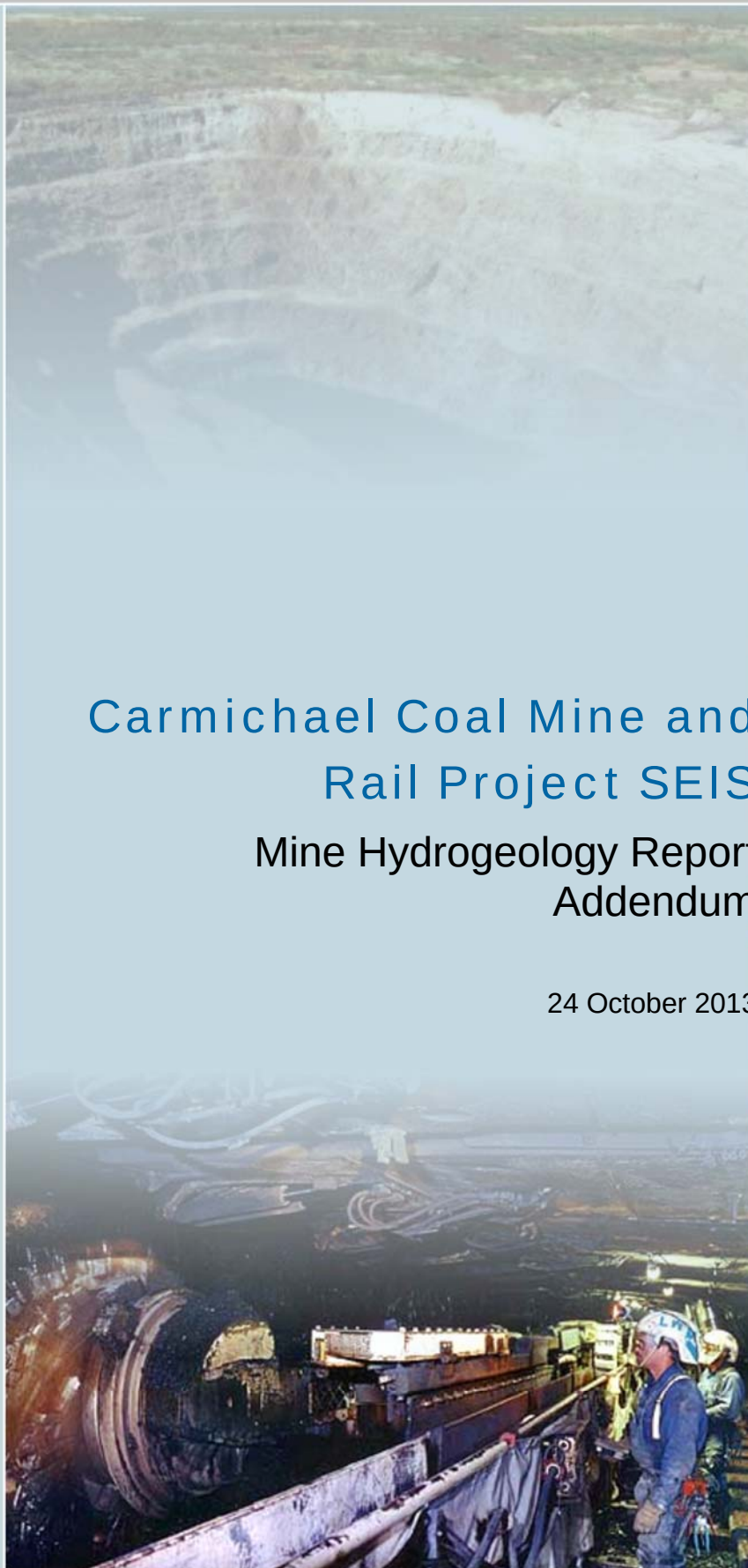




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adaniTM



**Carmichael Coal Mine and
Rail Project SEIS
Mine Hydrogeology Report
Addendum**

24 October 2013



Executive summary

Introduction and important notes

This addendum to the Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report (GHD, 2013) has been developed in response to comments received from a number of agency consultees including the DNR, DEHP, DoE and URS, who conducted a peer review of the numerical groundwater flow modelling component of the SEIS report.

Additional more detailed information to supplement the SEIS is presented relating to:

- The hydraulic properties of the Rewan Group and potential connectivity to the adjacent Great Artesian Basin (GAB);
- Groundwater flow directions;
- The key hydrogeological processes understood to be operating at the site (i.e. an overview of the conceptual model); and
- Groundwater model validation and sensitivity analysis.

It should be stressed whilst some additional work has been undertaken as part of this addendum and is summarised herein, the findings of this work are considered to be fully consistent with the work previously presented in the SEIS report. In particular, whilst a wide range of possible alternative scenarios have been explored as part of the sensitivity analysis work the 'best estimate' of the predicted impacts of the development, which are based on a calibrated model parameter set, are unchanged.

It should also be noted that all of the model based predictions included in the SEIS and this addendum are considered to be conservative. Actual impacts are therefore likely to tend towards the lower end of the impact ranges identified by the model sensitivity analysis. This reflects a general limitation of all numerical models of this type. The detailed geological information available for the site confirms that the majority of the strata present comprise alternating sequences of coal, siltstones, sandstones and mudstones. In general the more variable the strata which separate the unit to be de-watered (the Permian-age coal measures in this case) from the receptor of any impact (e.g. the Carmichael River or the Doongmabulla Spring) then the more significant attenuation of any impacts will be. Unfortunately it is not possible to accurately represent the complexity of these natural strata in a regional scale groundwater flow model and all models of this type therefore represent simplifications of a significantly more complex reality.

Rewan Group hydraulic conductivity

Site specific and regional data sets relating to the properties of the Rewan Group are presented and discussed. The main conclusions of this aspect the work are as follows:

- Project data sets confirm up to 250 m of Rewan Group strata towards the west of the Mine Area;
- Geological borehole logs confirm a highly variable interbedded sequence of claystones, siltstones, mudstones and fine to medium grained sandstones;
- Given the observed variable nature of the strata it is considered extremely unlikely that any vertical sequence will not include significant thicknesses of relatively fresh siltstone or claystone (i.e. relatively low permeability strata);

- In most vertical sequences a vertical hydraulic conductivity towards the lower end of the observed and/or literature ranges (i.e. as low as 8.6×10^{-7} m/d) is therefore anticipated;
- Analysis of regional test data for the Rewan Group suggest that 90 percent of the horizontal hydraulic conductivity values fall in the range 8.3×10^{-6} to 5.1×10^{-2} m/d and indicate a median value of 3.6×10^{-4} m/d;
- Site specific test results undertaken in weathered sandy clay return horizontal hydraulic conductivity values which range between 2.3×10^{-2} and 2.9×10^{-1} m/d;
- Site specific tests completed in unweathered siltstones returned values which range from 9.5×10^{-5} and 1.7×10^{-4} m/d (i.e. 3 to 4 orders of magnitude lower than the values returned for weathered strata).

Groundwater flow directions

Additional plots have been prepared showing:

- Calibrated steady state modelled groundwater level contours for key hydrogeological units;
- Observed groundwater levels for the Project monitoring network based on data for May/June 2013; and
- Average rest or standing water levels for nearby registered bores.

Both the observed and modelled data suggest flow in the Clematis Sandstone and the Dunda Beds towards the Carmichael River i.e. to the north-north east and south-south east. There is no evidence of flow towards the south west i.e. down dip into the main body of the GAB.

Groundwater flow contours for the underlying Permian-age strata also indicate groundwater flow in line with the topography from north west to south east across the northern part of the Mine Area and from west to east through central areas.

Hydrogeological processes

The key hydrogeological processes thought to be operating in the Project Area have been described based on the data and information provided in Section 4 of the Mine Hydrogeology SEIS report (GHD, 2013). These key processes are also illustrated in two illustrative sketch cross sections through the Mine Area and the Doongmabulla and Mellaluka spring complexes.

These sections and the associated text describe the following:

- The predominant groundwater recharge mechanism to groundwater is considered to be infiltration of rainfall to relatively permeable outcrop areas such as the Clematis Sandstone and the Dunda Beds;
- Minimal groundwater recharge is expected through the Tertiary-age clay which dominate the outcrop geology across the remainder of the Project Area
- Recharge rates of 0.1 to 4 mm/year are anticipated;
- Groundwater discharge within the Project Area is thought to be predominantly to the Carmichael River and the Doongmabulla spring complex area upstream of the Mine Area boundary and to the Mellaluka spring complex;
- The source aquifer for the GAB Doongmabulla spring complex is thought to be the Clematis Sandstone and/or the underlying Dunda Beds;
- The most likely source aquifer for the Mellaluka spring complex is thought to be the Permian-age units of the Colinlea Sandstone.

Further model validation

Further work has been carried out to validate modelled vertical gradients against observed vertical gradients across the mine site.

Modelled results suggest a generally good agreement between observed and modelled vertical gradients, a reflection of the good model calibration reported in the SEIS. Specifically the model replicates the direction of vertical flows at 17 out of 20 locations.

Additional drawdown mapping

A series of 35 additional maps showing the development of impacts through time in individual aquifers have been prepared to complement the maximum water table drawdown maps presented in the SEIS.

Modelled water balance errors

Cumulative water balance errors for the transient predictive simulation reported in the SEIS exceeded the 1 percent target recommended in the current Australian Groundwater Modelling Guidelines (National Water Commission, 2012). This has now been resolved by making some minor changes to the numerical solver parameters. Impacts calculated using the revised model are essentially identical to those previously calculated and hence no changes are required to the SEIS.

Revised sensitivity analysis presentation

A detailed analysis of the sensitivity of model predictions to a range of model parameters was previously presented in the SEIS. However, subsequent comments have suggested that this information could have been presented in a way which more clearly identifies the sensitivity of key impact predictions to modelled parameters. A series of revised plots were therefore developed to re-present the information with more clarity.

Maximum predicted impacts of 0.16 m drawdown in the Clematis Sandstone source aquifer are predicted at the Doongmabulla springs post closure based on the calibrated or 'best estimate' model parameters. Sensitivity analysis results, however, suggest that predicted impacts could range from 0.04 to 0.3 m if the actual hydraulic conductivity of selected strata differ significantly from the calibrated values.

Similarly based on the calibrated or 'best estimate' parameter set the predicted maximum long term drawdown impact in the Permian-age units (i.e. the source aquifer) at the Mellaluka Springs Complex is around 9 m. Sensitivity analysis results, however, suggest that predicted impacts could range from 2.2 to 18 m if the actual hydraulic conductivity of selected strata differ significantly from the calibrated values.

The best estimate of long term pit inflow to unremediated voids post closure based on the calibrated parameter set is around 2,400 m³/d. Sensitivity analysis results, however, suggest that predicted inflows could range from 1,500 to 4,000 m³/d if the actual hydraulic conductivity of selected strata differ significantly from the calibrated values.

Maximum predicted baseflow impact on the Carmichael River calculated using the calibrated model parameter set is around 1,000 m³/d. Sensitivity analysis results, however, suggest that predicted baseflow impacts could range from around 600 to 1,300 m³/d if the actual hydraulic conductivity of selected strata differ significantly from the calibrated values.

Additional sensitivity analysis

Additional sensitivity runs were also carried out with particular focus on the sensitivity of model predictions to:

- An expanded range of values for the hydraulic conductivity of the Rewan Group and modelled recharge quantities; and
- General head boundary conductance.

The calibrated horizontal hydraulic conductivity value for the Rewan Group of 7.4×10^{-5} m/d is:

- Well within the 5th and 95th percentile range of 8.3×10^{-6} to 5.1×10^{-2} m/d calculated from extensive regional data set collated for the Surat Cumulative Management Area Underground Water Impact Report and comparable to the median value of 3.6×10^{-4} m/d. (QWC, 2012 and GHD, 2012).
- Within the range of observed data from core test results at other proposed mining sites in the Galilee Basin (Heritage Computing, 2013) and towards the centre of a typical range for siltstone identified by Domenico & Schwartz (1990).

Furthermore the calibrated vertical hydraulic conductivity value of 7.4×10^{-6} m/d for the Rewan Group is also comparable (i.e. within an order of magnitude) to:

- Calibrated values for the Rewan Group obtained by other groundwater modelling studies completed in the area (Heritage Computing, 2013 and URS, 2012); and
- Calibrated values for the Rewan Group from other studies carried out elsewhere in Queensland (GHD, 2012, Matrix Plus, 2009).

The calibrated vertical hydraulic conductivity for the Rewan Group is, however, substantially lower than the upper bound calibrated vertical hydraulic conductivity of 1×10^{-3} m/d for GAB confining beds modelled by Audibert (1976) and quoted in the Galilee Basin groundwater study recently commissioned by the Lock the Gate Alliance (Hydrocology Environmental Consulting, 2013). It is not clear why the authors of this study have referenced the values calculated by Audibert (1976), in preference to other more recent studies, and there is some doubt as to whether these values are appropriate. Nevertheless the values estimated by Audibert (1976) have been adopted as upper bound values for the expanded sensitivity analysis in order to illustrate what the impacts on the Doongmabulla Springs might be in the extremely unlikely event that the actual bulk vertical hydraulic conductivity of the Rewan was as high as 1×10^{-3} m/d throughout the area. This scenario is considered unlikely since it would essentially require fresh siltstone and mudstone units to be entirely absent from the entire sequence throughout the whole area between the proposed Mine Area and the GAB. Given the thickness, depth and observed variability of the Rewan Group in this area the chances of this occurring are considered to be negligible.

The results of this extended sensitivity analysis suggest that maximum impacts at the Doongmabulla spring complex could be up to around 1 m in the event that the actual vertical hydraulic conductivity of the Rewan was 1×10^{-3} m/d as estimated by Audibert (1976) and close to zero if the lower bound value calibrated in the Surat CMA UWIR model (QWC, 2012) of 1×10^{-7} m/d was adopted. Results also suggest that the quantity of additional groundwater inflow induced from the GAB area into the adjacent Galilee Basin could range from 70 to 4,300 m³/d based on the same 'best' and 'worst' case values for the Rewan Group.

An extended range of recharge values from 0.004 to 33 mm/year has also been considered in the additional sensitivity analysis work. The calibrated recharge value is towards the lower end of this range and hence the majority of the recharge sensitivity analysis runs show less impact at the Doongmabulla spring complex, since higher modelled recharge values result in a smaller cone of influence.

For average recharge values greater than 15 mm/year model results suggest maximum drawdown impacts at Doongmabulla springs of less than 0.1 m. Maximum impacts based on the

lower bound recharge value tested are 0.18 m (i.e. only around 0.02 m higher than the calibrated or best estimate prediction quoted in the SEIS).

Additional sensitivity analysis results confirm that model predictions are insensitive to the conductance of the modelled general head boundaries.

Model predictions are also thought unlikely to be sensitive to initial conditions (i.e. whether the proposed mine commences operation in a dry, wet or average year) this assessment is based on:

- The generally relatively static groundwater level conditions observed at the site;
- The proposed 60 year mine life; and
- The long-time lags predicted between commencement of mining and any impacts

Table of contents

1.	Introduction	1
1.1	Purpose of this report	1
1.2	Scope.....	1
2.	Baseline Data Analysis and Conceptual Model Overview.....	2
2.1	Overview.....	2
2.2	Hydraulic properties of the Rewan Group	2
2.3	Groundwater flow directions	8
2.4	Hydrogeological processes.....	17
3.	Groundwater Modelling	23
3.1	Overview.....	23
3.2	Further model validation	23
3.3	Additional drawdown mapping	25
3.4	Resolution of elevated cumulative modelled water balance errors.....	27
3.5	Revised Sensitivity Analysis Presentation.....	29
3.6	Additional sensitivity analysis.....	36
4.	References	49

Table index

Table 1	Estimated Hydraulic Conductivity Values for the Rewan Group Carmichael Coal Project Site.....	7
Table 2	Comparison of Observed and Modelled Vertical Gradients – Riverside Bores.....	24
Table 3	Comparison of Observed and Modelled Vertical Gradients – North of the Carmichael River.....	24
Table 4	Comparison of Observed and Modelled Vertical Gradients – South of the Carmichael River.....	25
Table 5	Details of Spatial Drawdown Additional Mapping	26
Table 6	Sensitivity analysis– parameters and multipliers	29
Table 7	Sensitivity Analysis - Rewan Group Hydraulic Conductivity Scenarios.....	39
Table 8	Sensitivity Analysis – Recharge Scenarios.....	44
Table 9	Sensitivity Analysis – General Head Boundaries Multipliers	47

Figure index

Figure 1	Horizontal Hydraulic Conductivity, Rewan Group	6
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Figure 2	Modelled Groundwater Contours and Observed Groundwater Levels: Clematis Sandstone	10
Figure 3	Modelled Groundwater Contours and Observed Groundwater Levels: Dunda Beds	11
Figure 4	Modelled Groundwater Contours and Observed Groundwater Levels: Permian Overburden	12
Figure 5	Modelled Groundwater Contours and Observed Groundwater Levels: AB Seam.....	13
Figure 6	Modelled Groundwater Contours and Observed Groundwater Levels: Permian Interburden.....	14
Figure 7	Modelled Groundwater Contours and Observed Groundwater Levels: D Seam	15
Figure 8	Modelled Groundwater Contours and Observed Groundwater Levels: Permian below D Seam.....	16
Figure 9	Sketch Cross Section (west to east) through Doongmabulla Springs.....	18
Figure 10	Sketch Cross Section (west to east) through Mellaluka Springs	19
Figure 11	Comparison of Model Results at Doongmabulla Spring for Two Model Runs with Different Cumulative Water Balance Errors.....	28
Figure 12	Sensitivity Analysis – Doongmabulla Springs Maximum Impacts.....	32
Figure 13	Sensitivity Analysis – Mellaluka Springs Maximum Impacts.....	33
Figure 14	Sensitivity Analysis – Predicted Groundwater Inflow to Unremediated Voids	34
Figure 15	Sensitivity Analysis – Carmichael River Baseflow Impact.....	35
Figure 16	Summary of Rewan Group Hydraulic Conductivity Values Estimated by Other Modelling Studies	38
Figure 17	Sensitivity Analysis Rewan Group – Doongmabulla Springs Maximum Impacts	41
Figure 18	Sensitivity Analysis Rewan Group – GAB Groundwater Resource Impacts	43
Figure 19	Sensitivity Analysis Recharge – Doongmabulla Springs Maximum Impacts.....	46

Appendices

Appendix A –Additional Predictive Model Drawdown Maps

Appendix B – Typical Borehole Log Rewan Group

1. Introduction

1.1 Purpose of this report

This addendum is in response to comments received on the Carmichael Coal Mine and Rail SEIS Mine Hydrogeology Report (GHD, 2013). Comments were provided by the Department of Natural Resources and Mines (DNRM), the Department of Environment and Heritage Protection (DEHP), the Department of the Environment (DotE, formerly the Department of Sustainability Environment Water Population and Communities (SEWPaC)) and URS who conducted a peer review of the numerical groundwater flow modelling component of the report.

This addendum is designed to be read in conjunction with the Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report (GHD, 2013).

1.2 Scope

To present additional more detailed information to supplement the SEIS relating to:

- The hydraulic properties of the Rewan Group and potential connectivity to the adjacent Great Artesian Basin (GAB);
- Groundwater flow directions;
- The key hydrogeological processes understood to be operating at the site (i.e. an overview of the conceptual model); and
- Groundwater model validation and sensitivity analysis.

2. Baseline Data Analysis and Conceptual Model Overview

2.1 Overview

This section provides further information and analysis relating to:

- The hydraulic properties of the Rewan Group (Section 2.2);
- Groundwater flow directions (Section 2.3); and
- The key hydrogeological processes understood to be operating at the site (i.e. an overview of the conceptual model, Section 2.4).

2.2 Hydraulic properties of the Rewan Group

2.2.1 Introduction

Given the proximity of the Project Area to the GAB the bulk vertical hydraulic conductivity of the Rewan Group i.e. the basal aquitard of the GAB, is expected to represent a key parameter controlling the degree of connectivity between groundwater resources of the GAB and the Project Area. The potential groundwater impacts described in the SEIS (Section 5.6.6 GHD, 2012) include:

- Additional induced leakage of up to 2.2 ML/d from the GAB into the proposed mineworkings during the operational mining period; and
- Potential drawdown impacts of up to 0.19 m at the nearby GAB Doongmabulla Spring Complex.

Sensitivity analysis results presented in the SEIS (Section 5.8.2 GHD, 2012) suggest that these predicted impacts are relatively insensitive to the modelled hydraulic conductivity of the Rewan Group. However, this analysis only considered alternative values for the hydraulic conductivity of the Rewan Group which were within an order of magnitude of the calibrated values. Whilst this is considered to be consistent with normal practice for this kind of analysis other studies, including the Galilee Basin groundwater study recently commissioned by the Lock the Gate Alliance (Hydrocology Environmental Consulting, 2013), have quoted values for the Rewan Group which are outside of the range currently assessed. Further work has therefore been undertaken to:

- Review the available data relating to the the vertical and horizontal hydraulic conductivity of the Rewan Group with a view to identifying a range of possible values for the strata (see Sections 2.2.2 to 2.2.8); and
- Assess the sensitivity of key model predictions to this range of possible values (see Section 3.5 and 3.6).

2.2.2 General Description

The Rewan Group consists of interbedded green to reddish brown mudstone, siltstones and predominantly fine grained lithic sandstones with minor volcanolithic pebble conglomerate (at the base). The Rewan Group was deposited in a fluvial-lacustrine environment, typically forms a regionally significant confining unit and as such is considered to one of the main GAB aquitards.

2.2.3 Thickness and Extent

The Rewan Group is not mapped at outcrop anywhere within the Project Area but is present at subcrop beneath the overlying Tertiary cover over the much of the proposed of the Mine Area. Geological modelling of the Mine Area undertaken by Xenith Consulting, based on the extensive exploration drilling program, suggests that the limit of the Rewan Group lies close to the eastern boundary of the lease. The Rewan Group is therefore absent east of the Mine Area. In keeping with the other strata in the area the top of the Rewan dips towards the south west and attains a thickness of around 250 m close to the western boundary of the Mine Area. Elsewhere within the Galilee Basin Rewan Group thicknesses of up to 840 m are reported (RPS, 2012).

2.2.4 Degree of Weathering

Information is also available from the exploration drilling program on the degree and depth of weathering of the Rewan Group and other formations. The degree of weathering may be significant from a hydrogeological point of view since weathering may significantly enhance the hydraulic conductivity of the Rewan Group. Detailed information on the base of weathering is included in the project geological model which includes a base of weathering surface. Comparison of this surface with other modelled surfaces relating to the top and bottom of the Rewan Group allows a detailed picture of weathering in the Rewan Group to be developed. These data suggest up to 190 m of weathered Rewan strata in some places and since the base of the Rewan Group subcrops beneath the Tertiary-age cover close to the eastern boundary the full thickness of the Rewan Group is thought to be weathered across 10 percent of the Mine Area. However, exploration data also suggests:

- Only partial weathering of the Rewan Group over the remaining 90 percent of the Mine Area; and
- An average thickness of weathered Rewan strata of 55 m which equates to less than 21 percent of the 257 m average thickness of the Rewan Group.

Furthermore the minimum elevation of the base of the weathered Rewan Group within the Mine Area is 238 mAHD, whilst the top of the Rewan Group in the vicinity of the Doongmabulla spring complex is estimated to be at around around -200 mAHD (or around 400m below ground level). At this critical point close to the Doongmabulla spring complex it is therefore anticipated that the full thickness of the Rewan Group will be unweathered.

2.2.5 Typical Sequence

A typical geological log for an exploration borehole (C056C) penetrating the full thickness of the Rewan Group towards the west of the Mine Area is provided in Appendix B. Analysis of the geological information presented in this log which was derived from inspection of core log in this case indicates:

- Around 187 m of unweathered Rewan Group at this location; and
- 23 separate clay, claystone or siltstone horizons (i.e. strata likely to be characterised by relatively low hydraulic conductivity) any or all of which would be expected to significantly limit the effective vertical hydraulic conductivity of the Rewan Group.

2.2.6 Literature Values

Domenico and Schwartz (1990) quote a typical range of hydraulic conductivity values for siltstone of 8.6×10^{-7} to 1.2×10^{-3} m/d and 2.6×10^{-5} to 0.5 m/d for sandstone. Given the interbedded nature of the variable strata comprising the Rewan Group then based on these literature values hydraulic conductivity values of as low as 8.6×10^{-7} m/d might be expected in

tests completed in fresh siltstone strata and as high as 0.5 m/d in tests completed in highly weathered or sandstone horizons.

2.2.7 Regional data

Horizontal Hydraulic Conductivity (Kh)

The most comprehensive recent collation of data on the hydraulic properties of the Rewan Group is considered to be the analysis reported in Appendix C of the Surat CMA Underground Water Impact Report (QWC, 2012). This work, which was also undertaken by GHD, referenced some 822 estimates of hydraulic conductivity for the Rewan Group and other equivalent strata from Drill Stem Test (DST) results included in Queensland Petroleum Exploration Database (QPED), see Figure 1. As shown in Figure 1 these available data suggest that 90 percent of the horizontal hydraulic conductivity values for the Rewan Group fall in the range 8.3×10^{-6} to 5.1×10^{-2} m/d and suggest a median value of 3.6×10^{-4} m/d. The range of values returned by the regional test data are therefore comparable to the expected range suggested by the literature (Section 2.2.5). The available regional test data therefore also tends to confirm the extremely variable nature of the Rewan Group. For instance, as highlighted in Figure 1, 41 tests completed in the Glenmorgan 1 bore at depths ranging from 1605 to 1617 m below ground level (i.e. a test section of only around 12 m) returned hydraulic conductivity values which varied between 1.0×10^{-1} to 8.3×10^{-6} m/d (i.e. across four orders of magnitude).

The relatively large proportion of DST test results (6 percent) which return a value of 8.3×10^{-6} m/d is also considered worthy of comment. The 95th percentile of the regional data is the same as the minimum test value. This is considered likely to represent a physical constraint associated with DST test results and suggests that the regional test data may over-estimate the hydraulic conductivity of the Rewan Group towards the lower end of the theoretical range.

The only available information on the horizontal hydraulic conductivity of the Rewan Group from other Galilee Basin EIS projects is provided by laboratory permeameter test data for three samples submitted for testing as part of the Galilee Coal Project Groundwater Assessment report for Waratah Coal (Heritage Computing Pty Ltd, 2013). These test results indicate horizontal hydraulic conductivity values of between 4.5×10^{-5} and 4.3×10^{-3} m/d. Unsurprisingly, these test results fall well within the wide range of regional test data values.

Vertical Hydraulic Conductivity (Kv)

Reliable estimates of vertical hydraulic conductivity, for example from lab permeameter tests, are few and far between. However, lab permeameter data are reported for four tests undertaken in the Rewan Group in the Galilee Coal Project Groundwater Assessment report (Heritage Computing Pty Ltd, 2013). These results suggest vertical hydraulic conductivity values of between 7.5×10^{-6} and 1.1×10^{-2} m/d i.e. up to 570 times lower than the horizontal hydraulic conductivity values quoted above. The unusually high value of 1.1×10^{-2} m/d returned by one of the vertical tests was attributed to testing of near surface weathered strata (Heritage Computing, 2013).

