-to-sell-degulla-mine-as-coal-price-falls/story-e6frg9df-1226672230219#mm-premium>.

Waratah Coal (2011) Galilee Coal Project. Environmental impact statement. Viewed 20 August 2014, <http://www.waratahcoal.com/publications.htm>.

Waratah Coal (2013a) Galilee Coal Project. Supplementary environmental impact statement. Viewed 20 August 2014, <http://www.waratahcoal.com/publications.htm>.

Waratah Coal (2013b) Alpha North Coal Project. Brochure at Beijing Coaltrans Conference. Viewed 20 August 2014, <http://cloud2.snappages.com/7d02db4f8251a7a309f60c63fa1c911fdf2eb346/07%20Alpha%20North%20Coal%20Project.pdf>.

Waratah Coal (2014a) Alpha North Coal. Viewed 27 May 2014, <http://www.waratahcoal.com/alpha-north-coal-project>.

Waratah Coal (2014b) Carmichael East Coal. Viewed 27 May 2014, <http://www.waratahcoal.com/carmichael-east-coal.htm>.

Xenith (2013) Resource statement and independent geological appraisal for Pentland Project.

## 1.2.4 Catalogue of potential resource developments


**Summary**

There are currently 20 thermal coal deposits defined in the geological Galilee subregion with a combined identified resource tonnage (based on publicly released coal resource data) totalling about 36 billion tonnes. Most of these resources are hosted in Permian rocks that are close to surface along the eastern basin margin, extending in an arcuate zone from the central to the northern part of the subregion (Figure 12 in Section 1.2.3). However, there are also several identified coal resources south of Blackall which are hosted in Cretaceous rocks of the Eromanga Basin, younger than most other coal resources in the Galilee subregion.

There are three coal seam gas (CSG) prospects in the basin for which contingent resources (2C and 3C) have been defined. The coal and CSG projects listed in this catalogue are considered to be those which could potentially be developed into commercially producing mines or production fields at some time in the future, for example, within the next 10 to 20 years. Further analysis of each resource project listed in this catalogue will be used to determine the most likely coal resource development pathway in the Galilee subregion. The coal resource development pathway will then be reported in the product 2.3 for the Galilee subregion (conceptual modelling).


Potential coal resource developments in the Galilee subregion are listed alphabetically in Table 13 and shown in Figure 12 of Section 1.2.3. Most of these 20 coal deposits have an identified coal resource, as defined using the terminology of the Australian national classification system for mineral resources. This means that, as a minimum requirement, there is at least an inferred resource publically available, as reported in accordance with the JORC Code (refer to Appendix 1 in GA and BREE (2013) for further information on the resource classification schemes mentioned here). In some cases, the more advanced development projects also have measured and/or indicated resource estimates, indicating that there is an increased level of geological understanding about these resources.

The deposits listed in Table 13 are considered to be those within the Galilee subregion that could potentially be developed into commercially operating mines at some stage in the future. Two of the deposits mentioned previously in this report – Carmichael East and Degulla – are included in this catalogue even though it is currently unclear if a coal resource (as reported in accordance with the JORC Code) has been estimated. An assessment of the likelihood for each of the listed resource projects to be developed into a mining operation will be undertaken during the model-data analysis stage of the Galilee bioregional assessment (component 2). This analysis work will help to determine the coal resource development pathway in the subregion, which will be reported in product 2.3 for the Galilee subregion.

The potential coal seam gas (CSG) resource developments in the Galilee subregion are listed in Table 14. These three CSG plays all have current estimates for contingent resources (2C and 3C). Thus, there are currently no CSG commercial reserves (proved, probable or possible) identified within the subregion. Similar to the coal resources, further analysis of these CSG plays in the

Galilee Basin will be undertaken to determine the CSG projects to be included in the Galilee coal resource development pathway.

**Table 13 Catalogue of potential coal resource developments in the Galilee subregion**

| Project name | Company | Longitude | Latitude | Record date[a] | Material[b] | Total coal resources[c] (Mt) | Status of EIS[d] | Notes |
|---|---|---|---|---|---|---|---|---|
| Alpha | GVK Hancock | 146.4239° | –23.2170° | November 2010 (EIS submission) | Thermal coal | 1821 | EIS approved | Proposed Alpha development is in mining lease application (MLA) 70426 (lodged December 2009). Current coal resource comprises 821 Mt measured + 700 Mt indicated + 300 Mt inferred, and is mostly from the C and D coal seams. Geological and resource information in Alpha Coal Project EIS – Section 4 (Geology) |
| Alpha North | Waratah Coal Pty Ltd (Waratah Coal) | 146.5700° | –22.7600° | 2013 | Thermal coal | 3480 | Pre-EIS | The Alpha North project is in MLA 70489 (lodged November 2012). Further mining proposal details at Waratah Coal – Alpha North Coal Project website (Waratah Coal, 2014a) |
| Alpha West | GVK Hancock | 146.3444° | –23.2254° | August 2013 (company presentation) | Thermal coal | 1800 | Pre-EIS | Proposed Alpha West development is in mineral development licence (MDL) 285 (granted March 2008). Total coal resource consists of indicated + inferred. Located immediately west of Alpha, initial concept plan indicates an underground longwall mining operation |
| Blackall | East Energy Resources Limited | 145.4164° | –24.8565° | July 2014 (ASX announcement) | Thermal coal | 3445 | Pre-EIS | The Blackall Coal Project is in MDL 464 (granted July 2014). Total coal resource consists of 628 Mt indicated + 2817 Mt inferred across three resource areas south of Blackall |
| Carmichael | Adani Mining Pty Ltd | 146.3220° | –22.0180° | November 2013 (SEIS submission) | Thermal coal | 10150 | EIS approved | Proposed Carmichael development is in MLA 70441 (lodged November 2010, not yet granted), as well as MLA 70505 and MLA 70506 (lodged July 2013). Total coal resource consists of 1160 Mt measured, 3240 Mt indicated + 5740 Mt inferred, and is mostly in A-B and D coal seams. Resource details stated in Carmichael Coal Mine and Rail Project Supplementary EIS |

| Project name | Company | Longitude | Latitude | Record date[a] | Material[b] | Total coal resources[c] (Mt) | Status of EIS[d] | Notes |
|---|---|---|---|---|---|---|---|---|
| Carmichael East | Waratah Coal | 146.3747 | –22.4367° | unknown | Thermal coal | unknown | Pre-EIS | Carmichael East project is in the same mining lease application area as Alpha North (MLA 70489). A resource exploration target of 9000 Mt is quoted by Waratah Coal (2014b), but there is no indication of an identified resource reported in accordance with the JORC Code |
| China First | Waratah Coal | 146.2924° | –23.3747° | September 2011 (EIS submission) | Thermal coal | 3680 | EIS approved | Proposed China First development is in MLA 70454 (lodged May 2011, not yet granted). Total coal resource consists of 1975 Mt measured + 565 Mt indicated + 1140 Mt inferred. Resource details stated in Galilee Coal Project EIS (Volume 2, Chapter 1 – Project description) |
| China Stone | Macmines Austasia Pty Ltd | 146.1594° | –21.7795° | June 2011 | Thermal coal | 3786 | EIS in preparation | Proposed China Stone development is covered by five separate MLAs, lodged in February 2014 (not yet granted). These are MLAs 70514, 70515, 70516, 70517 and 70518. Total coal resource consists of 286 Mt indicated + 3500 Mt inferred. A significant exploration target of 9800 Mt is estimated for the entire exploration permit for coal (EPC) 987 |
| Clyde Park | Guildford Coal Limited (Guildford Coal) | 145.1500° | –20.4500° | February 2013 (ASX announcement) | Thermal coal | 728 | Pre-EIS | Clyde Park is in MLA 103689 (lodged December 2012, not yet granted). Total coal resource consists of 51 Mt indicated + 677 Mt inferred. There is also a 40 to 815 Mt resource exploration target in adjacent EPC 1250 |
| Degulla | Vale Coal Exploration Pty Ltd | 146.4786 | –22.5436° | unknown | Thermal coal | unknown | Pre-EIS | Degulla is in EPC 1078. A production rate of 20 to 40 Mt/year has been previously estimated as possible for Degulla (Price, 2011). This suggests that the total resource may be greater than one billion tonnes of raw coal, although the identified resource tonnage is not currently publicly available |