Further information on typical ratios between horizontal and vertical hydraulic conductivity in similar strata is provided by a substantial laboratory testing program of several hundred core samples which was undertaken on the claystone aquitards of the Sydney Basin, NSW. Results for this study suggest vertical hydraulic conductivity values of between 500 and 1900 times less than horizontal (Merrick, 2010). Such differences between vertical and horizontal hydraulic conductivity are consistent with the highly stratified nature of the Rewan Group. In interbedded strata like the Rewan Group then the overall bulk vertical hydraulic conductivity of the Rewan Group will effectively be governed by the hydraulic conductivity of the least permeable unit present in the sequence. Given that the Rewan Group in the Mine Area is around 250 m thick

on average, predominantly relatively fresh and typically comprises interbedded mudstone, sandstones and siltstones then it is extremely unlikely that any vertical sequence will not include significant thicknesses of relatively fresh siltstone or mudstone (see Appendix B). Hence in most vertical sequences a vertical hydraulic conductivity towards the lower end of the observed and/or literature ranges (i.e. as low as 8.6×10^{-7} m/d) is anticipated.

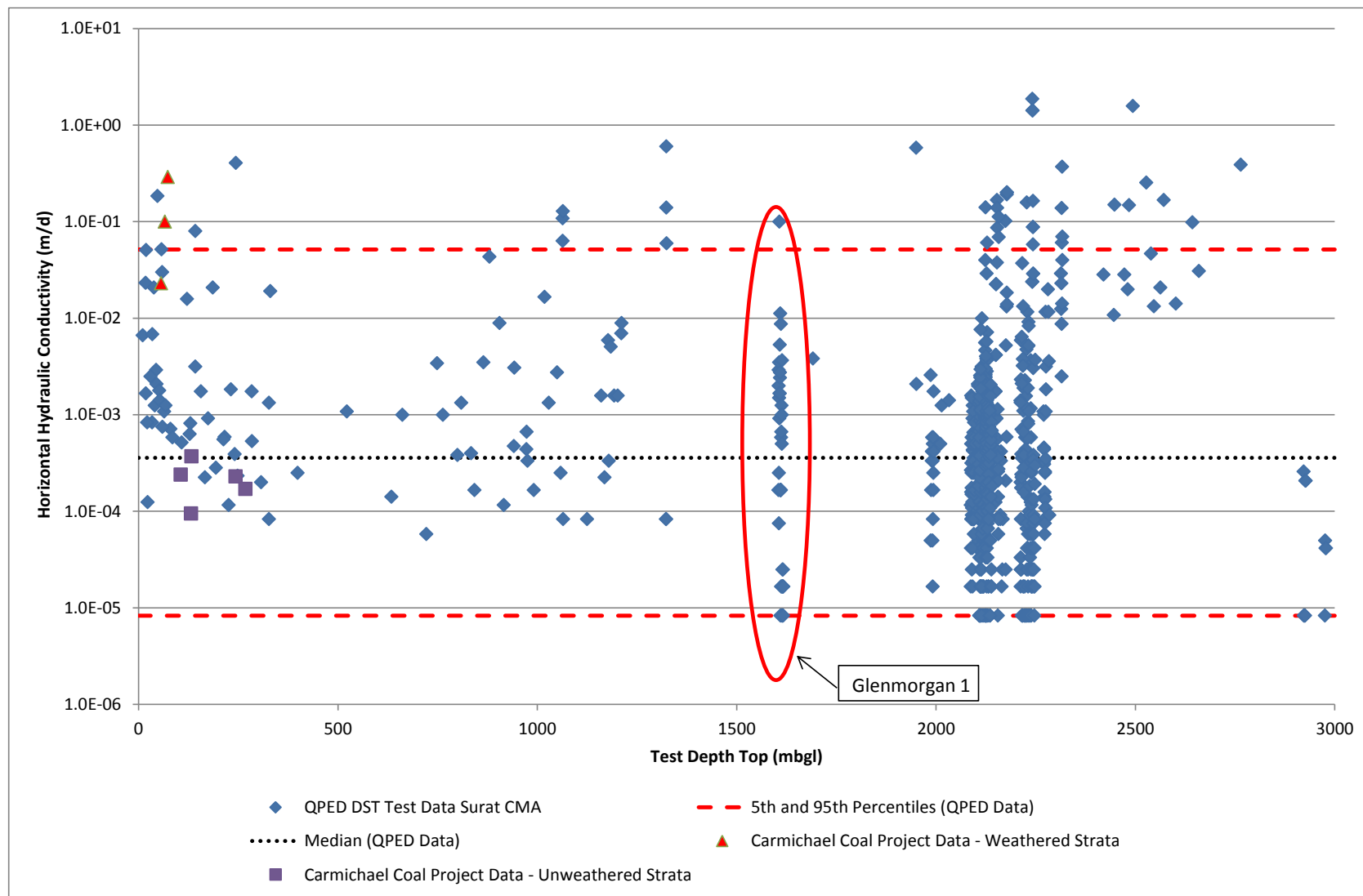


Figure 1 Horizontal Hydraulic Conductivity, Rewan Group

2.2.8 Site specific data

Horizontal Hydraulic Conductivity (Kh)

A total of five packer tests and three falling head tests were carried out at seven locations within the Carmichael Coal Project Mine Area. Given the sedimentary nature and highly variable nature of the Rewan Group, estimates of hydraulic conductivity derived from these kinds of tests are likely to be dominated by the horizontal hydraulic conductivity of the strata tested. The estimated hydraulic conductivity values for the site specific tests are summarised in Table 1 and suggest substantially lower hydraulic conductivity values in weathered zones. Hence, the three falling head tests completed in boreholes C035P1, C555P1 and C556P1 at relatively shallow depths in horizons where the Rewan Group had been weathered to sandy clay returned hydraulic conductivity values of between 2.3×10^{-2} to 2.9×10^{-1} m/d. These test results are comparable to values quoted in the literature for fine sand (for example Domenico and Schwartz (1990) quote a typical range of hydraulic conductivity values for fine sand of 0.02 to 17 m/d) which is consistent with the observed highly weathered nature of the material tested.

Conversely the five packer tests undertaken across zones below the base of observed weathering, in test sections dominated by relatively fresh siltstone with some sandstone layers, returned hydraulic conductivity values range between 9.5×10^{-5} and 1.7×10^{-4} m/d (i.e. 3 to 4 orders of magnitude lower than the values returned for weathered strata). As would be expected these values plot within the range of typical values for siltstone suggested by Domenico and Schwartz (1990, Section 2.2.5).

Vertical Hydraulic Conductivity (Kv)

No site specific data are available from laboratory permeameter or other similar tests which would return reliable estimates of the vertical hydraulic conductivity of the Rewan Group. Given the highly stratified nature of the Rewan Group and based on tests undertaken for other studies (Heritage Computing Pty Ltd, 2013 and Merrick, 2010) Kv values of up to 1900 times less than Kh are expected (i.e. a Kv:Kh ratio of 1:1900). In fact ratios between the hydraulic and vertical hydraulic conductivity of the Rewan Group at the field scale is likely to be well in excess of 1900 in most cases.

However, in the absence of any site specific data a Kv:Kh ratio of 1:10 has been assumed for the Rewan Group and other model layers for predictive modelling purposes. Given the interbedded nature of the Rewan Group and the use of two layers to represent Rewan Group in the model this is considered to be a very conservative assumption from the point of view of predicted impacts on the adjacent GAB. For instance reference to the multiple DST test results for the Glenmorgan 1 bore discussed previously (Section 2.2.7) indicates values ranging from 1.0×10^{-1} to 8.3×10^{-6} m/d which suggests a Kv:Kh ratio of up to 1:12000 would be appropriate for modelling purposes.

Table 1 Estimated Hydraulic Conductivity Values for the Rewan Group Carmichael Coal Project Site

Bore ID	Test Type	Test Interval (mBGL)	Tested Lithology	Estimated Hydraulic Conductivity (m/d)
C035P1	Slug	56 – 62 m	Sandy clay	2.3×10^{-02}
C555P1	Slug	66 – 75 m	Gravelly clay & clay with sand	1.0×10^{-01}

Bore ID	Test Type	Test Interval (mBGL)	Tested Lithology	Estimated Hydraulic Conductivity (m/d)
C556P1	Slug	73 – 82 m	Sandy clay	2.9×10^{-01}
C9556PR	Packer	243.07 - 249.07 m	Sandstone and siltstone	2.3×10^{-04}
C056	Packer	268 - 276.5 m	Siltstone	1.7×10^{-04}
842VWP	Packer	131.7 - 136.7 m	Siltstone and sandstone	9.5×10^{-05}
836VWP	Packer	132.79 - 137.79 m	Siltstone/ mudstone	3.7×10^{-04}
836VWP	Packer	105.8 - 110.8 m	Siltstone	2.4×10^{-04}

2.3 Groundwater flow directions

2.3.1 Introduction

Groundwater level contours interpreted from observed data for the monitoring network installed to provide baseline data for the project are presented in Chapter 4 of the SEIS Mine Hydrogeology Report (GHD, 2013). Whilst an extensive monitoring network has been installed, comprising some 86 piezometers at 41 locations, relatively few bores have been installed outside of the Mine Area due to land access constraints. Local groundwater level data held within the Queensland State Groundwater database is also limited and is typically not sufficient to significantly enhance the contours outside of the Mine Area. Given the relatively good match to observed data achieved by the modelling work, additional more detailed information on groundwater flow directions can be derived from information extracted from the groundwater model. Additional plots have therefore been prepared showing:

- Calibrated steady state modelled groundwater level contours for key hydrogeological units
- Observed groundwater levels for the Project monitoring network, based on data for May/June 2013; and
- Average rest or standing water levels for nearby registered bores

These contour plots are shown in Figure 2 (Clematis Sandstone), Figure 3 (Dunda Beds), Figure 4 (Permian overburden), Figure 5 (AB Seam), Figure 6 (Permian Interburden), Figure 7 (D Seam) and Figure 8 (Permian below D Seam).

In general, as would be expected given the relatively good model calibration, reference to these plots confirms that modelled groundwater level contours are comparable to the observed data and are generally within around 10 m of the actual observations. Observed levels are typically least well matched in the central part of the Mine Area around the Labona Homestead.

Observed groundwater levels are surprisingly low in this area and hence the groundwater level contours previously presented in the SEIS showed a marked depression which the model has been unable to replicate. Given that the low levels are seen in 15 bores (including C558P_v2, C558P_v3, C558P2, C006P1, C007P2, C008P1, C008P2, C555P_v2, see Figure 4, Figure 5 and Figure 6) which monitor a number of different horizons then it is considered unlikely that the depression is due to a data error. However, the cause of the very low readings is not known at this stage. Potential explanations include:

- Groundwater extraction impacts;

- Natural groundwater discharge to a topographic low;
- A structural control e.g. a high permeability fault zone connecting this area to say the Carmichael River to the east of the site.

The first explanation is considered most likely. A number of windmill driven extraction wells, including a bore close to the Labona Homestead, are present within this part of the Mine Area and have historically been used for stock watering purposes. No information is available on historic extraction volumes and hence whilst the amount extracted is expected to be relatively low a number of other sources of information also suggest both low hydraulic conductivity and recharge in the area north of the Carmichael River. It is therefore possible that long term extraction from these bores has led to the development of a localised cone of depression.

The remaining two explanations are considered less likely. Detailed topographic information is available across the whole Mine Area and indicates a minimum ground elevation close to the Carmichael River of around 215 mAHD. All 15 of the monitoring bores which return values below this minimum elevation plot in a relatively small area around the Labona Homestead. Natural discharge to surface in this area is therefore unlikely. Furthermore there are no known structural controls which might explain the low observed groundwater levels.

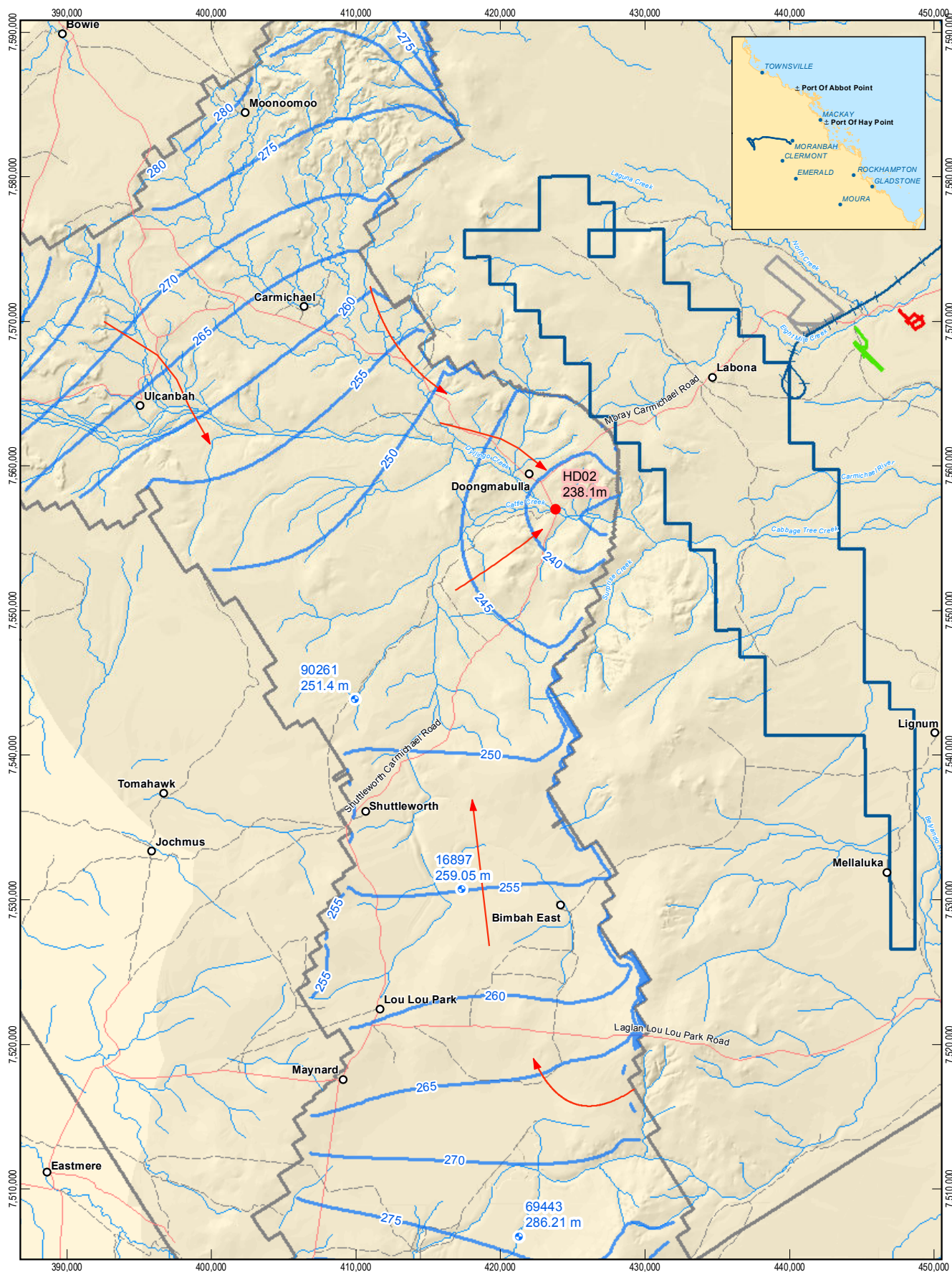
Further commentary of groundwater flow directions in each aquifer is provided below.

2.3.2 Clematis Sandstone / Dunda Beds

Interpretation of the modelled groundwater level contours indicates groundwater flow in the Clematis Sandstone (Figure 2) and the Dunda Beds (Figure 3) converges towards the Carmichael River predominantly upstream of the Mine Area boundary. Interpreted groundwater flows originate from topographically high areas to the north and south of the Carmichael River and flow towards the west (with the fall in topography) before curving back towards the south east and north east. Hence the majority of the modelled recharge to the Clematis Sandstone appears to discharge to the Doongmabulla Springs area and/or direct to the Carmichael River. The observed groundwater level data which includes three registered bores (RN69443, RN16897 and RN90261) thought to be completed into the Clematis Sandstone in the GAB area to south west of the Mine Area also suggest groundwater flow towards the north. Both the observed and modelled data suggest flow in the Clematis Sandstone and the Dunda Beds towards the Carmichael River i.e. to the north-north east and south-south east. There is no evidence of flow towards the south west i.e. down dip.

2.3.3 Permian-age strata

Modelled groundwater level contours for each of the Permian-age strata (Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8) indicate groundwater flow in line with the topography from north west to south east across the northern part of the Mine Area and from west to east through central areas. Across southern regions of the Mine Area interpreted groundwater flow is from south west towards the north east. However, unlike the contours for the Clematis Sandstone and Dunda Beds the contours for the Permian-age strata suggest limited interaction with the Carmichael River. This is as expected given the relatively thick clay rich Tertiary-age deposits which overlie the Permian Strata throughout the area modelled.



LEGEND

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| ○ Homestead | — Local Road | — Steady State Modelled Groundwater Contour (mAHD) | — Project (Rail) | — Mine (Offsite) |
| ● Groundwater monitoring bore (SWL in mAHD) | — Track | — Interpreted Flow Direction | — Project (Mine) | — Airport |
| ● Registered bore (SWL in mAHD) | — Watercourse | | — Formation extent (modelled) | — Industrial Area |
| | | | | — Accommodation Village |

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Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55



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Modelled Groundwater Contours and
Observed Groundwater Levels:
Clematis Sandstone

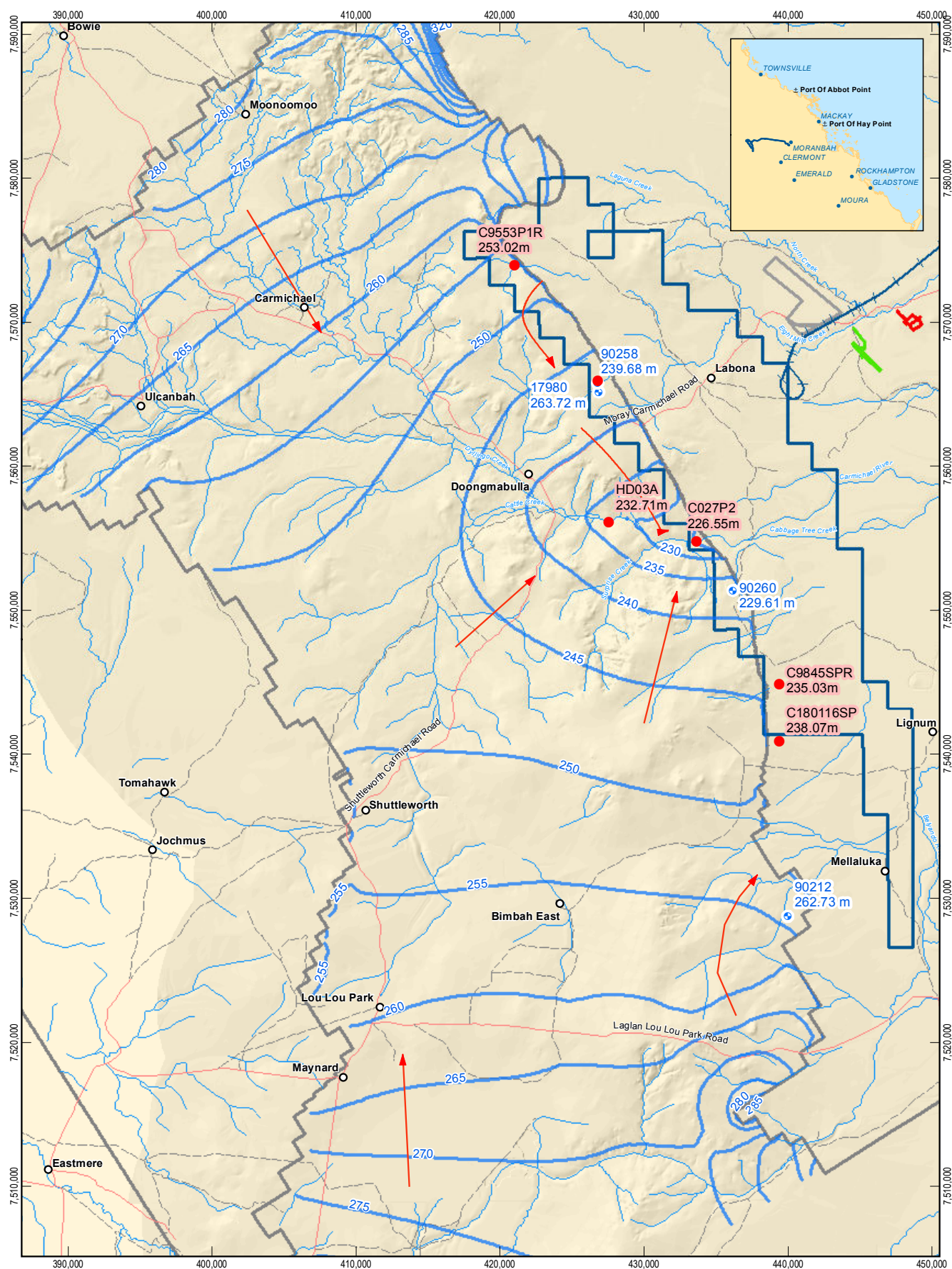
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Date 17-10-2013

Figure 2

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LEGEND

- Homestead
- Groundwater monitoring bore (SWL in mAHD)
- Registered bore (SWL in mAHD)
- Local Road
- Track
- Watercourse
- Steady State Modelled Groundwater Contour (mAHD)
- Interpreted
- Flow Direction
- Project (Rail)
- Project (Mine)
- Formation extent (modelled)
- Mine (Offsite)
- Airport
- Industrial Area
- Accommodation Village

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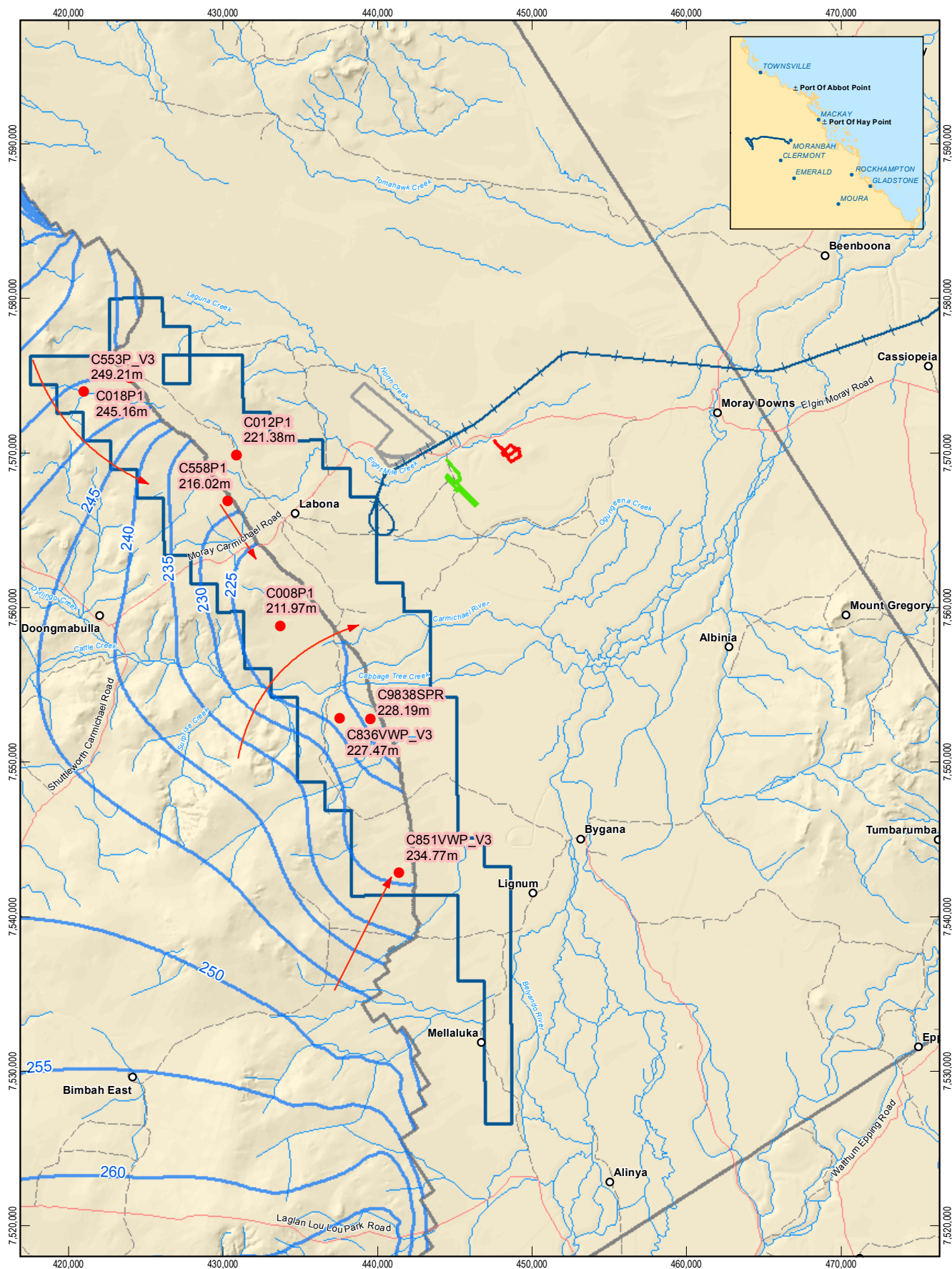


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Observed Groundwater Levels:
Dunda Beds

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Figure 3



Legend

- Groundwater monitoring bore (SWL in mAHD)
- Local Road
- Track
- Watercourse
- Steady State Modelled Groundwater Contour (mAHD)
- Interpreted Flow Direction
- Project (Rail)
- Project (Mine)
- Formation extent (modelled)
- Mine (Offsite)
- Airport
- Industrial Area
- Accommodation Village