| Project name | Company | Longitude | Latitude | Record date[a] | Material[b] | Total coal resources[c] (Mt) | Status of EIS[d] | Notes |
|---|---|---|---|---|---|---|---|---|
| Hughenden | Guildford Coal | 144.3330° | –20.3600° | February 2013 (ASX announcement) | Thermal coal | 1209 | Pre-EIS | The Hughenden Coal Project consists of numerous coal exploration tenements. The total resource at Hughenden reported in accordance with the JORC Code is 133 Mt indicated + 1076 Mt inferred which is from EPC 1477 and EPC 1478 (currently no MDL or MLA tenements) |
| Hyde Park | Resolve Coal Pty Ltd | 146.2443° | –21.5431° | November 2013 (company presentation) | Thermal coal | 1694 | Pre-EIS | The Hyde Park Coal Project is in EPC 1754 and EPC 2050. The total resource consists of 364 Mt indicated + 1330 Mt inferred, and is mostly in A and B, and C and D coal seams |
| Inverness | Coalbank Ltd | 145.4167° | –24.6667° | September 2012 (ASX announcement) | Thermal coal | 1300 | Pre-EIS | The Inverness Coal Project is in EPC 1993 and EPC 1719 (currently no MDL or MLA tenements). About 825 Mt of the total inferred resource of 1300 Mt occurs at depth of less than 50 m below surface |
| Kevin's Corner | GVK Coal Developers Pty Ltd | 146.4442° | –23.0528° | March 2010 | Thermal coal | 4269 | EIS approved | Proposed Kevin's Corner development is in MLA 70425 (lodged December 2009, not yet granted). The total coal resource consists of 229 Mt measured + 1040 Mt indicated + 3000 Mt inferred, to be mined from the A, B, C and D coal seams. Geology and resource data in Kevin's Corner Coal Project EIS – Section 4 (Geology) |
| Milray | Glencore Coal Queensland Pty Ltd (Glencore) | 145.6370° | –20.7464° | unknown | Thermal coal | 610 | Pre-EIS | Milray coal deposit is in EPC 771 (currently no MLA or MDL tenements). The total coal resource is inferred only |
| Pentland | Glencore | 145.1986° | –20.6335° | unknown | Thermal coal | 100 | Pre-EIS | Pentland Coal Project is in MDL 356 (granted in September 2006). The total coal resource consists of 65 Mt measured + 15 Mt indicated + 20 Mt inferred |
| South Galilee | AMCI – Bandanna Energy | 146.4604° | –23.7350° | October 2012 (EIS submission) | Thermal coal | 1179 | EIS submitted | Proposed South Galilee development is in MLA 70453 (lodged May 2011, not yet granted). The total coal resource consists of 167 Mt measured + 206 Mt indicated + 806 Mt inferred, within the D1 and D2 coal seams |

| Project name | Company | Longitude | Latitude | Record date[a] | Material[b] | Total coal resources[c] (Mt) | Status of EIS[d] | Notes |
|---|---|---|---|---|---|---|---|---|
| South Pentland | Cockatoo Coal Pty Ltd | 145.4713° | –20.7060° | September 2014 | Thermal coal | 445 | Pre-EIS | The South Pentland Coal Project is in EPC 1486 (currently no MLA or MDL tenements). The total coal resource consists of 94 Mt indicated and 351 Mt inferred. Exploration activities at South Pentland were undertaken by Blackwood Corporation prior to corporate takeover by Cockatoo Coal in February 2014 (Cockatoo Coal, 2014) |
| West Pentland | New Emerald Coal Ltd (NEC) | 145.3700° | –20.6110° | August 2013 | Thermal coal | 266 | Pre-EIS | The West Pentland Coal Project is in MDL 361 (granted in January 2012) and EPC 526. The total coal resource consists of 176 Mt indicated + 90 Mt inferred, contained within 5 mineable seams. NEC is wholly owned by Linc Energy Ltd. NEC generally refer to MDL 361 as the Pentland Coal Deposit, but it is here termed West Pentland to distinguish it from the earlier named Pentland Coal Deposit owned by Glencore (situated immediately east of West Pentland in MDL 356 |
| Yellow Jacket | Cuesta Coal Limited | 146.2722° | –21.7442° | October 2013 | Thermal coal | 364 | Pre-EIS | The Yellow Jacket Project (also known as East Galilee) occurs in EPC 1802. An inferred resource is defined, with further work planned to upgrade to an indicated resource in future. The deposit occurs east of the previously defined Galilee Basin boundary |

[a]The record date is the most recent date available for updated coal resource numbers.
[b]Materials fall into one of the following four classes: thermal coal, coking coal, 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 project within an environmental impact statement (EIS): pre-EIS, EIS in preparation, EIS submitted, EIS closed, supplementary EIS and EIS approved.
Mt – million tonnes