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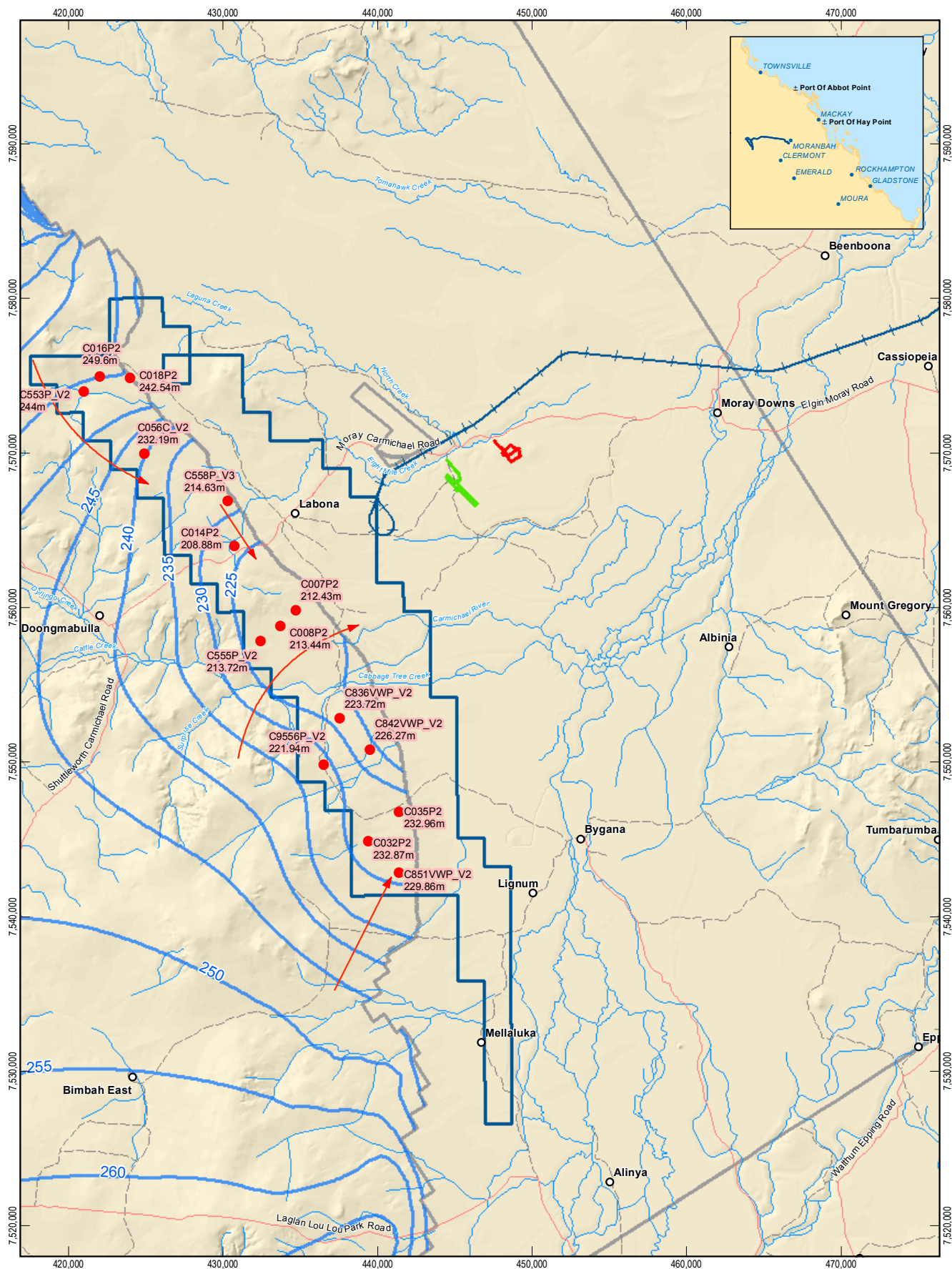
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Modelled Groundwater Contours and
Observed Groundwater Levels:
Permian Overburden

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Figure 4



LEGEND

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| ○ Homestead | — Watercourse | — Project (Rail) | Mine (Offsite) |
| ● Groundwater monitoring bore (SWL in mAHD) | — Steady State Modelled Groundwater Contour (mAHD) | — Project (Mine) | — Airport |
| — Local Road | — Interpreted Flow Direction | — Formation extent (modelled) | — Industrial Area |
| — Track | | | — Accommodation Village |

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Observed Groundwater Levels:
AB Seam

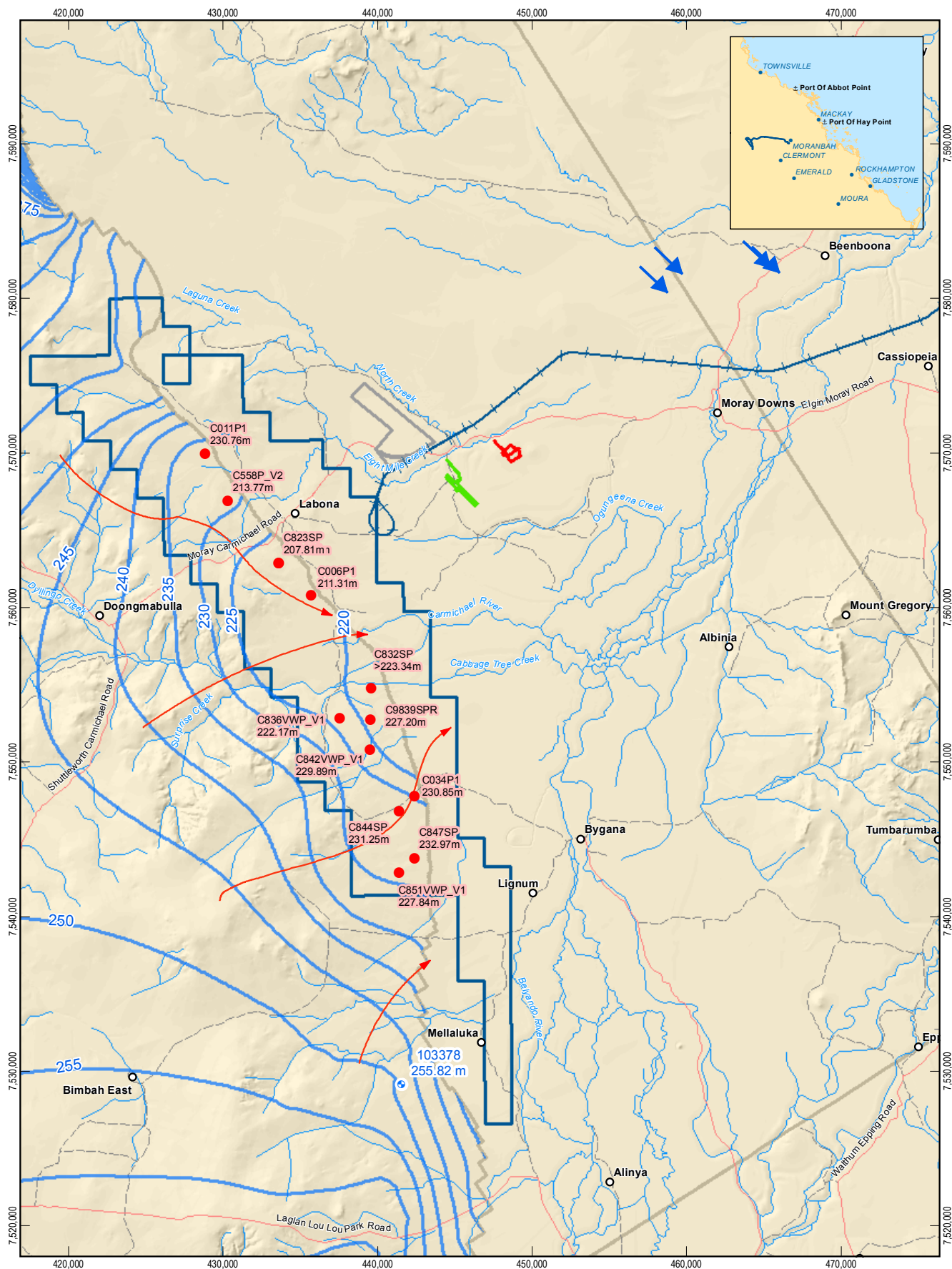
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Figure 5

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| ○ Homestead | — Local Road | — Steady State Modelled | — Project (Rail) | — Mine (Offsite) |
| ● Groundwater monitoring bore (SWL in mAHD) | — Track | — Groundwater Contour (mAHD) | — Project (Mine) | — Airport |
| ● Groundwater Monitoring Bore (SWL in mAHD) | — Watercourse | — Interpreted | — Formation extent (modelled) | — Industrial Area |
| | | → Flow Direction | | — Accommodation Village |

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55



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Modelled Groundwater Contours and
Observed Groundwater Levels:
Permian Interburden

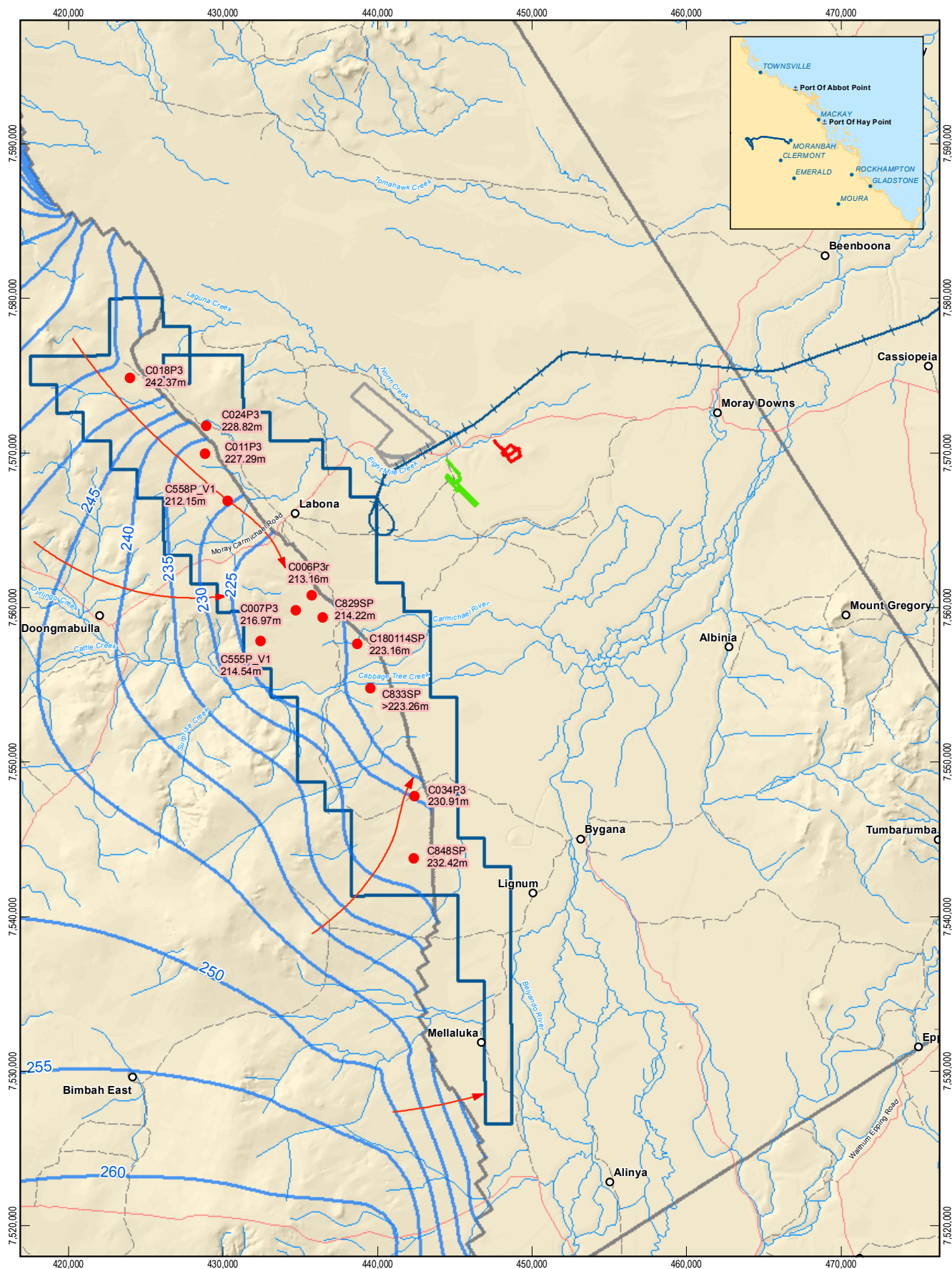
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Figure 6

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| ○ Homestead | — Watercourse | — Project (Rail) | Mine (Offsite) |
| ● Groundwater monitoring bore (SWL in mAHD) | — Steady State Modelled | ■ Project (Mine) | ■ Airport |
| — Local Road | — Groundwater Contour (mAHD) | ■ Formation extent (modelled) | ■ Industrial Area |
| — Track | → Interpreted | ■ Accommodation Village | |
| | → Flow Direction | | |

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Modelled Groundwater Contours and
Observed Groundwater Levels:
D Seam

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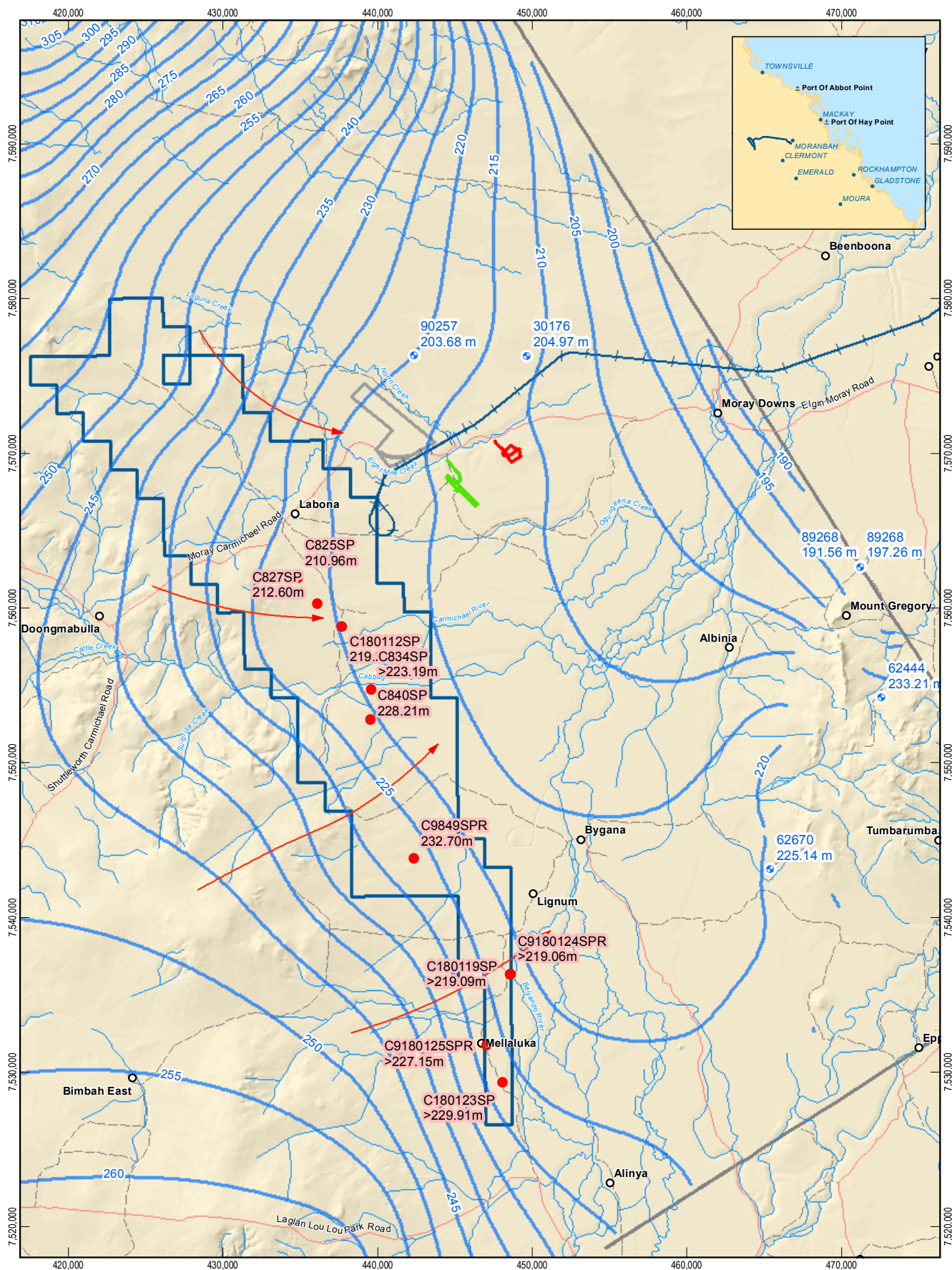
Figure 7

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| ○ Homestead | — Local Road | — Steady State Modelled | — Project (Rail) | Mine (Offsite) |
| ● Groundwater monitoring bore (SWL in mAHD) | — Track | — Groundwater Contour (mAHD) | — Project (Mine) | — Airport |
| ● Groundwater Monitoring Bore (SWL in mAHD) | — Watercourse | — Interpreted | — Formation extent (modelled) | — Industrial Area |
| | → Flow Direction | | | — Accommodation Village |

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55



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Carmichael Coal Mine and Rail Project SEIS
Modelled Groundwater Contours and
Observed Groundwater Levels:
Permian Below D Seam

Job Number 41-26422
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Date 17-10-2013

Figure 8

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2.4 Hydrogeological processes

2.4.1 Introduction

The key hydrogeological processes thought to be operating in the Project Area are described in the following paragraphs which draw on the data and information provided in Section 4 of the Mine Hydrogeology SEIS report (GHD, 2013). These key processes are also illustrated in two illustrative sketch cross sections:

- A roughly south west to north east section from the Doongmabulla Springs through the subdued ridge line, which lies close to the western edge of the Mine Area, and continues beyond the eastern limit of the Mine Area (Figure 9);
- A second south west to north east section, through an area to the south of the Mine Area, which runs across the same north-south ridge line and terminates close to the Mellaluka Springs (Figure 10).

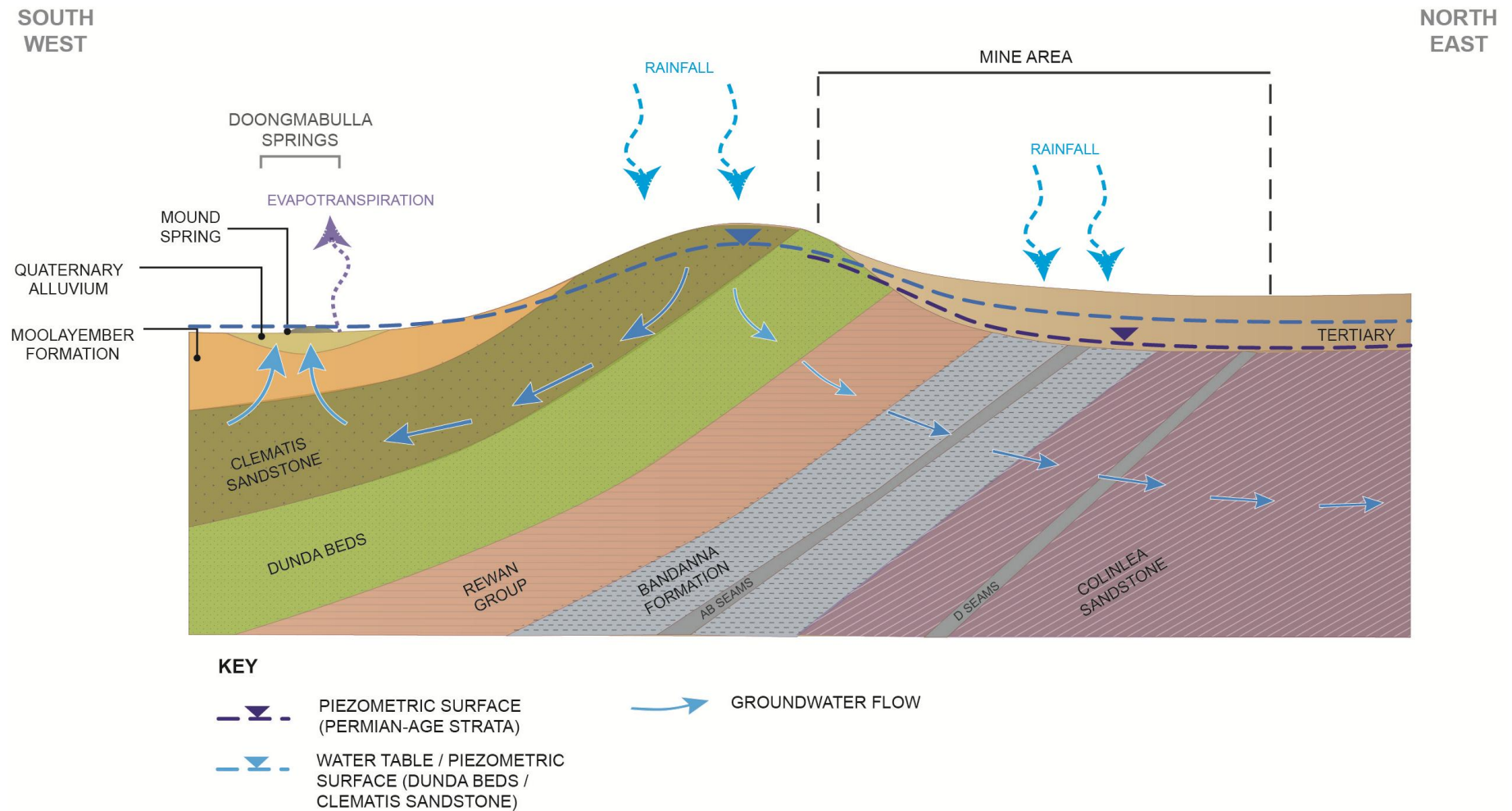


Figure 9 Sketch Cross Section (west to east) through Doongmabulla Springs

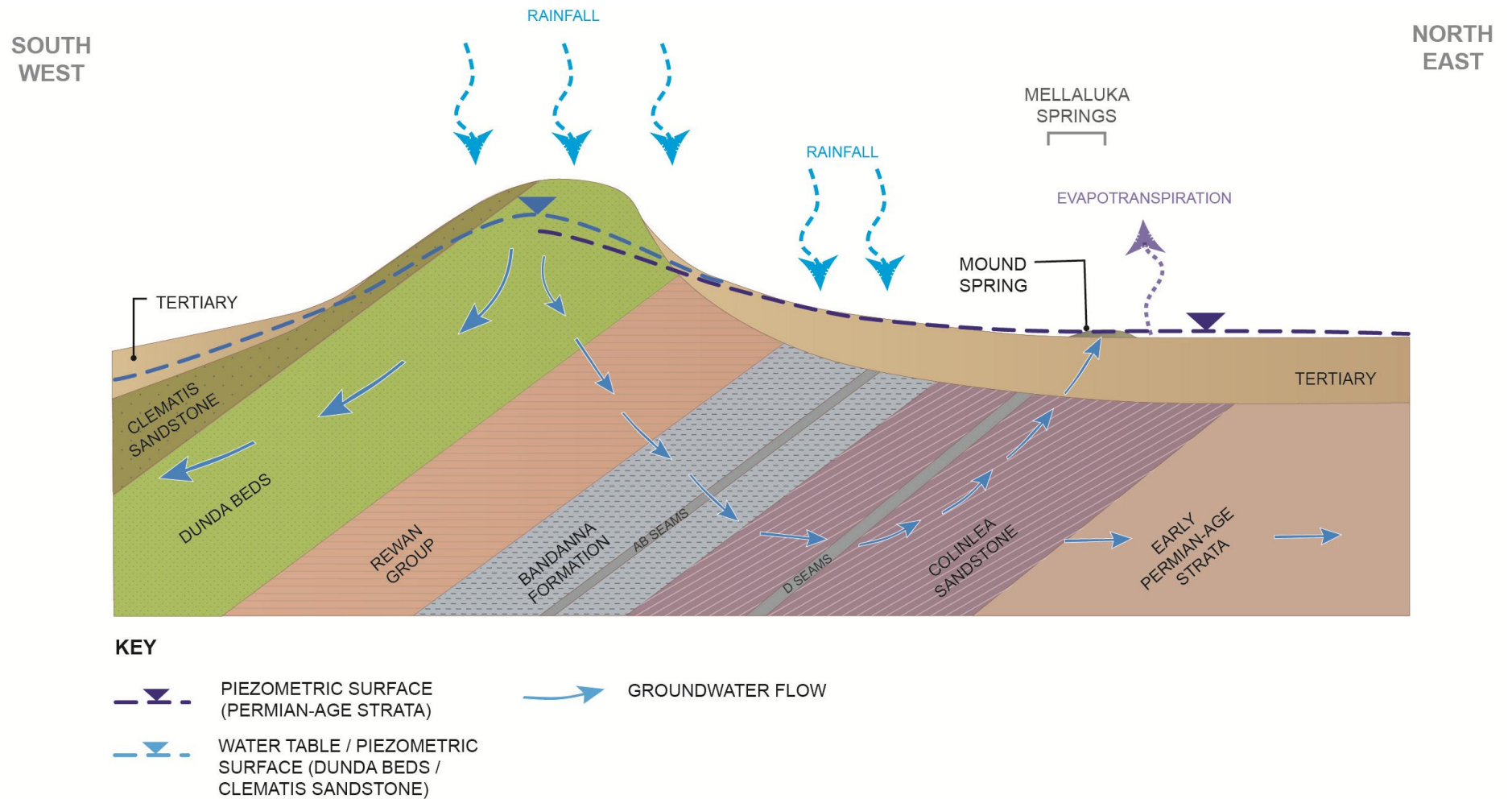


Figure 10 Sketch Cross Section (west to east) through Mellaluka Springs

2.4.2 Recharge, discharge and flow processes

The predominant recharge mechanism to groundwater is considered to be infiltration of rainfall to relatively permeable outcrop areas such as the Clematis Sandstone and the Dunda Beds, in the vicinity of and to the west of the western boundary of the Mine Area. Based on calculations previously described in Section 4.8 of the SEIS (GHD, 2013) rainfall derived recharge in these areas is expected to fall within the range 0.1 to 4 mm/yr. Elsewhere within the Project Area the near surface deposits predominantly comprise relatively low permeability Tertiary-age clay dominated deposits, overlying Permian-age bedrock and hence effective recharge to the underlying bedrock strata is expected to be low by comparison with areas where the Clematis Sandstone and the Dunda Beds are present at outcrop (i.e. towards the lower end of the 0.1 to 4 mm/year quoted above). As shown in the conceptual cross sections (Figure 9 and Figure 10) the Bandanna Formation (which includes the AB and C Seams) is also expected to receive a small component of recharge as a result of vertical leakage from the Dunda Beds, through the Rewan Group.

In areas close to the Carmichael River recharge to the sandy Quaternary alluvium which underlies the river is expected to be enhanced by:

- Leakage through the bed of the Carmichael River across central and eastern parts of the Mine Area where groundwater level observations suggest downward head gradients; and
- Discharge from the underlying Dunda Beds and Clematis Sandstone upstream of the Mine Area in areas where groundwater level observations suggest upward head gradients

However, significant interaction between the sandy Quaternary alluvium and the underlying Bandanna Formation and Colinlea Sandstone (which includes the D, E and F Seams) is not expected, due to the presence of the intervening low permeability Tertiary-age clays. By the same reasoning, infiltration from the numerous ephemeral surface water courses is not considered to be a significance source of additional recharge to the underlying bedrock.

Groundwater discharge within the Project Area is thought to be predominantly to the Carmichael River and the Doongmabulla Springs area upstream of the Mine Area boundary (Figure 9). This spatial pattern of groundwater discharge to the west of the Mine Area is consistent with the available data which suggest upward groundwater level gradients and persistent flow in the Carmichael River at the upstream boundary of the Mine Area. From this point the available information suggests that the Carmichael River generally loses flow during dry periods, probably via a combination of leakage through the bed of the river and/or evapotranspiration.

Groundwater discharge is also known to be occurring via the Mellaluka, Lignum and Storie's springs which are located towards the south of the Mine Area (Figure 10). Groundwater discharge in this area is consistent with the upward gradients and artesian conditions observed in a number of boreholes south the Carmichael River. Individual conceptual models for these springs are described separately below. There is no evidence of significant groundwater discharge in any other parts of the project area and this is consistent with the presence of low permeability Tertiary-age clay at outcrop across the majority of the area.

The north-south ridgeline which runs close to the western boundary of the Mine Area is thought to represent only a minor groundwater divide. Hence whilst groundwater flow is thought to be occurring to both the west and east from this ridge area the westward component of flow appears to turn south after only a short distance to discharge into the Carmichael River. To the east of the ridgeline groundwater flow in the various Permian-age strata is thought to be typically eastward parallel to the flow direction of the Carmichael River. Groundwater flows throughout most of the project area therefore appear to topographically controlled, i.e. parallel to or towards the Carmichael River which runs from west to east, despite the general dip of the

strata which is from north east to south west. In particular both the observed groundwater level data and modelled contours for the Clematis Sandstone suggest little or no flow into the main body of the GAB which is located to the south west of the Project Area. Whilst this finding was not necessarily expected a number of other areas close to the margins of the GAB are characterised by topographical controlled groundwater flow. For instance observed groundwater level data and groundwater modelling results (GHD, 2012) suggest that groundwater flow in the Clematis Sandstone in the southern Bowen Basin is towards the Dawson River (i.e. to the north east) rather than into the main body of the GAB to the south west. It may be that weathering of the upper bedrock horizons plays an important role in promoting topographically driven groundwater flow rather than flow down dip in the area. Groundwater flow within fresh sedimentary bedrock strata is typically controlled by layering/stratification. However, in areas where fresh bedrock has been exposed to weathering a complete loss of structure and cementation can occur resulting in significantly higher permeability and transmissivity than in the underlying fresh bedrock.

Loss of groundwater to the atmosphere (via evapotranspiration) can occur where the water table is within a few metres of the ground surface. This is the case along and in the near vicinity of the Carmichael River particularly in areas close to and upstream of the western boundary of the Mine Area and in the vicinity of the various springs such as at Doongmabulla, Mellaluka and Lignum. Evapotranspiration is therefore likely to be a mechanism for additional loss of groundwater from these areas.

2.4.3 Doongmabulla Spring Complex

As shown in Figure 9 the source aquifer for the GAB Doongmabulla spring complex is thought to be the Clematis Sandstone and/or the underlying Dunda Beds, which are also understood to be dominated by Sandstone units, at least in places. Groundwater quality data collected for the project is consistent with this hypothesis. Recharge to the Clematis Sandstone / Dunda Beds discharges through the overlying Moolayember Formation and Quaternary Alluvium, which form a confining layer in the area of the springs, leading to artesian head pressures. Given the proximity of the springs to the Carmichael River and its tributaries direct groundwater discharge to these surface water courses is also considered likely to be occurring. Areas of outcropping Clematis Sandstone/Dunda Beds are mapped on relatively high ground to the north-west, north, north-east, south and south-east of the springs and hence groundwater modelling results suggest flow within the Clematis Sandstone towards the springs from a number of different directions. The precise mechanism by which groundwater is able to discharge through the overlying low permeability Moolayember Formation and Quaternary alluvium is not known and may vary from discrete fractures in some springs to areas of relatively sandy and/or thin confining beds in others.

2.4.4 Mellaluka Spring Complex

As shown in Figure 10 the most likely source aquifer for the Mellaluka spring complex is thought to be the underlying Permian-age units of the Colinlea Sandstone. Groundwater quality data collected for the project is consistent with this hypothesis. However, given that the Colinlea Sandstone is overlain throughout the Project Area by low permeability Tertiary-age clay then the most likely recharge area for the Mellaluka spring complex is considered to be the outcropping Dunda Beds along the ridgeline to the west. Potential pathways for groundwater flow from this outcrop area through the underlying Rewan Group aquitard and other units to the springs include:

- Horizontal groundwater flow within near surface weathered strata and discharge at the springs, possibly caused by pinching out of the weathered zone as the thickness of the Tertiary-age clays thickens to the east; and/or

- A deeper groundwater flow path characterised by vertical leakage through the Rewan Group and underlying Bandanna Formation with flow returning to the surface in the vicinity of the springs via more permeable units and/or fractures within the Colinlea Sandstone.

3. Groundwater Modelling

3.1 Overview

In response to the comments received the following additional modelling and reporting tasks were undertaken:

- Additional validation of the model calibration through comparison of observed and modelled vertical gradients. This task was undertaken in response to comments included in the groundwater model peer-review (URS, 2013).
- Additional mapping of predicted model drawdowns for each of the modelled aquifer layers at specific times
- Resolution of the water balance errors in the transient predictive model. This task was undertaken based on comments included in the groundwater model peer-review (URS, 2013).
- Re-presentation of the sensitivity analysis results previously reported in Section 5.8 of the SEIS (GHD, 2013) such that the sensitivity of key impact predictions to alternative model parameters is more clearly shown; and
- Additional analysis of the sensitivity of predicted impacts on GAB groundwater resources and the Doongmabulla springs to the modelled hydraulic conductivity of the Rewan Group, modelled recharge and general head boundary conductance. Additional sensitivity analysis work was also recommended in the groundwater model peer-review carried out by URS (2013).

Each of the topics listed above are discussed further in the following sections.

3.2 Further model validation

Further work has been carried out to validate modelled vertical gradients against observed vertical gradients across the Mine Area.

Observed vertical gradients are available at 20 locations within the Mine Area and these data have been separated geographically into bores located to the north, south and along the Carmichael River as shown in Table 2, Table 3 and Table 4. Modelled results suggest a generally good agreement between observed and modelled vertical gradients, a reflection of the good model calibration reported in Section 5.5.3 of the SEIS (GHD, 2013). Specifically the model replicates the direction of vertical flows at 17 out of 20 locations. The model also replicates reasonably well the magnitude of vertical gradients, although as would be expected given that it not normally considered to be good practice to vary modelled parameters on a borehole by borehole basis the match between observed and modelled gradients is variable. Information on the observed gradients between the Rewan Group and other adjacent strata are considered to be of particular interest given the focus on the modelled hydraulic conductivity of the Rewan Group elsewhere in this addendum. In this case the observed data suggests downward gradients of between 5.4 and 10.9 m between the Rewan Group and the underlying Permian strata (Table 3 and Table 4) at three 'nested' sites located towards the west of the Mine Area which:

- Tends to confirm the generally low vertical hydraulic conductivity of the Rewan Group; and
- Is consistent with pre-development leakage from the GAB through the Rewan Group into the underlying Permian-age strata (i.e. into the adjacent Galilee Basin)

Data for bores C035P1 and C0235P2 suggests a slight upward gradient from the AB Coal Seam to the overlying Rewan Group. This is considered to be consistent with the location of this monitoring site further from the western boundary of the site and south of the Carmichael River (i.e. in part of the Mine Area where generally upward gradients have been observed).

Table 2 Comparison of Observed and Modelled Vertical Gradients – Riverside Bores

Upper Bore ID	Upper Monitored Layer / Geological Unit	Lower Bore ID	Lower Monitored Layer / Geological Unit	Observed Vertical Gradient ¹	Modelled Vertical Gradient	Flow Direction Reproduced by the Model?
C027P1	1 (Quaternary alluvium)	C027P2	5 (Dunda Beds)	-1.80	-2.73	Yes
C029P1	1 (Quaternary Alluvium)	C029P2	2 (Tertiary-age strata)	-5.57	-0.002	Yes
C025P1	2 (Tertiary-age strata)	C025P2	2 (Tertiary-age strata)	-1.31	-0.002	Yes
			Average	-2.9	-0.9	

Table 3 Comparison of Observed and Modelled Vertical Gradients – North of the Carmichael River

Upper Bore ID	Upper Monitored Layer / Geological Unit	Lower Bore ID	Lower Monitored Layer / Geological Unit	Observed Vertical Gradient ²	Modelled Vertical Gradient	Flow Direction Reproduced by the Model?
056C_V03	6 (Rewan Group)	056C_V02	9 (Coal Seam AB)	5.41	2.77	Yes
555P_V03	6 (Rewan Group)	555P_V02	9 (Coal Seam AB)	10.92	4.75	Yes
C008P1	8 (Permian overburden)	C008P2	9 (Coal Seam AB)	-1.54	-0.0002	Yes
C018P1	8 (Permian overburden)	C018P2	9 (Coal Seam AB)	1.20	0.02	Yes
553P_V03	8 (Permian overburden)	553P_V02	9 (Coal Seam AB)	10.76	0.00	Yes
C012P1	8 (Permian overburden)	C012P2	8 (Permian overburden)	-0.01	-0.003	Yes
C007P2	9 (Coal Seam AB)	C007P3	11 (Coal Seam D)	-4.46	-0.004	Yes
C018P2	9 (Coal Seam AB)	C018P3	11 (Coal Seam D)	1.66	0.77	Yes
558P_V03	9 (Coal Seam AB)	558P_V02	10 (Permian interburden)	0.94	0.84	Yes
555P_V02	9 (Coal Seam AB)	555P_V01	11 (Coal Seam D)	1.83	0.07	Yes
C006P1	10 (Permian interburden)	C006P3r	11 (Coal Seam D)	-1.95	-0.05	Yes

¹ Negative values indicate an upward gradient, positive downward

² Negative values indicate an upward gradient, positive downward

Upper Bore ID	Upper Monitored Layer / Geological Unit	Lower Bore ID	Lower Monitored Layer / Geological Unit	Observed Vertical Gradient ²	Modelled Vertical Gradient	Flow Direction Reproduced by the Model?
C011P1	10 (Permian interburden)	C011P3	11 (Coal Seam D)	3.32	-0.0003	No
558P_V02	10 (Permian interburden)	558P_V01	11 (Coal Seam D)	0.59	0.76	Yes
			Average	2.2	0.8	

Table 4 Comparison of Observed and Modelled Vertical Gradients – South of the Carmichael River

Upper Bore ID	Upper Monitored Layer / Geological Unit	Lower Bore ID	Lower Monitored Layer / Geological Unit	Observed Vertical Gradient ³	Modelled Vertical Gradient	Flow Direction Reproduced by the Model?
C035P1	6 (Rewan Group)	C035P2	9 (Coal Seam AB)	-0.91	0.37	No
9556P_V03	6 (Rewan Group)	9556P_V02	9 (Coal Seam AB)	7.21	6.16	Yes
9556P_V02	9 (Coal Seam AB)	9556P_V01	11 (Coal Seam D)	-0.62	0.20	No
C034P1	10 (Permian interburden)	C034P3	11 (Coal Seam D)	-0.08	-0.04	Yes
			Average	1.4	1.7	

3.3 Additional drawdown mapping

Operational and Post-Closure maximum water table drawdown “all time” (i.e. across all model stress periods) are presented in Figure 35 and Figure 40 of the SEIS (GHD, 2013).

Further information has been requested on how these impacts develop through time in individual aquifers. Spatial plots of drawdowns for selected model layers (aquifer layers) at specific times have been compiled and are presented in Appendix A. Table 2 summarises the model layers and times at which modelled spatial drawdowns have been extracted from the model.

³ Negative values indicate an upward gradient, positive downward

Table 5 Details of Spatial Drawdown Additional Mapping

Dominant Strata	Model Layer	Years / Time
Quaternary Alluvium	1	2019, 2039, 2071, 2092, 2109, 2129, Post-Closure (Long Term)
Tertiary-Age Clay	2	2019, 2039, 2071, 2092, 2109, 2129, Post-Closure (Long Term)
Clematis Sandstone	4	2019, 2039, 2071, 2092, 2109, 2129, Post-Closure (Long Term)
Coal Seam AB	9	2019, 2039, 2071, 2092, 2109, 2129, Post-Closure (Long Term)
Coal Seam D	11	2019, 2039, 2071, 2092, 2109, 2129, Post-Closure (Long Term)

Years 2019, 2039 and 2071 were selected as these are some of the years for which a mine plan was available to use in the groundwater model. Year 2071 is of particular importance as it represents the end of the mine operational phase.

Years 2092, 2109 and 2129 were selected as this is the time period when model predictive results suggest the maximum drawdown impacts at Doongmabulla springs are likely to occur

The post-closure (long term) time was selected as it provides an indication of long term steady state impacts and model predictions suggest that at most locations of interest the largest impacts are likely to occur in the post-closure (long term) scenario.

3.3.1 Discussion of aquifer specific drawdowns

Quaternary Alluvium (Model Layer 1)

Spatial plots of Quaternary alluvium drawdowns at specific years are illustrated in Figures A.1 to A.7 in Appendix A.

Model results suggest that drawdowns in the Quaternary alluvium are primarily concentrated within the proposed Mine Area during the mine operational phase. The model suggests a predicted maximum drawdown of 6.3 m occurring in Year 2129.

Predicted modelled post-closure (long term) drawdowns are larger than those suggested during the mine operational phase. Modelled drawdowns extend eastward beyond the limit of the proposed Mine Area where drawdowns larger than 2 m are predicted in places. As expected the largest drawdowns are predicted within the Mine Area, where the model suggests drawdowns up to 19.4 m.

Impacts along the Carmichael River corridor are generally small (lower than 0.2 m) with the model suggesting drawdown impacts up to 1 m only along a short stretch of the river within the Mine Area.

Tertiary-age Clay (Model Layer 2)

Spatial plots of predicted drawdowns within Tertiary-age strata at specific years are illustrated in Figures A.8 to A.14 in Appendix A.

As for the Quaternary alluvium, model results suggest that drawdowns in the Tertiary-age strata are primarily concentrated within the proposed Mine Area during the mine operational phase. The model suggests a predicted maximum drawdown of 14.5 m occurring in Year 2129.

Predicted model results suggest that drawdowns expand eastward and south-westward in the post-closure (long term) scenario. Modelled impacts are largest within the Mine Area itself where drawdowns up to 61 m are predicted at the location of the proposed mine open-pits.

Clematis Sandstone (Model Layer 4)

Spatial plots of predicted drawdown in the Clematis Sandstone at specific years are illustrated in Figures A.15 to A.21 in Appendix A.

The Clematis Sandstone is only present to the west of the Mine Area, outside of the proposed active mining area (see Figure A.15 to A.21). To the east model layer 4 is simulated with the properties of the Tertiary Alluvium.

Predicted impacts on groundwater levels within the Clematis Sandstone extend westward from the mine site in the direction of the dipping strata and tend to be relatively minor. Model predictions suggest maximum drawdowns generally between 0.2 and 1 meter for the Clematis Sandstone.

Coal Seam AB and Coal Seam D

Spatial plots of predicted drawdown in the AB and D coal seams at specific years are illustrated in Figures A.22 to A.35 in Appendix A.

During the operational phase groundwater levels are at the bottom of the coal seam being mined, in agreement with the provided mining schedule. Thus model predictions suggest maximum impacts within the Mine Area in excess of 300 m.

In the post-closure (long term) scenario impact drawdowns within the Mine Area are determined by the elevations of the proposed final voids. As explained in the SEIS (GHD, 2013), pits B, D and G will be backfilled up to the top of seam D whilst pits C, E and F will be backfilled up to the top of seam AB.

3.4 Resolution of elevated cumulative modelled water balance errors

Cumulative water balance errors for the calibrated steady state model, the steady state post-closure model and the transient post-operational model are all below 1 percent as recommended in the current Australian Groundwater Modelling Guidelines (National Water Commission, 2012). Unfortunately it was not possible to achieve this target prior in the transient predictive model prior to issuing the SEIS. It should be stressed that all numerical models are subject to a degree of numerical error and that the scale of the proposed mineworkings, the relatively rapid rate of coal extraction and the complex hydrogeological setting are considered to make this model particularly prone to water balance errors. An initial unreported run of the predictive model was characterised by even higher water balance errors and whilst this was improved during the SEIS reporting period it was not possible to reduce the overall level of error to the less than 1 percent cumulative error target suggested by the groundwater modelling guidelines (National Water Commission, 2012). However, several checks were undertaken, by comparing output from two runs with different water balance errors, which confirmed that neither the reported modelled mine inflow rates or predicted groundwater impacts reported in the SEIS were sensitive to the modelled water balance error.

Further modelling work has now been completed which has reduced the cumulative water balance error in a revised transient predictive run (Adv6TR017_test7) to less than 1 percent. This was achieved by changing some of the numerical solver parameters, including the head closure criteria and hence all other physical parameters of the revised transient predictive model (Adv6TR017_test7) are identical to the model described in the SEIS (Adv6TR017b) which was characterised by a cumulative water balance error of 8.2 percent. Furthermore as shown in Figure 11 predicted impacts at the Doongmabulla springs calculated using these two runs are essentially identical. Very minor differences of up to five millimetres can be observed which are considered to be insignificant compared to the maximum predicted impacts of up to 180 mm.

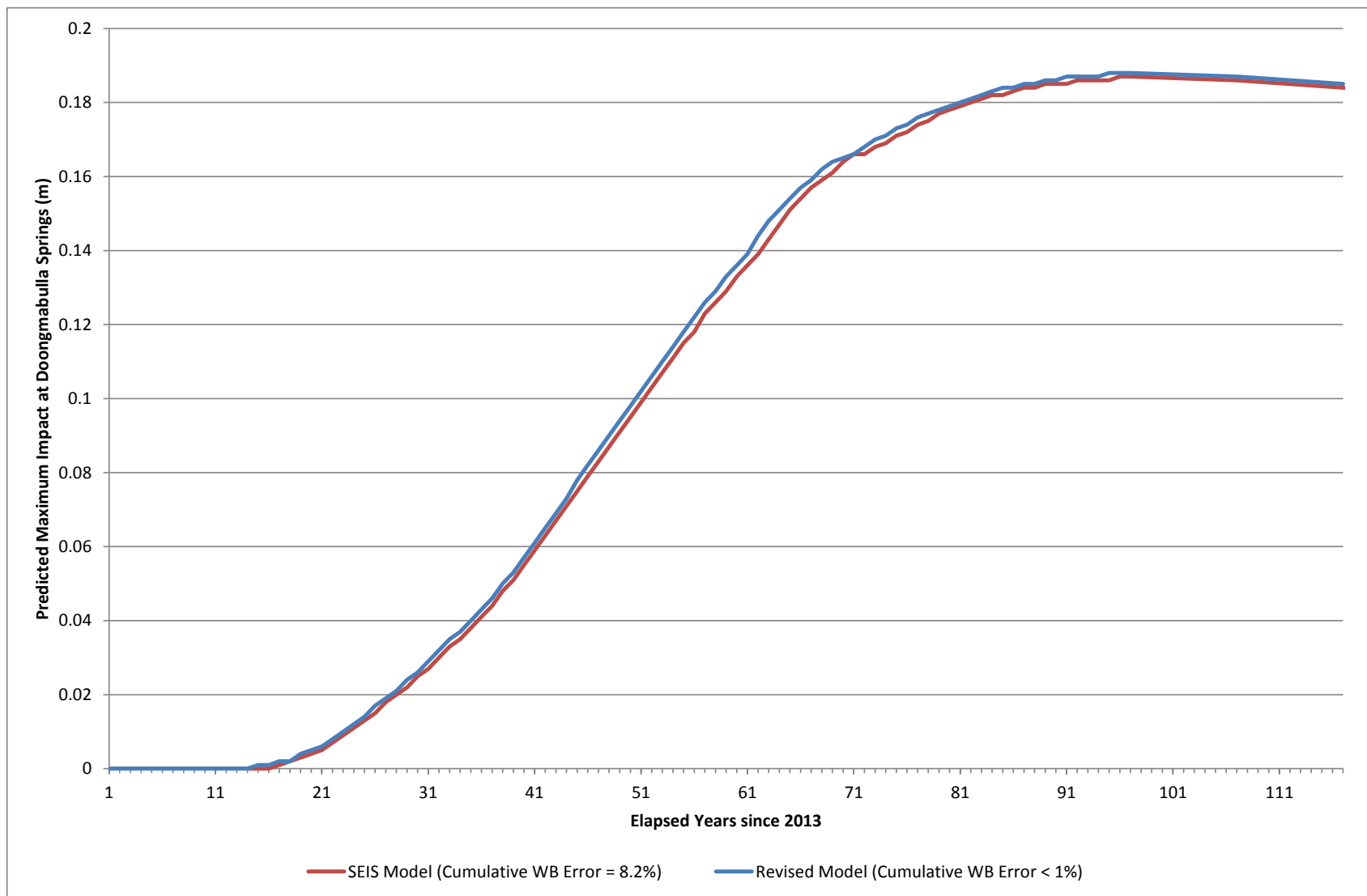


Figure 11 Comparison of Model Results at Doongmabulla Spring for Two Model Runs with Different Cumulative Water Balance Errors

3.5 Revised Sensitivity Analysis Presentation

A detailed analysis of the sensitivity of model predictions to a range of model parameters was previously presented in Section 5.8 of the SEIS (GHD, 2013). However, subsequent comments have suggested that this information could have been presented in a way which more clearly identifies the sensitivity of key impact predictions to modelled parameters. The following Sections 3.5.1 to 3.5.4 therefore discuss the same sensitivity analysis results previously presented in Section 5.8 of the SEIS (GHD, 2013) but based on the revised presentation format shown in Figure 12 to Figure 15.

Parameter values considered in the SEIS sensitivity analysis are summarised below in Table 6.

Table 6 Sensitivity analysis– parameters and multipliers

Parameter	Calibrated Parameter Value	Parameter multipliers	Sensitivity Analysis Parameter Range
K Layer 1– Quaternary	$2.0 \times 10^{+01}$ m/d	0.1,0.2,0.5,2,5,10	$2.0 \times 10^{+00} - 2.0 \times 10^{+02}$ m/d
K Layer 2– Tertiary	1.0×10^{-02} m/d	0.1,0.2,0.5,2,5,10	$1.0 \times 10^{-03} - 1.0 \times 10^{-01}$ m/d
K Layer 3 – Moolayember Formation	5.2×10^{-02} m/d	0.1,0.2,0.5,2,5,10	$5.2 \times 10^{-03} - 5.2 \times 10^{-01}$ m/d
K Layer 4 – Clematis Sandstone	$1.6 \times 10^{+00}$ m/d	0.1,0.2,0.5,2,5,10	$1.6 \times 10^{-01} - 1.6 \times 10^{+01}$ m/d
K Layer 5 – Dunda Beds	7.9×10^{-02} m/d	0.1,0.2,0.5,2,5,10	$7.9 \times 10^{-03} - 7.9 \times 10^{-01}$ m/d
K Layer 6/7 – Rewan Group	7.4×10^{-05} m/d	0.1,0.2,0.5,2,5,10	$7.4 \times 10^{-06} - 7.4 \times 10^{-04}$ m/d
K Layer 8 – Permian OB	1.1×10^{-03} m/d	0.1,0.2,0.5,2,5,10	$1.1 \times 10^{-04} - 1.1 \times 10^{-02}$ m/d
K Layer 9 – AB Coal Seam	1.9×10^{-03} m/d	0.1,0.2,0.5,2,5,10	$1.9 \times 10^{-03} - 1.9 \times 10^{-03}$ m/d
K Layer 10 – Permian IB	3.5×10^{-04} m/d	0.1,0.2,0.5,2,5,10	$3.5 \times 10^{-05} - 3.5 \times 10^{-03}$ m/d
K Layer 11 – D Coal Seams	3.1×10^{-03} m/d	0.1,0.2,0.5,2,5,10	$3.1 \times 10^{-04} - 3.1 \times 10^{-02}$ m/d
K Layer 12 – Older Permian Units	3.6×10^{-04} m/d	0.1,0.2,0.5,2,5,10	$3.6 \times 10^{-05} - 3.6 \times 10^{-03}$ m/d
Recharge	0.3 mm/year	0.1,0.2,0.5,2,5,10	0.03 – 3 mm/year
River / Stream Conductance	50 to 1000 m ² /d	0.1,0.2,0.5,2,5,10	5 – 10,000 m ² /d
Drain Conductance	1000 m ² /d	0.1,0.2,0.5,2,5,10	100 – 10,000 m ² /d

It should be noted that the predicted impacts discussed below relate to the post closure or long term impacts of the proposed development. Predicted post closure impacts are typically similar to or in excess of predicted operational impacts and the sensitivity analysis results presented below could be equally applied to the operational impacts.

In interpreting the sensitivity analysis results it should also be stressed that the impacts summarised in Section 5.7 of the SEIS (GHD, 2013) are considered to represent a 'best estimate' prediction of the likely impacts of the proposed development since they are based on a calibrated parameter set. However, as previously outlined in Section 5.6.1 of the SEIS even these 'best estimate' predictions are considered to be conservative predominantly since it is not possible to accurately represent the complexity of highly variable natural strata such as the Rewan Group in a regional scale groundwater flow model. For instance accurate simulation of the typical Rewan Group sequence shown in Appendix B would require a much larger number of layers than the two layers currently assigned in the model to represent the Rewan Group. The numerical modelling work is therefore considered to be inherently conservative and hence in most cases actual impacts are likely to be less than those predicted. If anything actual impacts are therefore likely to tend towards the lower end of the impact ranges identified by the model sensitivity analysis.

3.5.1 Doongmabulla spring complex

As illustrated in Figure 12 based on the calibrated or 'best estimate' parameter set the predicted maximum long term drawdown impact in the Clematis Sandstone (i.e. the source aquifer) at the Doongmabulla Springs Complex is around 0.16 m. This is the predicted impact at the Joshua Spring which is located geographically closest to the proposed Mine Area.

Hence whilst it should be stressed that the calibrated or best estimate of impact is considered to be 0.16 m in this case it is recognised that the actual values of the modelled parameters may vary from the calibrated values, especially in the cases where the model calibration is not particularly sensitive to the parameter in question. A range of different alternate parameter values have therefore been considered as shown in Table 6.

For the Doongmabulla spring complex results suggest that predicted drawdown impacts are relatively sensitive to the modelled hydraulic conductivity of the Clematis Sandstone and Rewan Group (Figure 12). Model results suggest that predicted drawdown impacts at the springs could be increased from 0.16 m to around 0.3 m if the hydraulic conductivity of the Clematis Sandstone or the Rewan Group were increased from the calibrated value by one order of magnitude to $1.55 \times 10^{+01}$ m/d and 7.38×10^{-04} m/d respectively.