**Table 14 Catalogue of potential coal seam gas resource developments in the Galilee subregion**

| Project name | Company | Longitude | Latitude | Record date[a] | Contingent coal seam gas resource[b] (PJ) | Status of EIS[c] | Notes |
|---|---|---|---|---|---|---|---|
| EPP 813 | Blue Energy Limited | 145.2510° | –22.8542° | June 2011 | 2C resource of 43 PJ and 3C resource of 544 PJ | Pre-EIS | Resource is in part of EPP 813 in central Galilee Basin, in which there is also an identified 1142 PJ of prospective resources |
| Galilee Gas Project (Glenaras) | AGL Energy | 144.7242° | –23.0962° | June 2011 | 2C resource of 259 PJ and 3C resource of 1090 PJ | Pre-EIS | Resource is in part of exploration permit for petroleum (EPP) 529, and focused on the Glenaras production pilot which has five test wells |
| Gunn | Comet Ridge Limited | 145.8681° | –22.3671° | October 2010 | 2C resource of 67 PJ and 3C resource of 1870 PJ | Pre-EIS | Resource is in part of EPP 744, in which there is also an identified 597 PJ of prospective resources |

[a]The record date is the most recent date for updated coal seam gas resource numbers.
[b]Based on the classification scheme of the Petroleum Resource Management System of the Society of Petroleum Engineers (PRMS-SPE).
[c]The status of the project within an environmental impact statement (EIS): pre-EIS, EIS in preparation, EIS submitted, EIS closed, supplementary EIS and EIS approved.
PJ – petajoules

### *References*

Cockatoo Coal (2014) JORC upgrades at South Pentland Project to 445 Mt. ASX announcement, 10 September 2014. Viewed 7 October 2014, <http://www.cockatoocoal.com.au/index.cfm/investors/asx-announcements/2014-asx-announcements/jorc-upgrades-at-south-pentland-project/>.

GA and BREE (2013) Australia’s Mineral Resource Assessment 2013. Geoscience Australia and Bureau of Resources and Energy Economics, Canberra. Viewed 5 August 2013, <http://www.ga.gov.au/data-pubs/data-and-publications-search/publications/australian-minerals-resource-assessment>.

Price B (2011) We would love control: Vale. International Longwall News. Viewed 23 June 2014, <http://www.aquilaresources.com.au/files/International%20Longwall%2024062011.pdf>.

Waratah Coal (2014a) Alpha North Coal. Viewed 27 May 2014, <http://www.waratahcoal.com/alpha-north-coal-project>.

Waratah Coal (2014b) Carmichael East Coal. Viewed 27 May 2014, <http://www.waratahcoal.com/carmichael-east-coal.htm>.

# Appendix A

## A.1 Classification scheme for coal

The American Society for Testing and Materials (ASTM) classification scheme for coal rank, referred to in places throughout this report, is shown below.

| Class | Group | Fixed Carbon Limits (Dry, Mineral-Matter-Free Basis) (%) | | Volatile Matter Limits (Dry, Mineral-Matter-Free Basis) (%) | | Calorific Value Limits (Moist [A], Mineral-Matter-Free Basis) (Mj/kg) | | Agglomerating Character |
|---|---|---|---|---|---|---|---|---|
| | | Equal or greater than | Less than | Greater than | Equal or less than | Equal or greater than | Less than | |
| Anthracite | Meta-anthracite | 98 | | | 2 | | | Nonagglomerating |
| | Anthracite | 92 | 98 | 2 | 8 | | | |
| | Semianthracite [B] | 86 | 92 | 8 | 14 | | | |
| Bituminous | Low volatile bituminous coal | 78 | 86 | 14 | 22 | | | Commonly agglomerating [D] |
| | Medium volatile bituminous coal | 69 | 78 | 22 | 31 | | | |
| | High volatile A bituminous coal | | 69 | 31 | | 32.6 [C] | | |
| | High volatile B bituminous coal | | | | | 30.2 [C] | 32.6 | |
| | High volatile C bituminous coal | | | | | 26.7 | 30.2 | |
| | | | | | | 24.4 | 26.7 | Agglomerating |
| Subbituminous | Subbituminous A coal | | | | | 24.4 | 26.7 | Nonagglomerating |
| | Subbituminous B coal | | | | | 22.1 | 24.4 | |
| | Subbituminous C coal | | | | | 19.3 | 22.1 | |
| Lignite | Lignite A | | | | | 14.7 | 19.3 | |
| | Lignite B | | | | | | 14.7 | |

GAL-120-019

**A.** Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.
**B.** If agglomerating, classify in low volatile group of the bituminous class.
**C.** Coals having 69% or more fixed carbon on a dry, mineral-matter-free basis are classified according to fixed carbon, regardless of calorific value.
**D.** There may be nonagglomerating varieties in these groups of the bituminous class, with notable exceptions in the high volatile C bituminous group.