Conversely, however, sensitivity analysis results also suggest that predicted impacts at the Joshua Spring could be reduced to less than 0.04 m if the hydraulic conductivity of the Clematis Sandstone or the Rewan Group were decreased from the calibrated value by one order or magnitude to 1.55×10^{-01} and 7.38×10^{-06} m/d respectively

Predicted impacts at the Doongmabulla spring complex based on an even wider range of possible values for the hydraulic conductivity of the Rewan Group are presented in Section 3.6.1.

3.5.2 Mellaluka Spring Complex

As illustrated in Figure 13 based on the calibrated or 'best estimate' parameter set the predicted maximum long term drawdown impact in the Permian-age units (i.e. expected the source aquifer) at the Mellaluka Spring Complex is around 9 m. In this case sensitivity analysis results suggest that predicted drawdown impacts at Mellaluka are particularly sensitive to the modelled hydraulic conductivity of model layer 11, which represents Coal Seam D, across most of the model area. Sensitivity analysis results suggest that maximum drawdown impacts at Mellaluka Springs could be as high as 18 m if both the horizontal and vertical hydraulic conductivity of model layer 11 was increased by a factor of 10 to 3.05×10^{-02} m/d and 3.05×10^{-03} m/d, respectively.

Conversely, however, sensitivity analysis results also suggest that maximum impacts at Mellaluka Springs could be reduced to as low as 2.2 m if the average recharge applied to the model was increased by one order of magnitude from the calibrated value to around 3 mm/year.

3.5.3 Post Closure Pit Inflows

As illustrated in Figure 14 the best estimate of long term pit inflow to unremediated voids based on the calibrated parameter set is around 2,400 m³/d.

Predicted groundwater inflows appear to be particularly sensitive to the modelled hydraulic conductivity of model layer 12, which represents the older Permian-age units underlying Coal Seam D. Sensitivity analysis results suggest that groundwater discharge to the final voids could be as high as 4,000 m³/d if the actual hydraulic conductivity of the older Permian-age units was 10 times higher than the calibrated value for this layer. Sensitivity analysis results therefore suggest an upper bound inflow of around 4,000 m³/d or 1,600 m³/d higher than the best estimate inflow calculated using the calibrated parameter set. Conversely results suggest predicted inflows of as low as 1,500 m³/d if the hydraulic conductivity of model layer 4, which represents the Clematis Sandstone in areas where this unit is present and Tertiary-age units elsewhere within the model, is reduced by an order of magnitude.

3.5.4 Carmichael River Baseflow Impacts

As illustrated in Figure 15 the best estimate of maximum baseflow impact on the Carmichael River is around 1,000 m³/d.

Predicted baseflow impacts appear to be particularly sensitive to the hydraulic conductivity of Quaternary alluvium which immediately underlies the river (i.e. model layer 1), the main 'aquifer' units which are thought to provide baseflow in the upper reaches of the river (i.e. the Clematis Sandstone and Dunda Beds, model layers 4 and 5) and the Moolayember Formation (model layer 3). Sensitivity analysis results suggest that baseflow impacts could be as high as 1,600 m³/d if the hydraulic conductivity of the Moolayember Formation were increased by one order of magnitude from the calibrated value of 5.2×10^{-02} m/d to 5.2×10^{-01} m/d. Sensitivity analysis results also suggest that the baseflow impact could be as high as 1,600 m³/d if the modelled recharge was increased by one order of magnitude from the average calibrated value of 0.32 mm/year to 3.2 mm/year. Conversely results suggest predicted baseflow impacts of less than 600 m³/d would occur if the modelled hydraulic conductivity of the Dunda Beds was decreased by an order of magnitude.

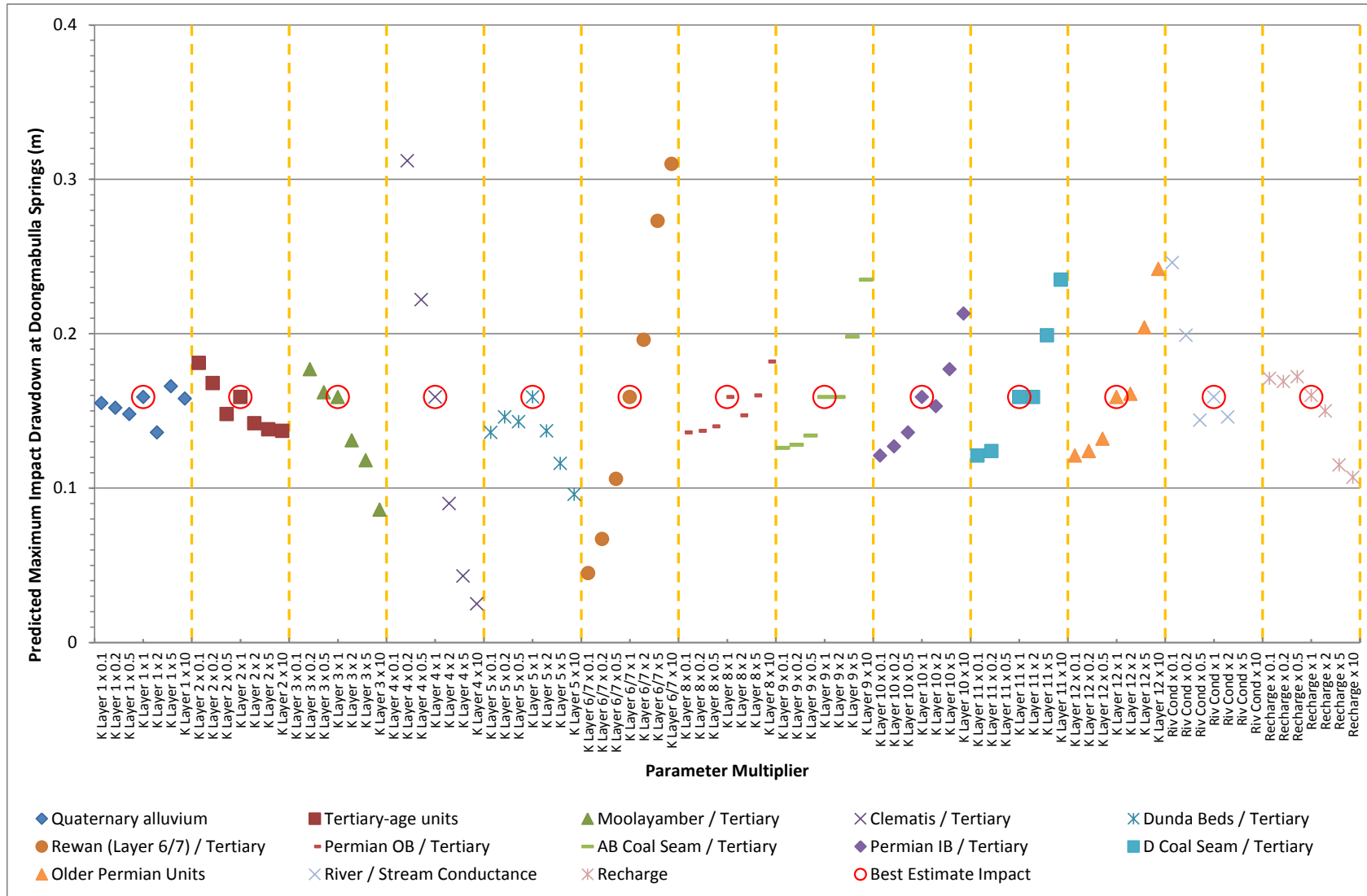


Figure 12 Sensitivity Analysis – Doongmabulla Springs Maximum Impacts

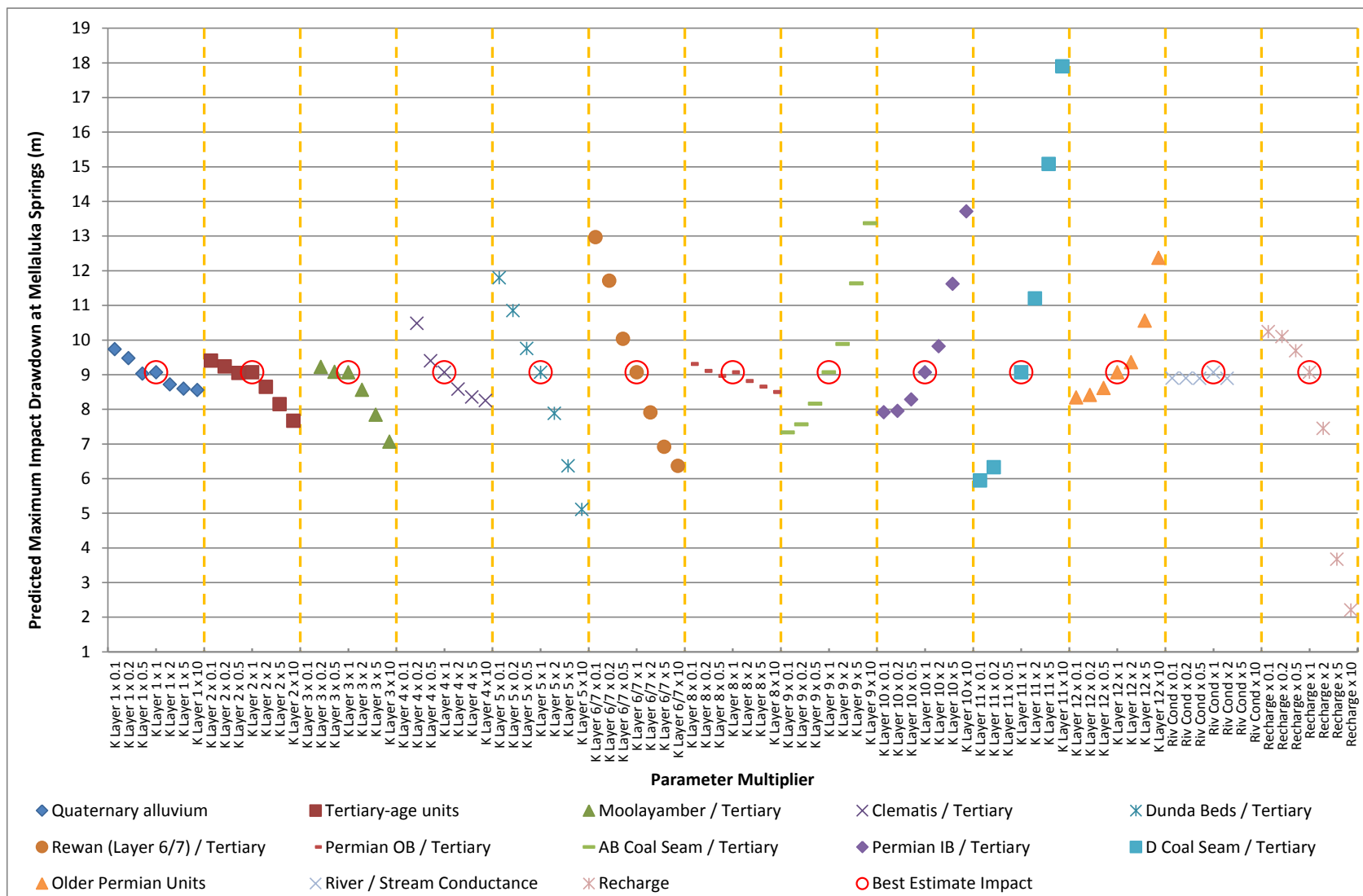


Figure 13 Sensitivity Analysis – Mellaluka Springs Maximum Impacts

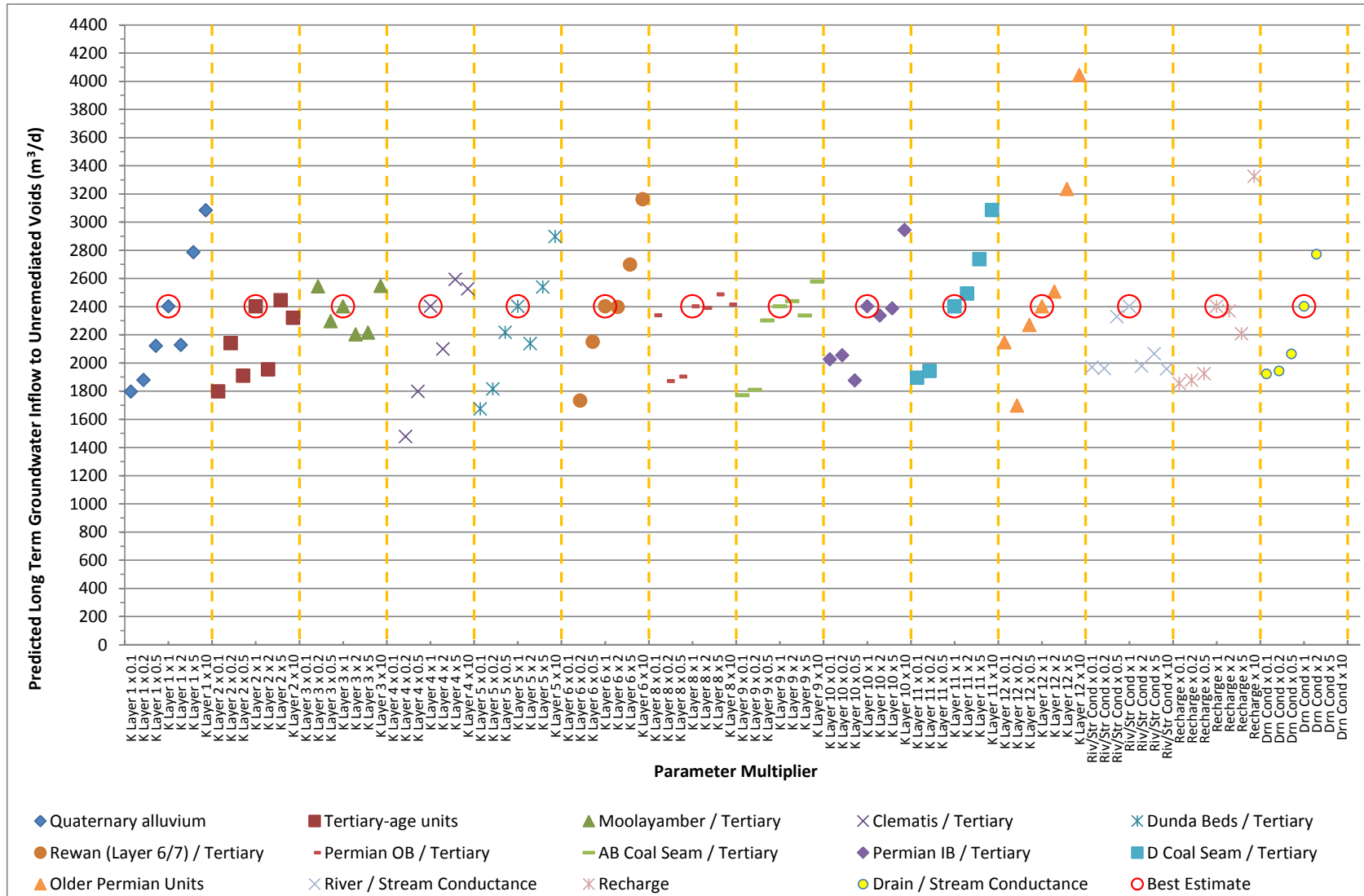


Figure 14 Sensitivity Analysis – Predicted Groundwater Inflow to Unremediated Voids

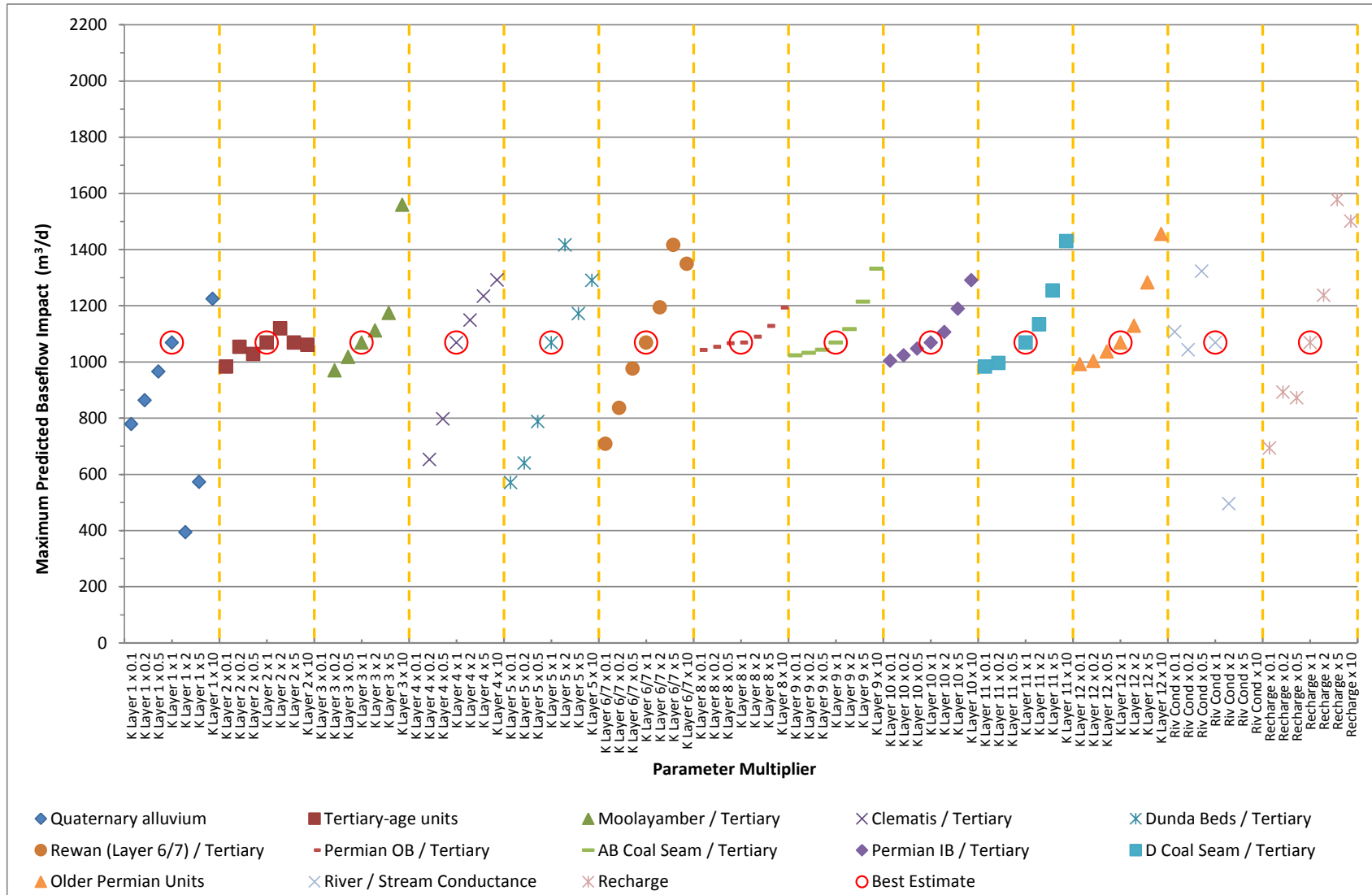


Figure 15 Sensitivity Analysis – Carmichael River Baseflow Impact

3.6 Additional sensitivity analysis

Based on comments received from the DNRM, DEHP, DotE and URS additional sensitivity runs were carried out as described below in Sections 3.6.1 to 3.6.3 with particular focus on the sensitivity of model predictions to:

- An expanded range of values for the hydraulic conductivity of the Rewan Group and modelled recharge quantities; and
- General head boundary conductance.

Further modelled work related to the assessing the sensitivity of model predictions to initial conditions was also considered but has not been completed at this stage for the reasons outlined in Section 3.6.4.

3.6.1 Hydraulic Conductivity Rewan Group

Comparison of calibrated values with other studies

Calibrated horizontal and vertical hydraulic conductivity for the Rewan Group are 7.4×10^{-5} and 7.4×10^{-6} m/d, respectively, and hence the calibrated horizontal conductivity value is slightly lower than the minimum observed value of 9.5×10^{-5} m/d recorded from site testing (Section 2.2.8). As explained in Section 5.5.2 of the SEIS (GHD, 2013) due to the relatively small number of site specific test values acceptable ranges for the Rewan Group for calibration purposes were derived from regional, rather than site specific data. The calibrated value Kh value of 7.4×10^{-5} is, therefore, well within the 5th and 95th percentile range of 8.3×10^{-6} to 5.1×10^{-2} m/d calculated from regional data set collated for the Surat CMA UWIR (QWC, 2012 and GHD, 2012) and comparable to the median regional value of 3.6×10^{-4} m/d. (QWC, 2012 and GHD, 2012). The calibrated horizontal hydraulic conductivity value is also within the range of observed data from core test results at other proposed mining sites in the Galilee Basin (Heritage Computing, 2013) and towards the centre of a typical range for siltstone identified by Domenico & Schwartz (1990).

Furthermore as shown in Figure 16 the calibrated vertical hydraulic conductivity value of 7.4×10^{-6} m/d for the Rewan Group is also comparable (i.e. within an order of magnitude) to calibrated values for the Rewan obtained by other groundwater modelling studies completed in the area (Heritage Computing, 2013 and URS, 2012) and other studies carried out elsewhere in Queensland (GHD, 2012, Matrix Plus, 2009).

The calibrated vertical hydraulic conductivity for the Rewan Group is, however, substantially lower than the upper bound of calibrated vertical hydraulic conductivity for GAB confining beds modelled by Audibert (1976) and quoted in the Galilee Basin groundwater study recently commissioned by the Lock the Gate Alliance (Hydrocology Environmental Consulting, 2013). It is not clear why the authors of this study have referenced these values, rather than field and/or laboratory tests values, or calibrated values for the Rewan Group from any one of a number of more recent modelling studies. In particular it should be stressed that whilst the Audibert study was potentially 'state of the art' at the time, by current standards the computing power available to the authors was very basic. A very simple model of the GAB was therefore developed comprising two unidentified aquifer layers and two confining beds which are also not named. The vertical hydraulic conductivity values calibrated by Audibert (1976) can therefore only be treated as some kind of average value for confining beds in the GAB. It is not therefore considered appropriate to quote this value in relation to the Rewan Group, especially since more relevant values are available from more recent studies. Nevertheless, and despite these reservations, the vertical hydraulic conductivity values estimated by Audibert (1976) have been adopted as upper bound values for the expanded sensitivity analysis in order to illustrate what

the impacts on the Doongmabulla Springs might be in the extremely unlikely event that the actual bulk vertical hydraulic conductivity of the Rewan was as high as 1×10^{-3} m/d throughout the area. This scenario is considered unlikely since it would essentially require fresh siltstone and mudstone units to be entirely absent from the entire sequence throughout the whole area between the proposed Mine Area and the GAB. Given the thickness, depth and observed variability of the Rewan Group in this area (see Appendix B) the chances of this occurring are considered to be negligible.

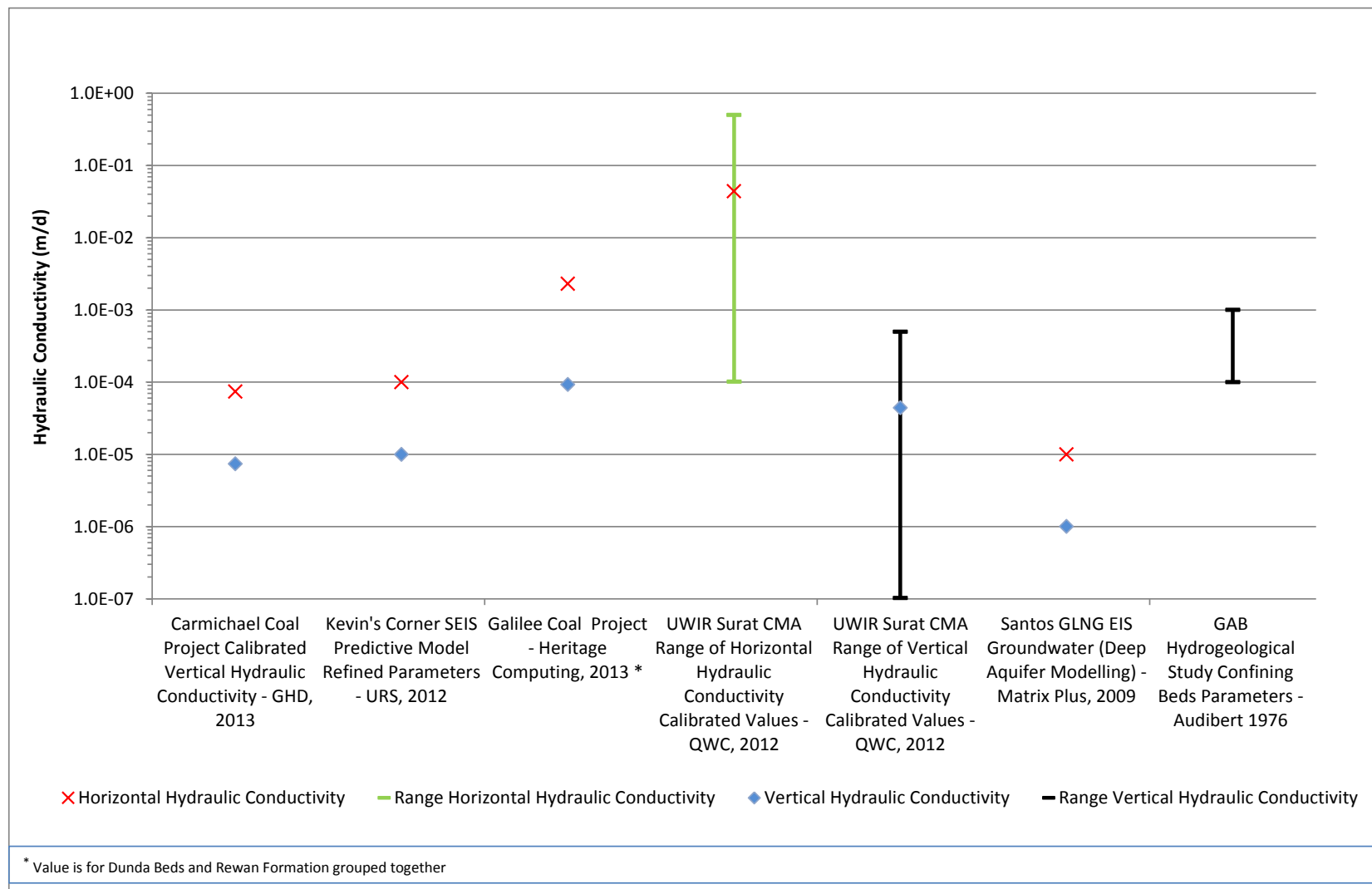


Figure 16 Summary of Rewan Group Hydraulic Conductivity Values Estimated by Other Modelling Studies

As part of the sensitivity analysis originally reported in the SEIS (GHD 2013, Section 5.8) and represented in Section 3.5, six model runs were carried out to assess the sensitivity of model predictions to changes in the calibrated Rewan Group hydraulic conductivity. Standard practice for this kind of analysis is to consider a range of alternative parameter values an order of magnitude either side of the calibrated or best estimate parameter value. The factors used in the sensitivity analysis were therefore 0.1, 0.2, 0.5, 2, 5 and 10. The upper bound vertical hydraulic conductivity value for the Rewan Group considered in the analysis summarised in the SEIS was therefore 7.4×10^{-5} m/d, a value which exceeds the calibrated values previously estimated by URS (2012), Matrix Plus (2009) and the median value from the Surat CMA model (QWC, 2012; QHD, 2012), see Figure 16. However, as shown in Figure 16 both Heritage Computing (2013) and Audibert (1976) have calculated higher vertical hydraulic conductivity values than 7.4×10^{-5} m/d. Given the potential significance of the vertical hydraulic conductivity of the Rewan Group, the large variability of the observed values for this geological unit and the higher values calculated by some modelling studies further model sensitivity analysis has been undertaken.

Table 7 lists the Rewan Group hydraulic conductivity multipliers and parameter ranges adopted for the revised sensitivity analysis.

Predicted impacts at the Doongmabulla spring complex

Maximum predicted post closure impacts at Doongmabulla spring complex using the range of vertical hydraulic conductivity values adopted for the expanded sensitivity analysis are shown in Figure 17, where the calibrated values estimated by other modelling studies are also shown. It should be stressed that the calibrated Kv value for the Rewan Group quoted in the SEIS is considered to represent the best available estimate of this parameter as it results in an optimal fit to the available data. As shown in Figure 17 the best estimate of maximum drawdown impacts at the Doongmabulla spring complex is therefore 0.16 m since this is the calibrated or best estimate parameter set. Sensitivity analysis results, however, suggest that maximum impacts could be up to around 1 m in the event that the actual vertical hydraulic conductivity of the Rewan Group was 1×10^{-3} m/d (i.e. around two orders of magnitude higher than the calibrated value) as estimated by Audibert (1976) and close to zero if the lower bound value calibrated in the Surat CMA UWIR model (QWC, 2012) of 1×10^{-7} m/d (i.e. around two orders of magnitude lower than the calibrated value) was adopted. As previously discussed it should be stressed that the Audibert (1976) Kv estimate of 1×10^{-3} m/d in particular is considered to be an extreme case since it would require fresh siltstone and mudstone units to be entirely absent from the Rewan Group sequence throughout the whole area between the proposed Mine Area and the GAB.

Table 7 Sensitivity Analysis - Rewan Group Hydraulic Conductivity Scenarios

Geological Unit	Model Layer	Model Parameter	Multipliers	Range of Horizontal Hydraulic Conductivity Values (m/d)	Range of Vertical Hydraulic Conductivity Values (m/d)
Rewan Group	6	Kh	1.36, 0.1, 0.2, 0.5, 2, 5, 10, 15, 20, 50, 100, 150	7.4×10^{-6} – 1.0×10^{-2}	1.0×10^{-7} – 1.0×10^{-3}
		Kv	0.014, 0.1, 0.2, 0.5, 2, 5, 10, 15, 20, 50, 100, 150		

Geological Unit	Model Layer	Model Parameter	Multipliers	Range of Horizontal Hydraulic Conductivity Values (m/d)	Range of Vertical Hydraulic Conductivity Values (m/d)
Rewan Group	7	Kh	1.36, 0.1, 0.2, 0.5, 2, 5, 10, 15, 20, 50, 100, 150	$7.4 \times 10^{-06} - 1.0 \times 10^{-2}$	$1.0 \times 10^{-7} - 1.0 \times 10^{-3}$
		Kv	0.014, 0.1, 0.2, 0.5, 2, 5, 10, 15, 20, 50, 100, 150		

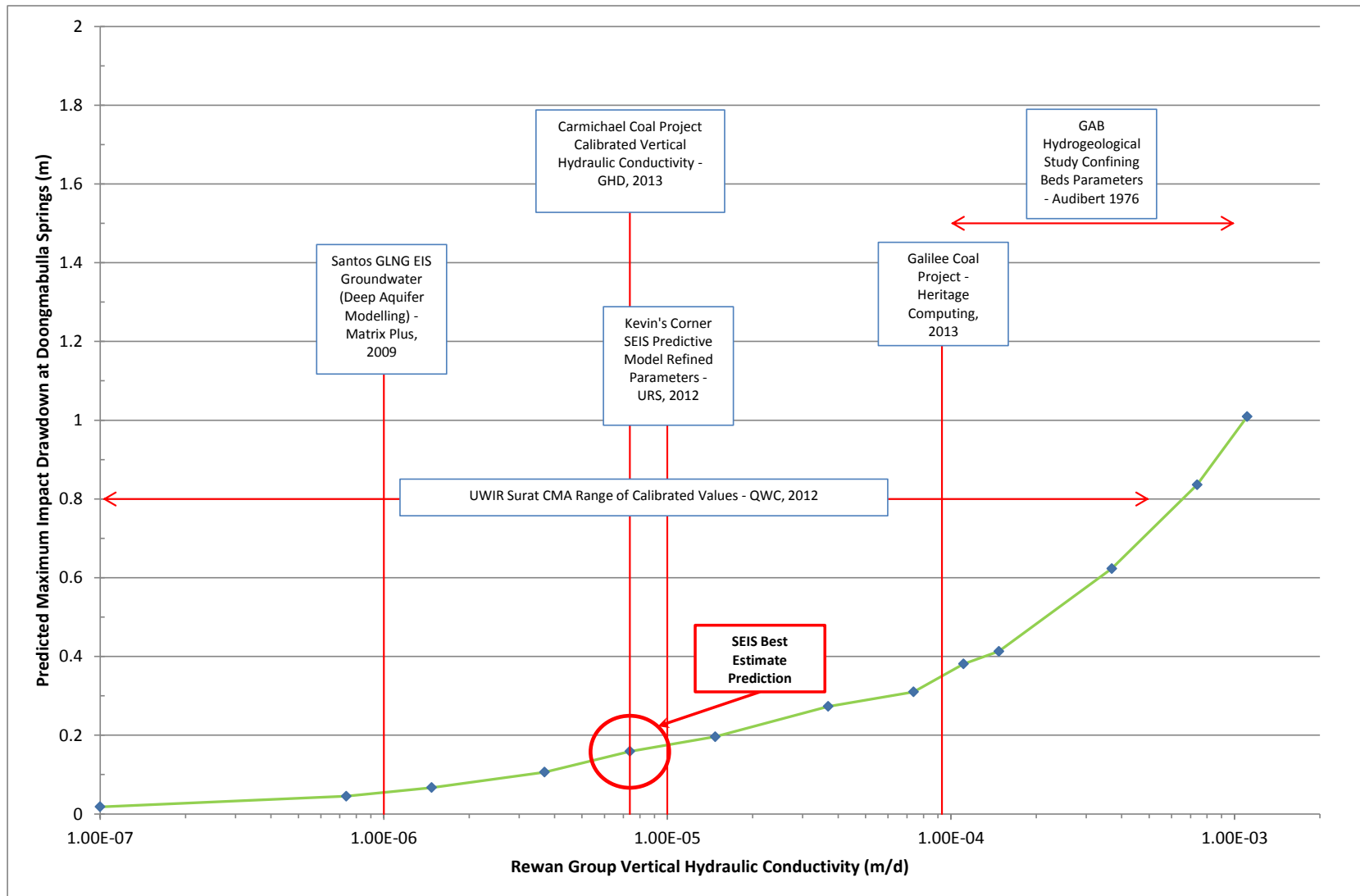


Figure 17 Sensitivity Analysis Rewan Group – Doongmabulla Springs Maximum Impacts

Predicted Impacts on GAB Groundwater Resources

The hydraulic conductivity of the Rewan Group also represents a key parameter in controlling the quantity of additional groundwater inflow induced from the GAB area into the adjacent Galilee Basin i.e. on potential long term impacts on the groundwater resources of the GAB. As discussed previously in Sections 2.4 and 3.2 the available groundwater level data suggests groundwater is currently discharging from the GAB area into the adjacent Galilee Basin. Output from the calibrated pre-development steady state model suggests around 100 m³/d of net vertical leakage from the lowest unit of the GAB (the Rewan Group) to the underlying Permian-age units is currently occurring. However, model predictions based on the calibrated or 'best estimate' parameter set suggest that net leakage through the base of the Rewan Group to the underlying Permian-age strata will be increased to around 1,000 m³/d post closure due to ongoing evaporation from the final voids, and hence long term groundwater level drawdown. A long term increase in net vertical leakage from the GAB to the adjacent Permian-age units of up to around 900 m³/d is therefore predicted.

Sensitivity analysis results (Figure 18), however, suggest that maximum impacts could be up to around 4,300 m³/d in the event that the actual vertical hydraulic conductivity of the Rewan was 1x10⁻³ m/d (i.e. around two orders of magnitude higher than the calibrated value) as estimated by Audibert (1976) and around 70 m³/d if the lower bound values calibrated in the Surat CMA UWIR model (QWC, 2012) of 1x10⁻⁷ m/d (i.e. around two orders of magnitude lower than the calibrated value) was adopted.

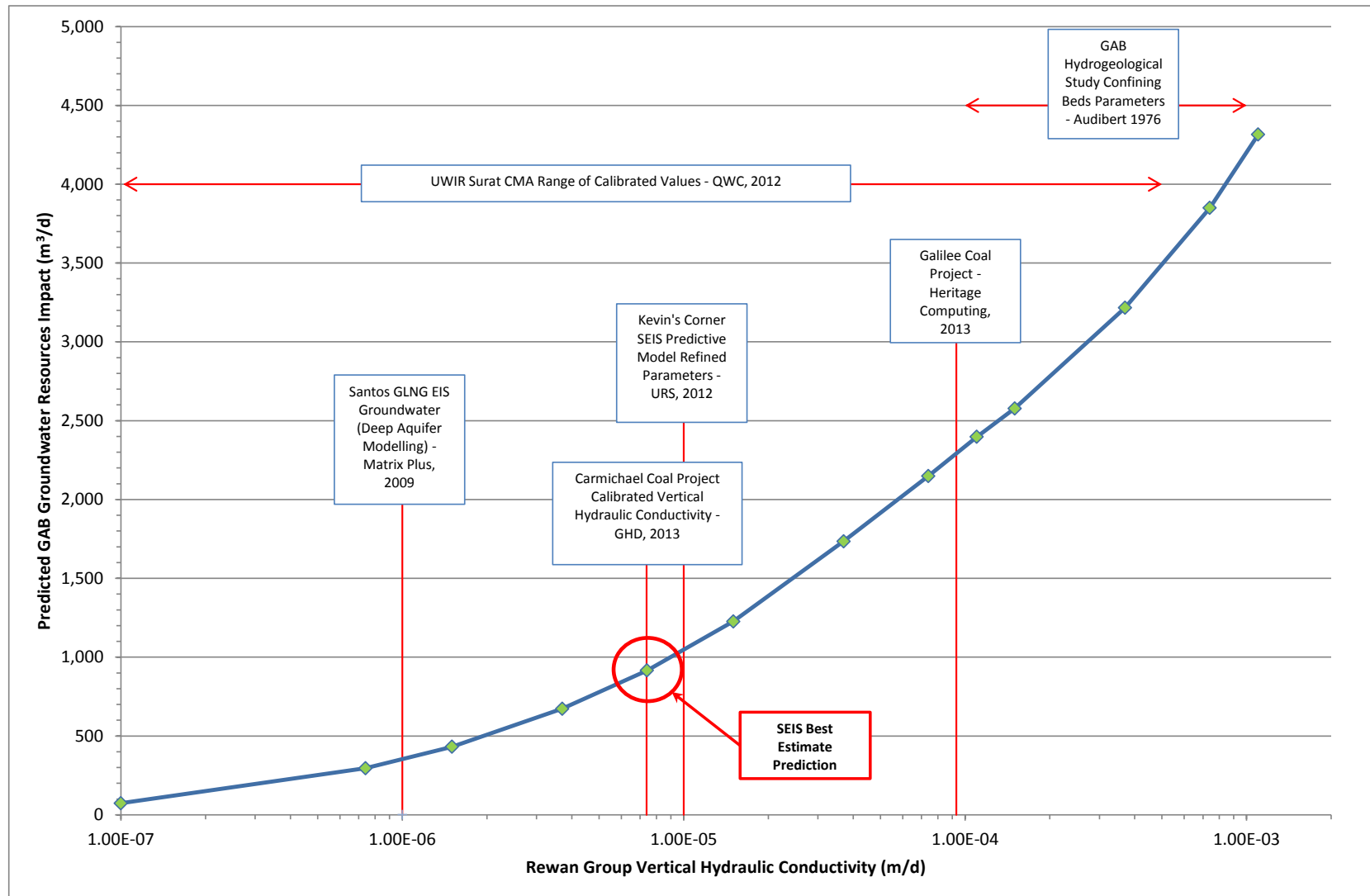


Figure 18 Sensitivity Analysis Rewan Group – GAB Groundwater Resource Impacts

3.6.2 Recharge

Comparison of calibrated values with other studies

The sensitivity of model predictions to recharge was previously assessed and reported in Section 5.8 of the SEIS (GHD, 2013).

A range of calculations were carried out prior to undertaking any numerical modelling as previously described in Section 4.8 of the SEIS (GHD, 2013). These calculations suggested rainfall derived recharge in the Project Area falling within the range 0.1 to 4 mm/yr. This range of values, which is considered to be consistent with previous estimates made by Kellet et al. (2003) for minor aquifers of the GAB, was then used to define upper and lower bounds for model calibration purposes. Calibration of the groundwater model suggests a best estimate long term average recharge rate of 0.32 mm/year across the whole model area. A higher rate of 1.1 mm/year was calibrated for areas where the Clematis Sandstone is present at outcrop with only around 0.1 mm/year modelled in other areas. Whilst it is recognised that these values are relatively low they are considered to be consistent with estimates made by Kellet et al. (2003), who describe typical rainfall recharge rates of less than 0.5 mm/year outside of the main GAB aquifer outcrop areas. However, Kellett et al. (2003) also describe rainfall derived recharge rates (i.e. diffuse rainfall and preferred pathway or bypass flow) of up around 30 mm/year in other areas.

As part of the sensitivity analysis originally reported in the SEIS (GHD 2013, Section 5.8) and represented in Section 3.5 six model runs were carried out to assess the sensitivity of model predictions to changes in recharge. The factors used in the sensitivity analysis were 0.1, 0.2, 0.5, 2, 5 and 10. A factor of 10 corresponds to one order of magnitude change in recharge to an average value of 3.2 mm/year across the whole model domain and 11.0 mm/year for the Clematis Sandstone.

A variety of recharge values have been estimated in other modelling studies carried out in the Galilee Basin. For example, URS (2012) reports calibrated recharge rates between 3.65×10^{-2} mm/year and 3.65×10^{-3} mm/year, whilst Heritage Computing (2013) uses values as high as 30 mm/year for the Clematis Sandstone.

Given the wide range of recharge estimates used in similar EIS studies and elsewhere in Queensland further sensitivity analysis scenarios have been undertaken to test a range of values from 0.004 to 33 mm/year (i.e. the full range of values estimated by previous studies as shown in Table 8).

Table 8 Sensitivity Analysis – Recharge Scenarios

Model Layer	Model Parameter	Multiplier	Range of Recharge Values (mm/year) – Clematis Sandstone
1-5	Recharge	0.003, 0.027, 0.1, 0.2, 0.5, 2, 5, 10, 15, 20, 25, 30	0.004 - 32.9

The largest adopted multiplier of 30 corresponds to an average recharge of 9.6 mm/year across the whole model domain and a recharge value of around 33 mm/year for the Clematis Sandstone which is similar to the upper bound of the estimates reported by Kellett et al. (2003).

Predicted Impacts at Doongmabulla Springs

Maximum predicted impacts at Doongmabulla Springs using a range of recharge values are shown in Figure 19.

As expected drawdown impacts at the springs reduces as recharge increases in the model since higher modelled recharge values result in a smaller cone of influence. For recharge values greater than 15 mm/year model results suggest maximum drawdown impacts at Doongmabulla springs of around 0.1 m which corresponds to an impact decrease of around 35 percent from the calibrated realisation. Predicted drawdown impacts at the Doongmabulla Springs are relatively insensitive to further reductions in recharge from the already relatively low calibrated value. Maximum impacts based on the lower bound recharge value tested are 0.18m (i.e. only around 0.02m higher than the calibrated or best estimate prediction quoted in the SEIS).

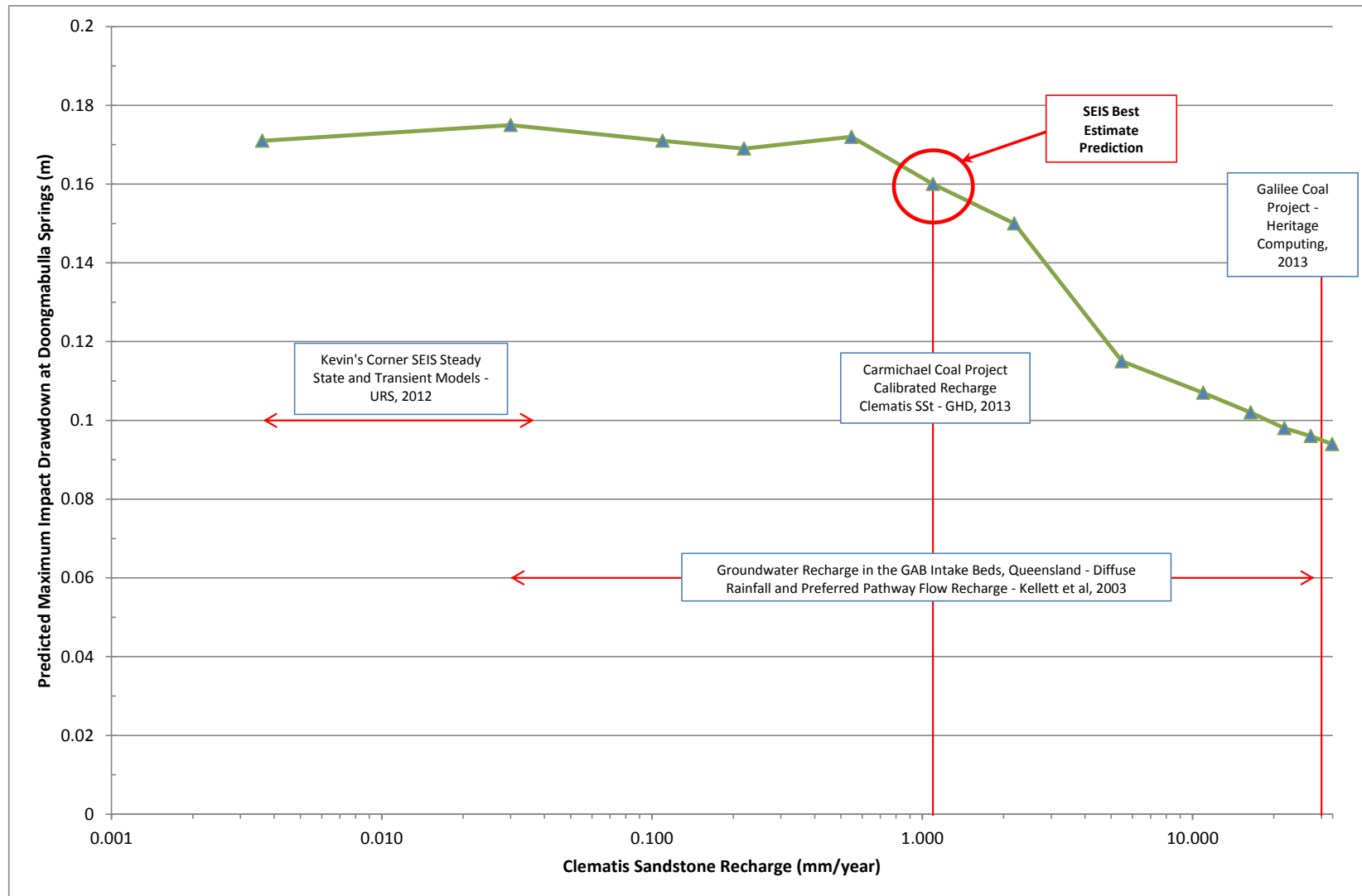


Figure 19 Sensitivity Analysis Recharge – Doongmabulla Springs Maximum Impacts

3.6.3 General Head Boundary Conductance

Given the distance between the modelled general head boundaries and the predicted impact area it was not expected that the model predictions would be sensitive to either the elevation or conductance of the modelled general head boundaries which are located at the margins of the modelled area. The sensitivity analysis reported in Section 5.8 of the SEIS (GHD, 2013) therefore excluding consideration general head boundaries. However, comments have subsequently been received that general head boundary sensitivity should be assessed and further work has now been completed.

Table 9 lists the general head boundaries conductance multipliers used in the sensitivity analysis.

Table 9 Sensitivity Analysis – General Head Boundaries Multipliers

Model Layer	Model Parameter	Multiplier
All layers with GHB	GHB Conductance	0.1, 0.2, 0.5, 2, 5, 10

As expected there is no significant difference in the predicted maximum impact at the Doongmabulla spring complex due to changes in the general head boundaries conductance. The maximum change in predicted drawdowns across all sensitivity runs is equal to 0.004 m. It can be therefore concluded that model predictions are insensitive to the conductance term of the general head boundaries. Since the modelled GHB elevations and conductance are related (i.e. increasing the conductance has the same effect as reducing the GHB elevation and vice versa) then it can also be stated that model predictions are insensitive to the modelled GHB elevations.

3.6.4 Initial Conditions

Comments have also been received to the effect that the model calibration and associated predictions may be sensitive to the use of:

- Average observed groundwater levels as calibration targets; and/or
- Initial conditions for the transient predictive runs which are based on steady state or long term average modelled heads.

Neither of these perceived 'issues' is considered to be a significant limitation of the model. With regard to the use of average groundwater levels as calibration targets it should be noted that observed groundwater level data for boreholes completed in the various Triassic, Permian and Tertiary-age strata show very minor seasonal and other fluctuations of less than 0.5 m. More substantial fluctuations can only be seen in some bores installed into the Quaternary alluvium which underlies the Carmichael River. Hence outside of the narrow strip of the Quaternary alluvium associated with the Carmichael River the current groundwater system appears to be a relatively static one and hence for most model layers the adoption of say minimum observed groundwater levels, rather than average levels would have made not material difference to the calibration. Where observed minima were used as calibration targets for the Quaternary alluvium (model layer 1) then this may have resulted in a different calibrated value for this unit. However, the sensitivity of potential variations in this parameter have been assessed in some detail as part of the sensitivity analysis and predominantly tend to confirm that the key model predictions including predicted impacts at the Doongmabulla (Figure 12) and Mellaluka (Figure 13) spring complexes are relatively insensitive to the hydraulic conductivity of the Quaternary alluvium. As would be expected predicted baseflow impacts on the Carmichael River are more

sensitive to this parameter, however the alternative parameter values considered in the sensitivity analysis result in either very minor increases or more significant reductions in impact.

With regard to the potential sensitivity of model predictions to the initial conditions assumed for the transient predictive run (i.e. whether the proposed mine commences operation in a dry, wet or average year) given the long time-lags predicted between extraction and impacts (Figure 11) and the generally static nature of the groundwater system in the area it is considered unlikely that the long term impacts of the proposed mine will be sensitive to initial conditions.