**Figure 19 Classification of coals by rank**

Source: modified after Wood et al. (1983)

# A.2 Mineral and petroleum tenure types in Queensland

## A.2.1 Tenure types for coal

The Queensland *Mineral Resources Act 1989* is the relevant legislation providing the framework for the exploration, development and tenure of coal resources in Queensland. There are several different types of tenement granted and administered under this Act, and these are summarised below. Further information about relevant legislation for coal tenements is available from the Queensland Department of Natural Resources and Mines.

An *exploration permit for coal* (EPC) is issued (usually to a private or publically listed company) for the purpose of allowing exploration work for coal. The permit allows the holder to undertake activities to determine the existence, quality and quantity of coal in the tenement area. This may include prospecting, mapping, geophysical surveys, drilling, and sampling/analysis of materials. These can be granted for up to five years, and can also subsequently be renewed. Depending on the success of the exploration work, part of the EPC may eventually lead to application for a mineral development licence or a mining lease.

A *mineral development licence* (MDL) is commonly regarded as a precursor to a mining lease. A MDL is used to permit more detailed investigation of mineral occurrences considered to have economic potential for further development. Activities permitted under auspices of a MDL include geoscientific programmes involving drilling and geophysical surveying (e.g. seismic reflection surveys), mining feasibility studies, and environmental, engineering and design studies.

A *mining lease* (ML) permits mining operations to occur and is granted specifically to extract the type of mineral resource (including coal) targeted by preceding exploration permits or mineral development licences. It effectively entitles the holder to use machinery to mine the specified mineral type, and to conduct the various associated activities of mining. A mining lease is not restricted to a maximum term; rather, the length of time that the ML operates for is determined (case-by-case) based on the amount of identified reserves and the expected life of mine. The size and shape of most mining leases differs based on the characteristics of the deposit.

## A.2.2 Tenure types for petroleum

The exploration, development and tenure types for petroleum resources (including coal seam gas, CSG) in Queensland are currently governed by the *Petroleum and Gas (Production and Safety) Act 2004* (the Act). Prior to 2004, similar matters were administered under the *Petroleum Act 1923*. To explore for CSG in Queensland a company (or individual) must be granted an *exploration permit for petroleum* (EPP), also known as an authority to prospect (ATP). An EPP is granted by the Minister for Natural Resources and Mines, following receipt of applications for the exploration permit which are submitted after a ministerial ‘call for tenders’.

An EPP can only be granted from a call for tenders under section 35 of the Act. There are certain requirements for making such a tender, especially around providing suitable details of an initial work program. These are specified in sections 37 and 48 of the Act and section 13 of the *Petroleum and Gas (Production and Safety) Regulation 2004*. In general, the details required about each applicant's proposed annual exploration and testing work plan must be provided for at least the first four years. The maximum area of any single EPP that can be published in a call for tenders is 100 blocks. Each block is approximately 67 $km^2$.

The maximum period for which an EPP can be granted is 12 years. There are also periodic requirements (at least every four years) to relinquish some areas of the tenement. This usually equates to 33% of the tenement area every four years.

Separate to an EPP, a *petroleum lease* (PL) gives the holder the right to explore, evaluate and produce petroleum (including CSG) within the PL area. The maximum size of a PL is 75 sub-blocks, and the maximum term is 30 years. To apply for a PL, an initial development plan must be submitted to provide details about the nature and extent of proposed activities.

### ***References***

Wood GH, Kehn TM, Devereux Carter, M and Culbertson WC (1983) Coal resource classification system of the U.S. Geological Survey. Geological Survey Circular 891, United States Geological Survey, Denver. Viewed 4 August 2014, <http://www.pubs.usgs.gov/circ/c891/>.

www.bioregionalassessments.gov.au

Australian Government
Department of the Environment
Bureau of Meteorology
Geoscience Australia

CSIRO