4. References

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Appendices

Appendix A –Additional Predictive Model Drawdown Maps

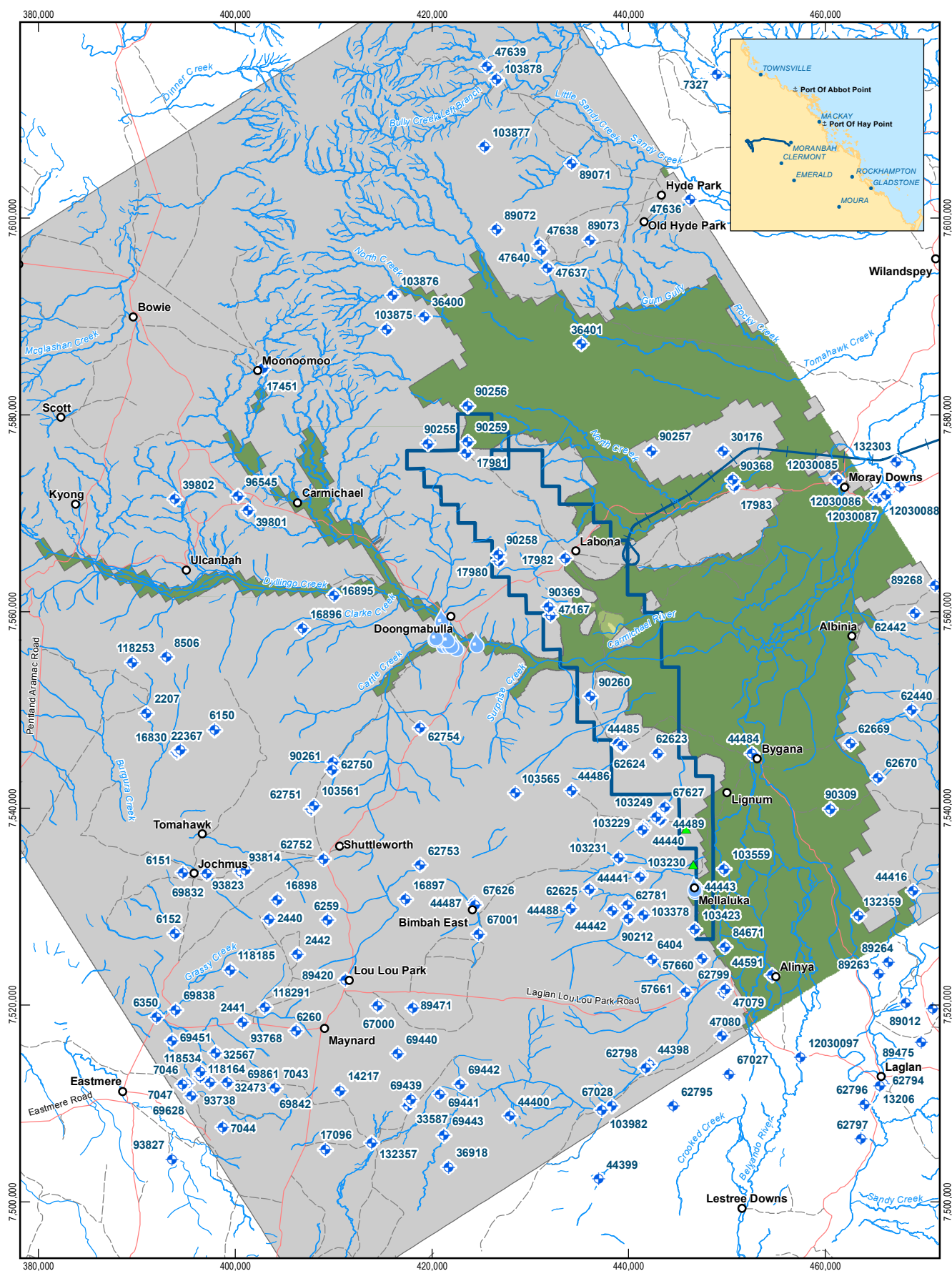
Maps

- A.1 Predicted Quaternary Alluvium Drawdowns - Year 2019
- A.2 Predicted Quaternary Alluvium Drawdowns - Year 2039
- A.3 Predicted Quaternary Alluvium Drawdowns - Year 2071
- A.4 Predicted Quaternary Alluvium Drawdowns - Year 2092
- A.5 Predicted Quaternary Alluvium Drawdowns - Year 2109
- A.6 Predicted Quaternary Alluvium Drawdowns - Year 2129
- A.7 Predicted Quaternary Alluvium Drawdowns – Post-Closure (Long Term)
- A.8 Predicted Tertiary Alluvium Drawdowns - Year 2019
- A.9 Predicted Tertiary Alluvium Drawdowns - Year 2039
- A.10 Predicted Tertiary Alluvium Drawdowns - Year 2071
- A.11 Predicted Tertiary Alluvium Drawdowns - Year 2092
- A.12 Predicted Tertiary Alluvium Drawdowns - Year 2109
- A.13 Predicted Tertiary Alluvium Drawdowns - Year 2129
- A.14 Predicted Tertiary Alluvium Drawdowns – Post-Closure (Long Term)
- A.15 Predicted Clematis SSt Drawdowns - Year 2019
- A.16 Predicted Clematis SSt Drawdowns - Year 2039
- A.17 Predicted Clematis SSt Drawdowns - Year 2071
- A.18 Predicted Clematis SSt Drawdowns - Year 2092
- A.19 Predicted Clematis SSt Drawdowns - Year 2109
- A.20 Predicted Clematis SSt Drawdowns - Year 2129
- A.21 Predicted Clematis SSt Drawdowns – Post-Closure (Long Term)
- A.22 Predicted Coal Seam AB Drawdowns - Year 2019
- A.23 Predicted Coal Seam AB Drawdowns - Year 2039
- A.24 Predicted Coal Seam AB Drawdowns - Year 2071
- A.25 Predicted Coal Seam AB Drawdowns - Year 2092
- A.26 Predicted Coal Seam AB Drawdowns - Year 2109
- A.27 Predicted Coal Seam AB Drawdowns - Year 2129
- A.28 Predicted Coal Seam AB Drawdowns – Post-Closure (Long Term)
- A.29 Predicted Coal Seam D Drawdowns - Year 2019
- A.30 Predicted Coal Seam D Drawdowns - Year 2039
- A.31 Predicted Coal Seam D Drawdowns - Year 2071
- A.32 Predicted Coal Seam D Drawdowns - Year 2092

A.33 Predicted Coal Seam D Drawdowns - Year 2109

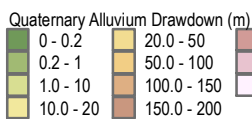
A.34 Predicted Coal Seam D Drawdowns - Year 2129

A.35 Predicted Coal Seam D Drawdowns – Post-Closure (Long Term)

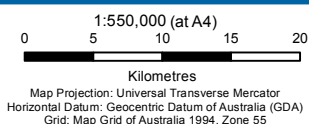


LEGEND

- Homestead
- ▲ Spring
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)



Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

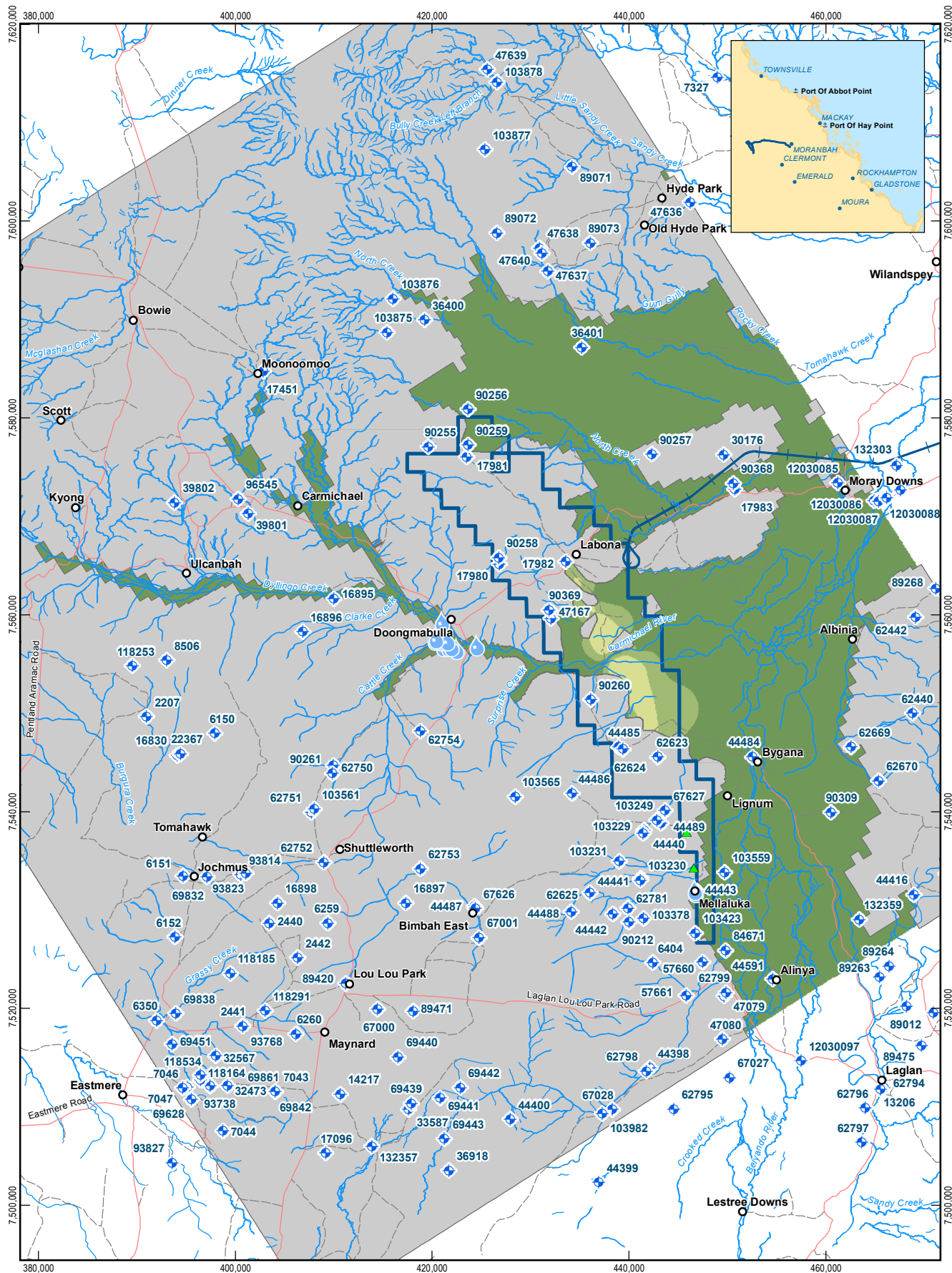


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Quaternary Alluvium
Drawdowns - Year 2019

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.1



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Quaternary Alluvium Drawdown (m)
- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:550,000 (at A4)
0 5 10 15 20
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

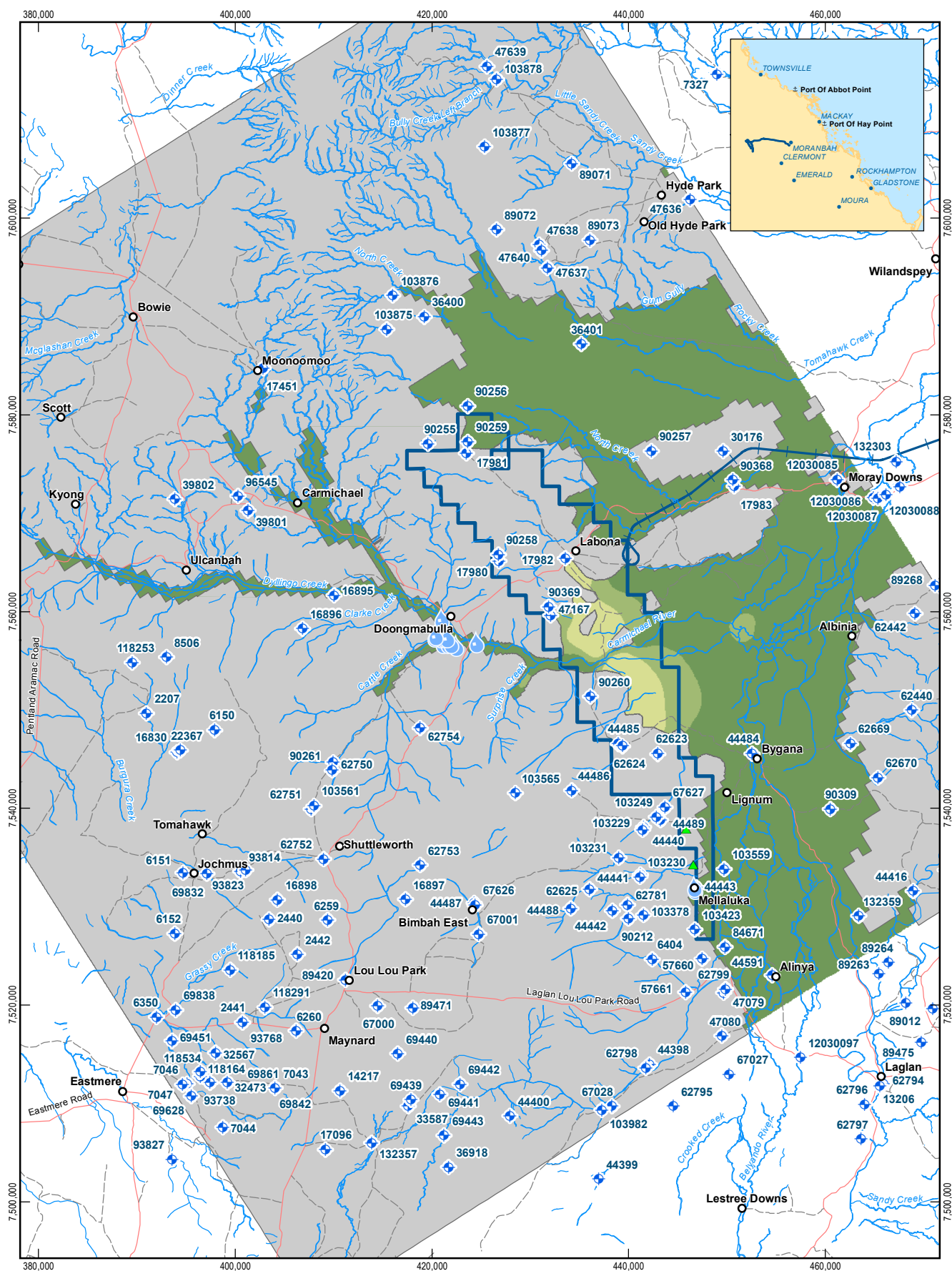


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Carmichael Coal Mine and Rail Project SEIS
Predicted Quaternary Alluvium
Drawdowns - Year 2039

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.2



LEGEND

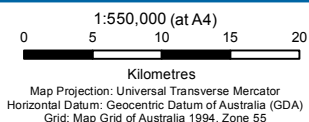
- Homestead
- ▲ Spring
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- Local Road
- Track
- Watercourse

Quaternary Alluvium Drawdown (m)

- | | | |
|-----------|-------------|-------------|
| 0 - 0.2 | 20.0 - 50 | 200.0 - 250 |
| 0.2 - 1 | 50.0 - 100 | 250.0 - 300 |
| 1.0 - 10 | 100.0 - 150 | 300.0 - 350 |
| 10.0 - 20 | 150.0 - 200 | |

- Project (Rail)
- Project (Mine)

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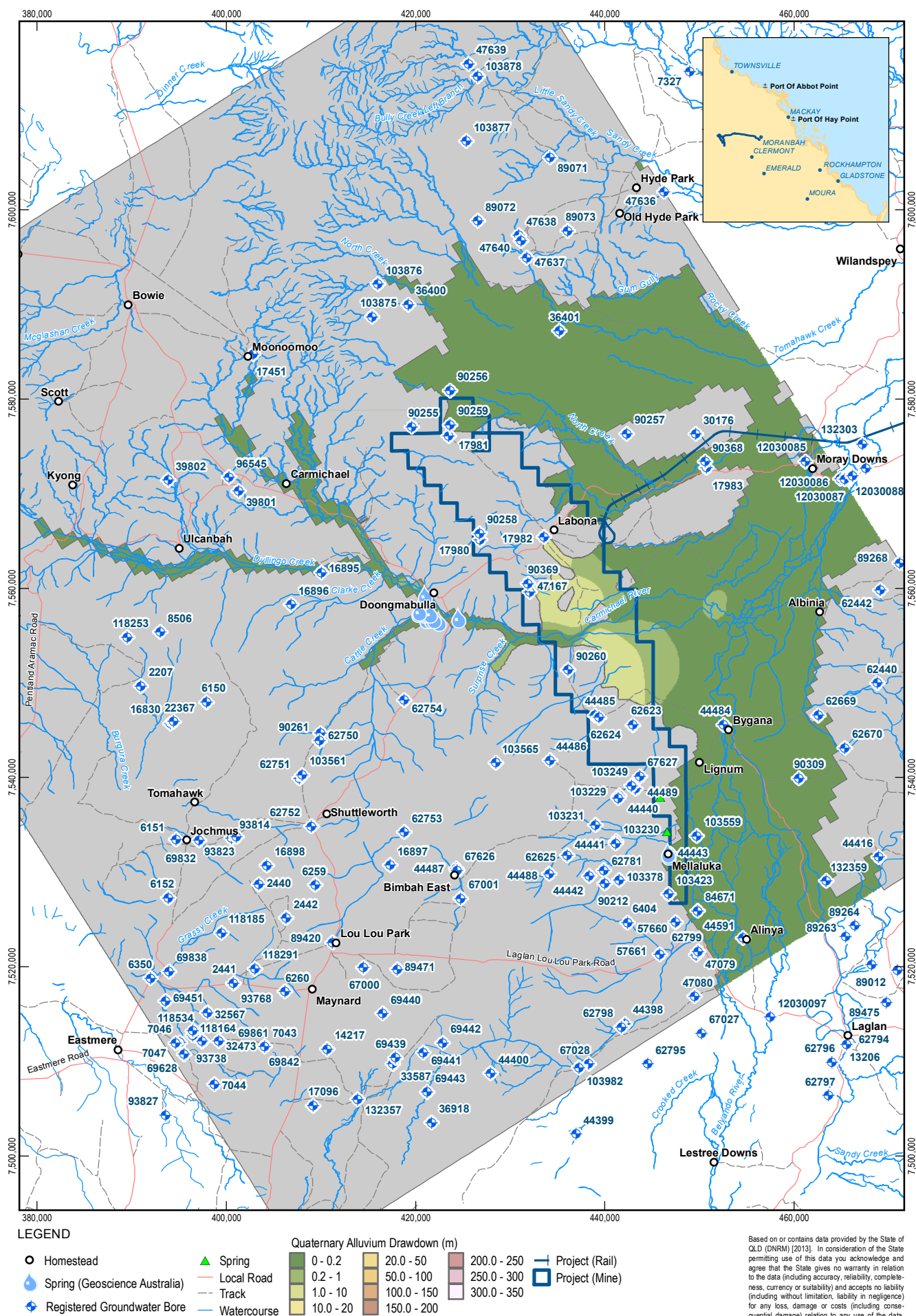


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Carmichael Coal Mine and Rail Project SEIS
Predicted Quaternary Alluvium Drawdowns - Year 2071

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.3



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1:550,000 (at A4)
0 5 10 15 20
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55



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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Quaternary Alluvium Drawdowns - Year 2092

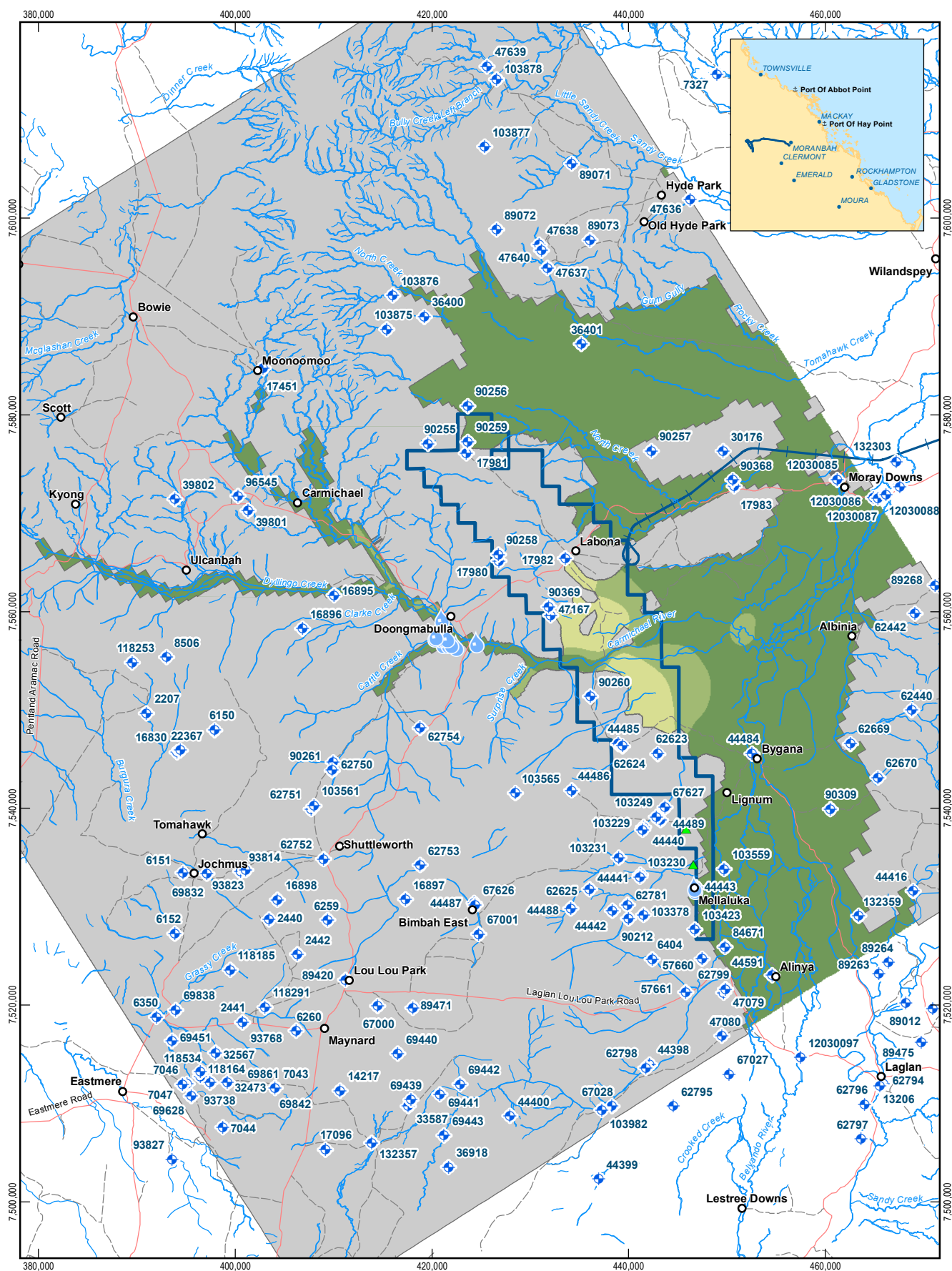
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Date 04-10-2013

Figure A.4

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Data Source: DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Spring Locations, Watercourse (2007); GHD: Monitoring Bores, Interpreted Groundwater Level Contour (2012); DNRM: Streams (2012), Registered Groundwater Bores (2010); Adani: Project Rail 1 (Opt11 Rev2) & 2 (Opt9 Rev3) (2013). Created by: BW, MS



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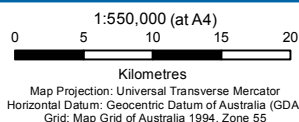
- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse

Quaternary Alluvium Drawdown (m)

- | | | |
|-----------|-------------|-------------|
| 0 - 0.2 | 20.0 - 50 | 200.0 - 250 |
| 0.2 - 1 | 50.0 - 100 | 250.0 - 300 |
| 1.0 - 10 | 100.0 - 150 | 300.0 - 350 |
| 10.0 - 20 | 150.0 - 200 | |

- Project (Rail)
- Project (Mine)

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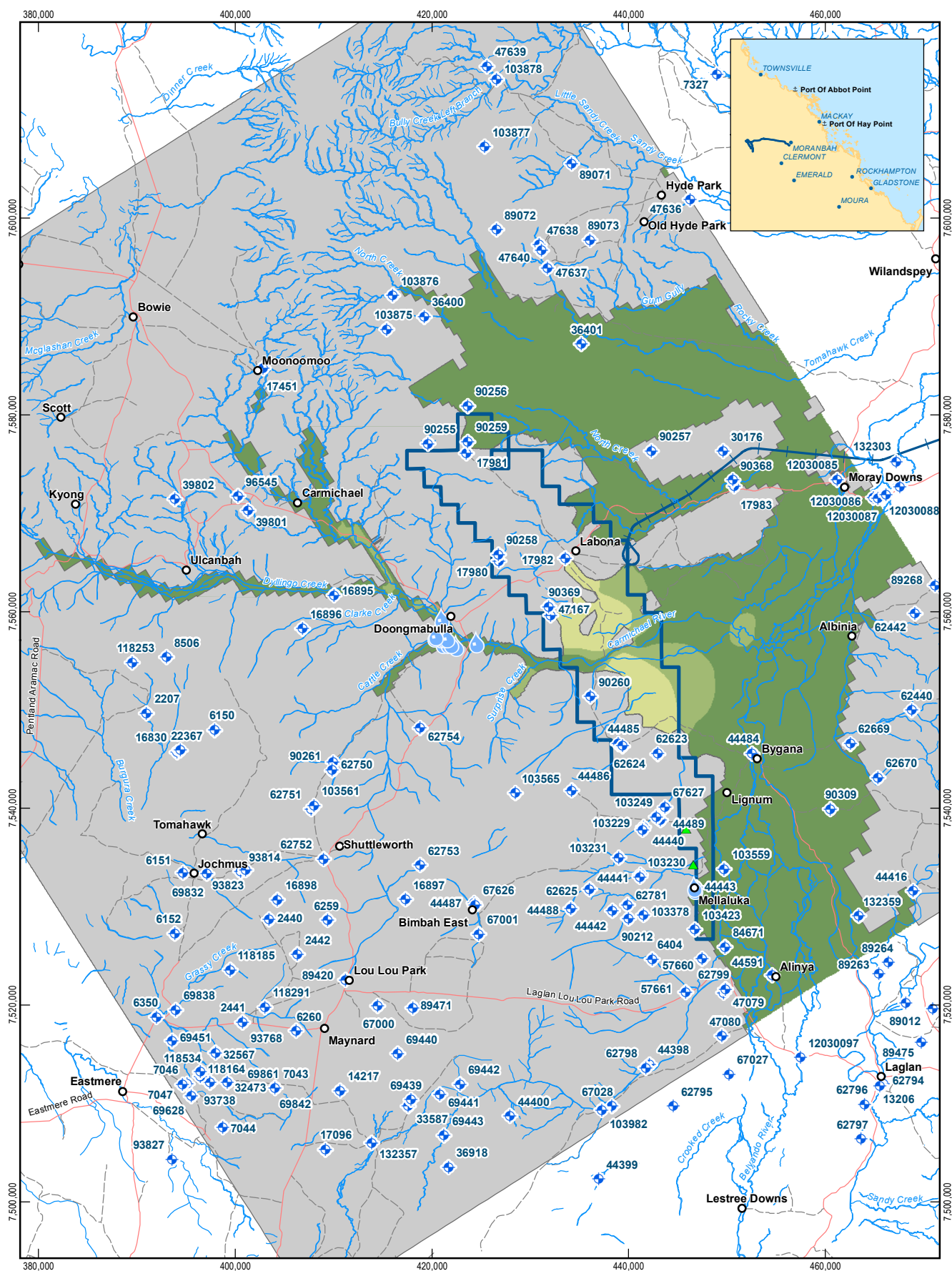


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Quaternary Alluvium Drawdowns - Year 2109

Job Number 41-26422
Revision A
Date 04-10-2013

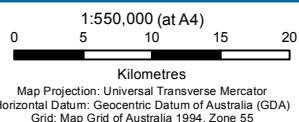
Figure A.5



LEGEND

- Homestead
 - Spring (Geoscience Australia)
 - ◆ Registered Groundwater Bore
 - ▲ Spring
 - Local Road
 - Track
 - Watercourse
- | Quaternary Alluvium Drawdown (m) | | | |
|----------------------------------|-------------|-------------|-------------|
| 0 - 0.2 | 0.2 - 1 | 1.0 - 10 | 10.0 - 20 |
| 20.0 - 50 | 50.0 - 100 | 100.0 - 150 | 150.0 - 200 |
| 200.0 - 250 | 250.0 - 300 | 300.0 - 350 | |
- Project (Rail)
 - Project (Mine)

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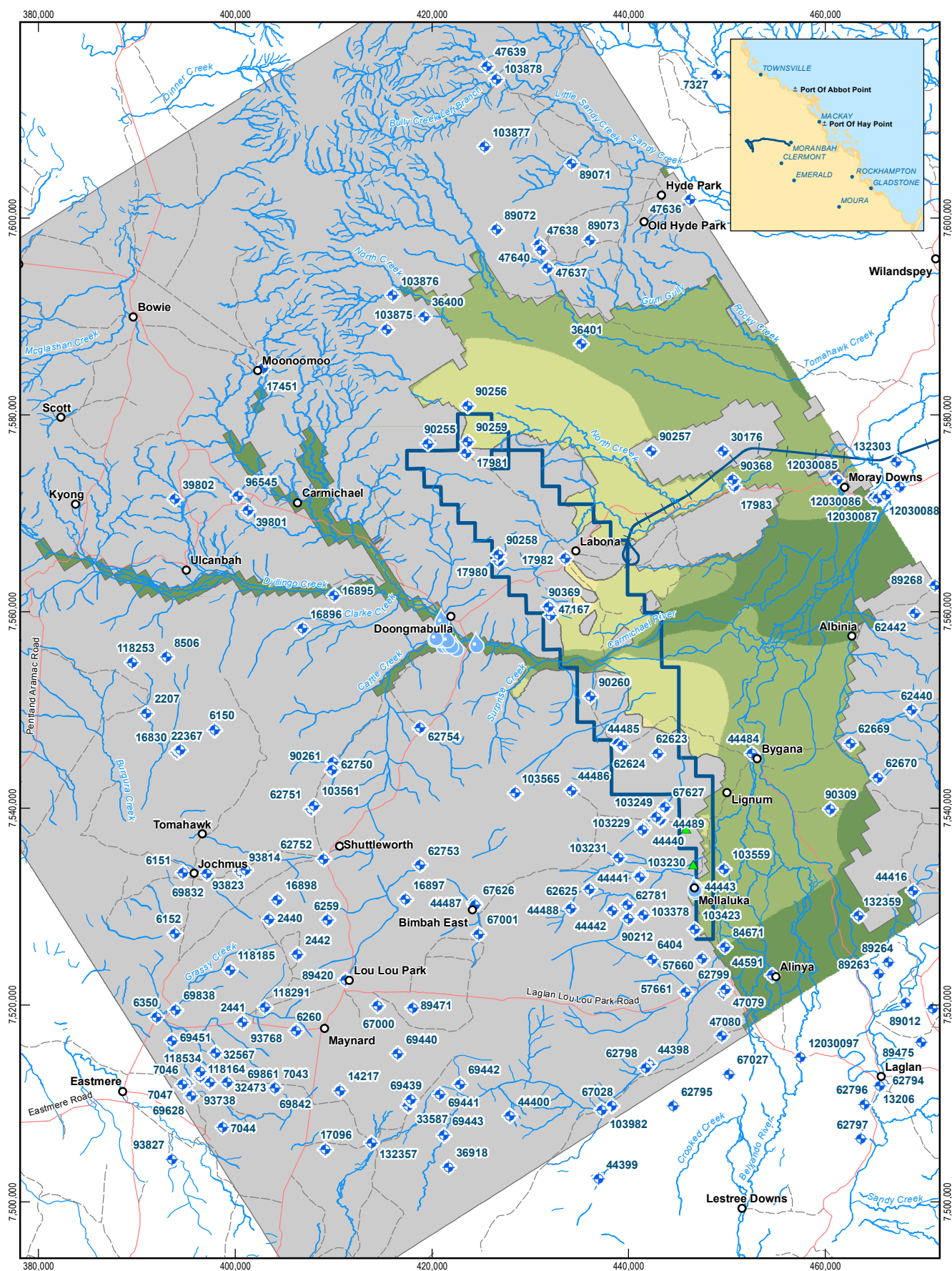


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Quaternary Alluvium Drawdowns - Year 2129

Job Number: 41-26422
Revision: A
Date: 04-10-2013

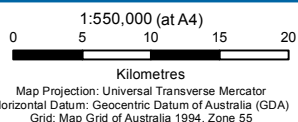
Figure A.6



LEGEND

- Homestead
- Spring
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Quaternary Alluvium Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

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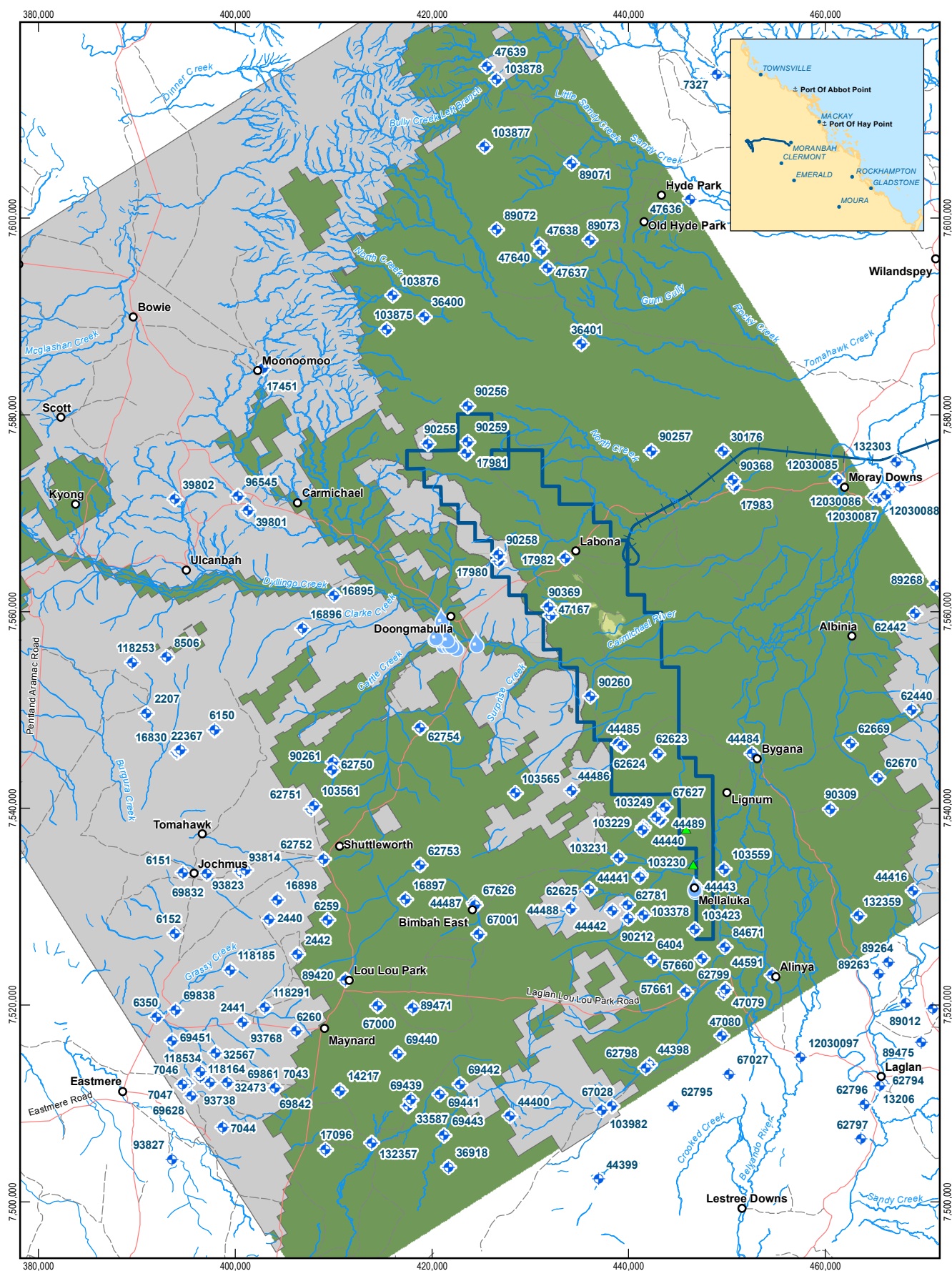


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision A
Date 04-10-2013

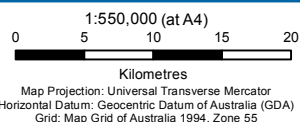
Predicted Quaternary Alluvium Drawdowns - Post-Closure (Long Term) Figure A.7



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350
- Project (Rail)
- Project (Mine)

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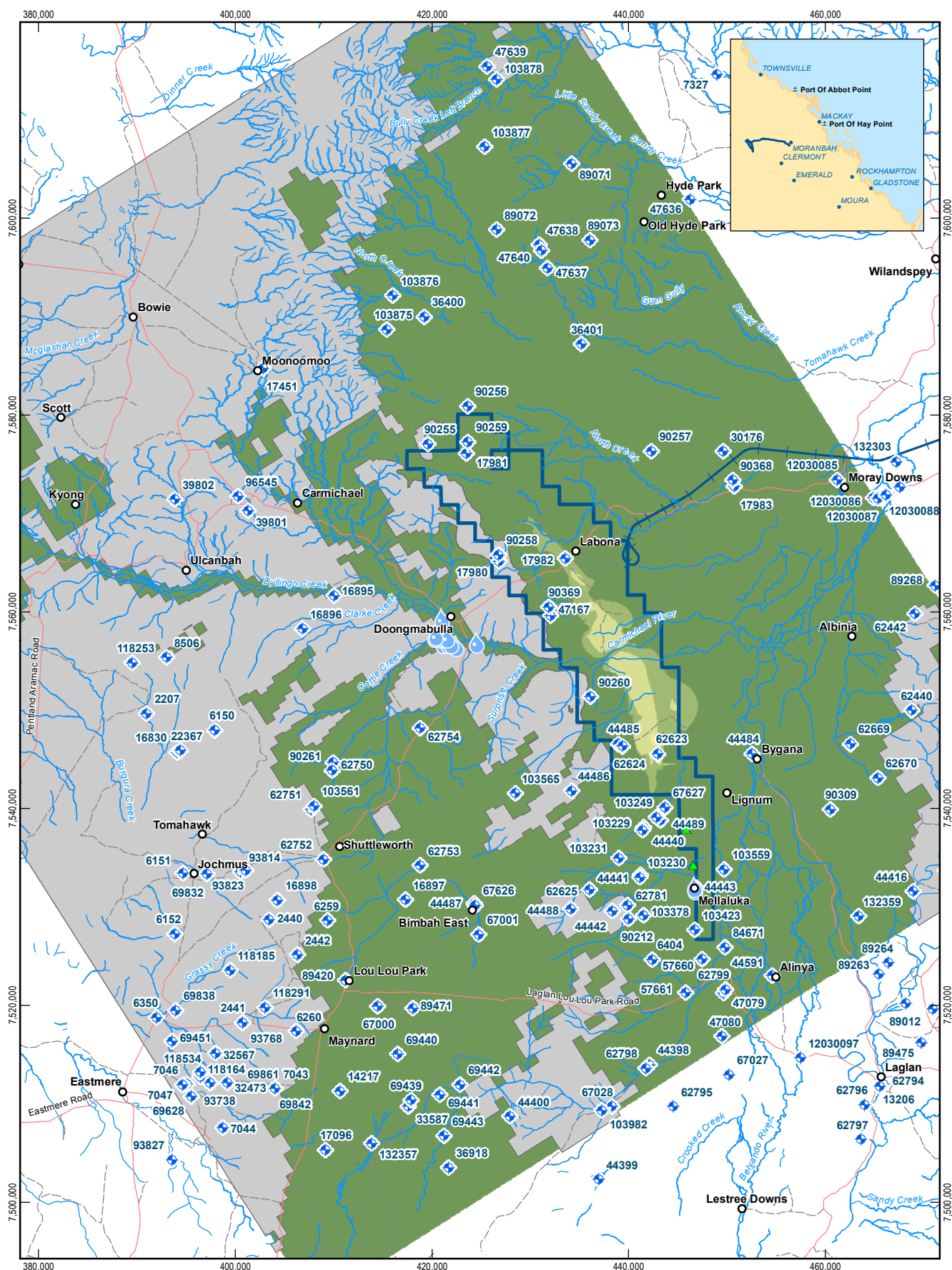


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Tertiary-age Strata
Drawdowns - Year 2019

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.8



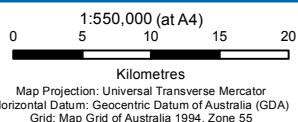
LEGEND

- Homestead
- Spring
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

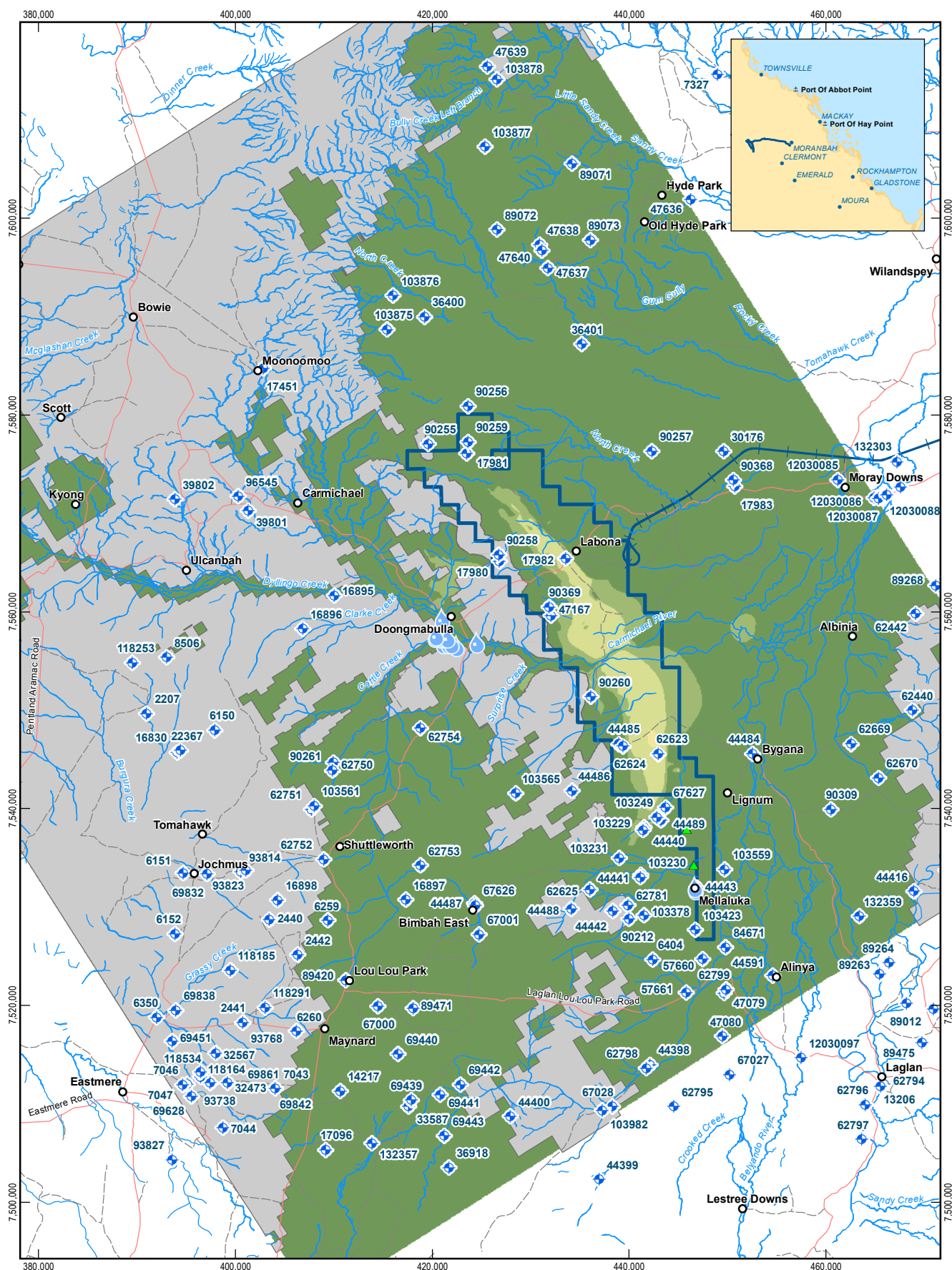


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Tertiary-age Strata
Drawdowns - Year 2039

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.9



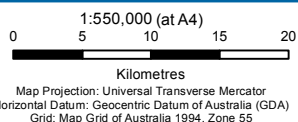
LEGEND

- Homestead
- ▲ Spring
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRMP) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

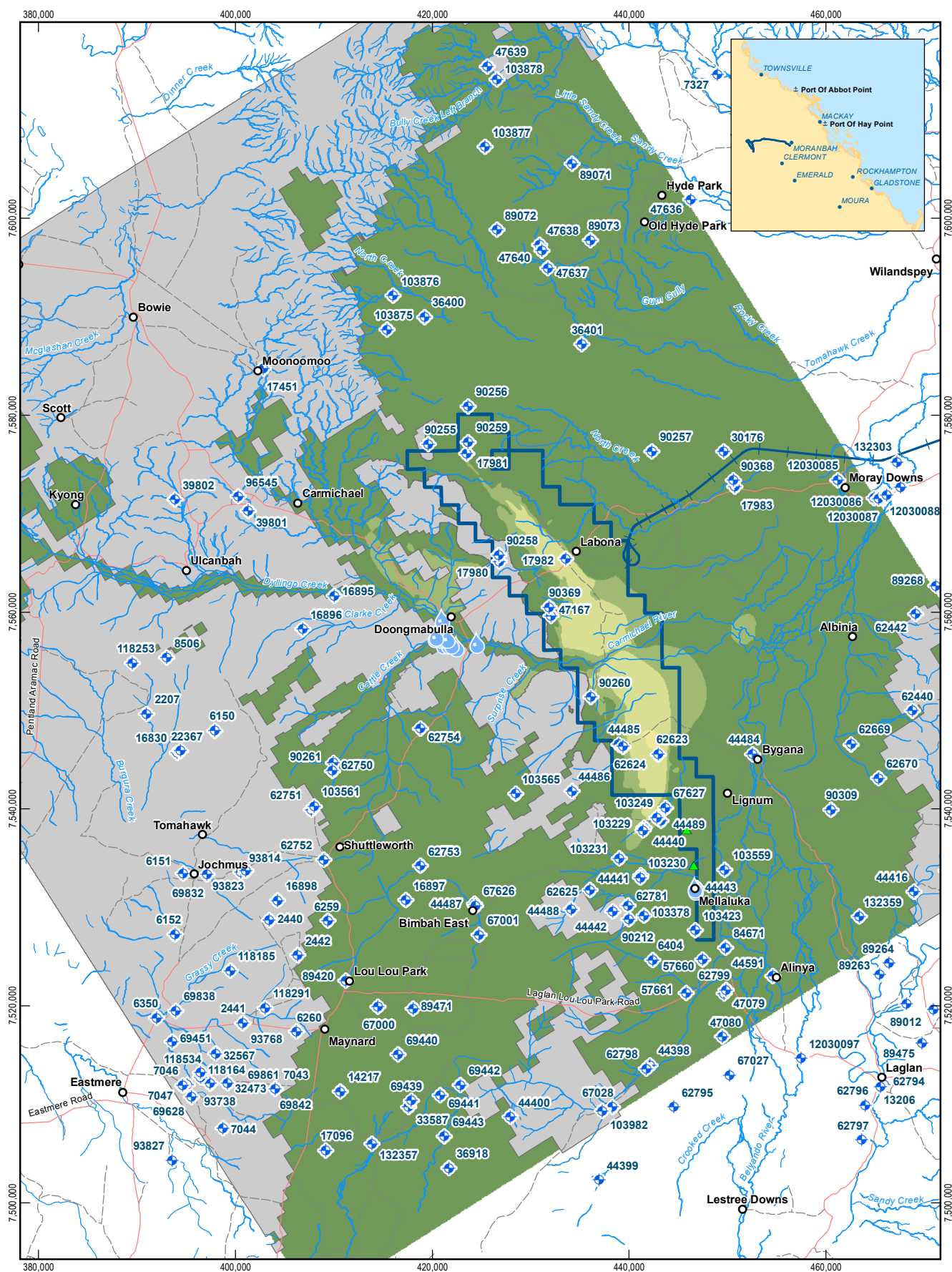


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Tertiary-age Strata Drawdowns - Year 2071

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.10



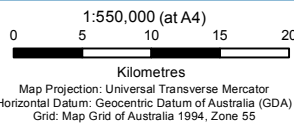
LEGEND

- Homestead
- Spring
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

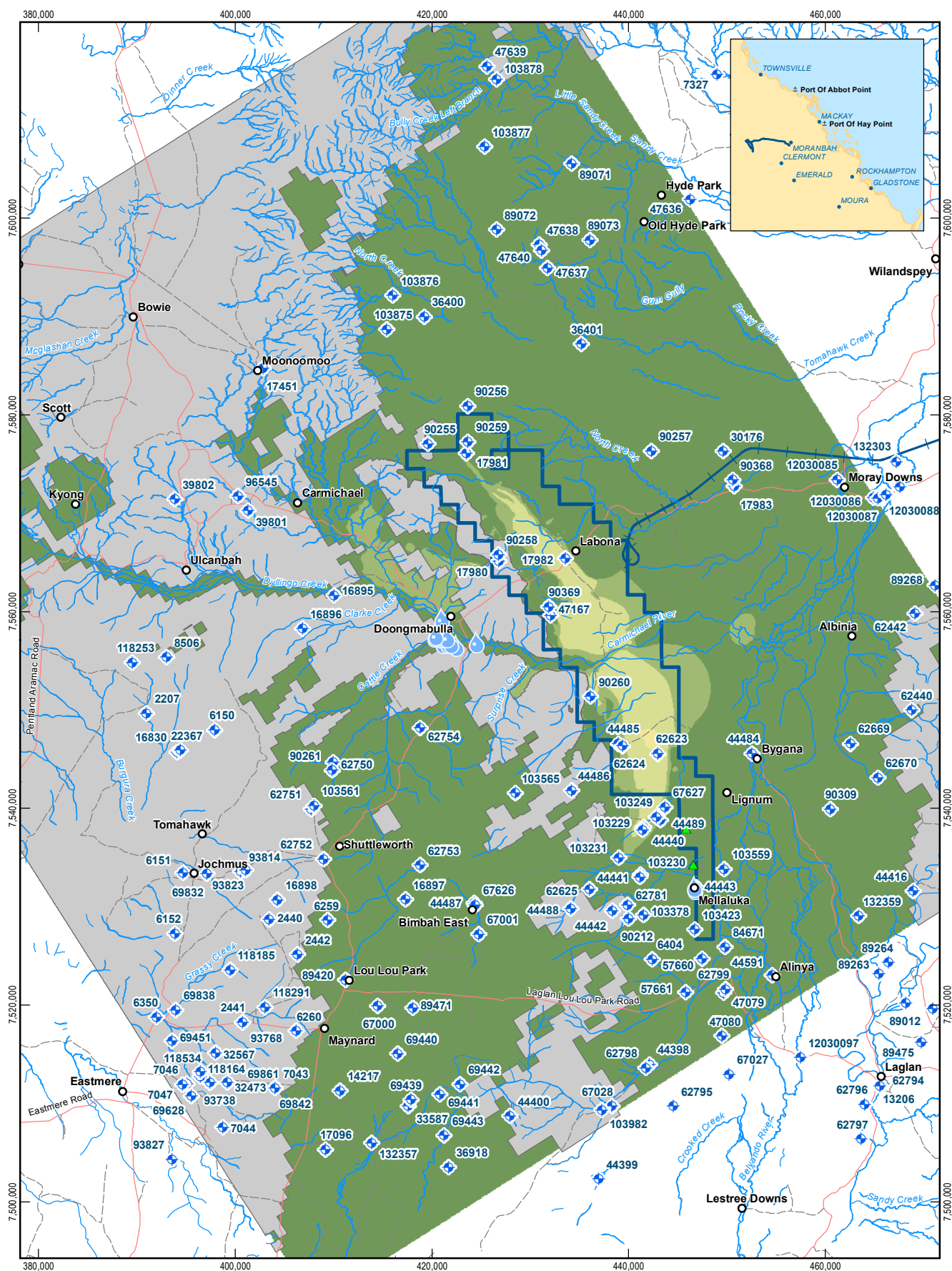
Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.



Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Tertiary-age Strata Drawdowns - Year 2092

Job Number: 41-26422
Revision: A
Date: 04-10-2013

Figure A.11



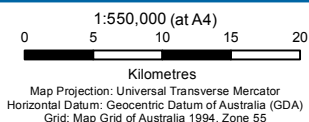
LEGEND

- Homestead
- ▲ Spring
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRM) [2013]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

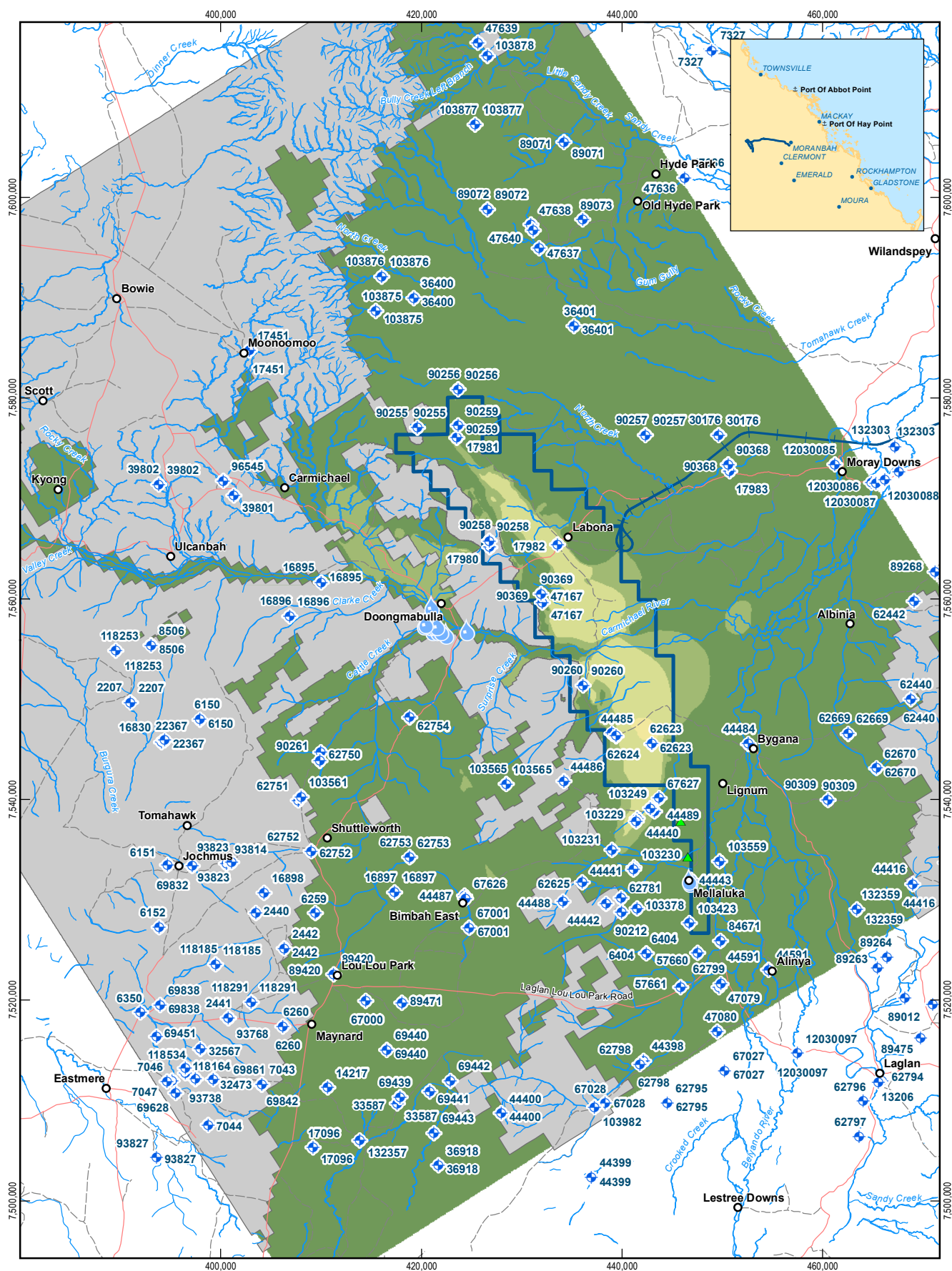


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Tertiary-age Strata
Drawdowns - Year 2109

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.12



LEGEND

- Homestead
- Spring
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Tertiary-age Strata Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:539,179 (at A4)
0 5 10 15 20
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

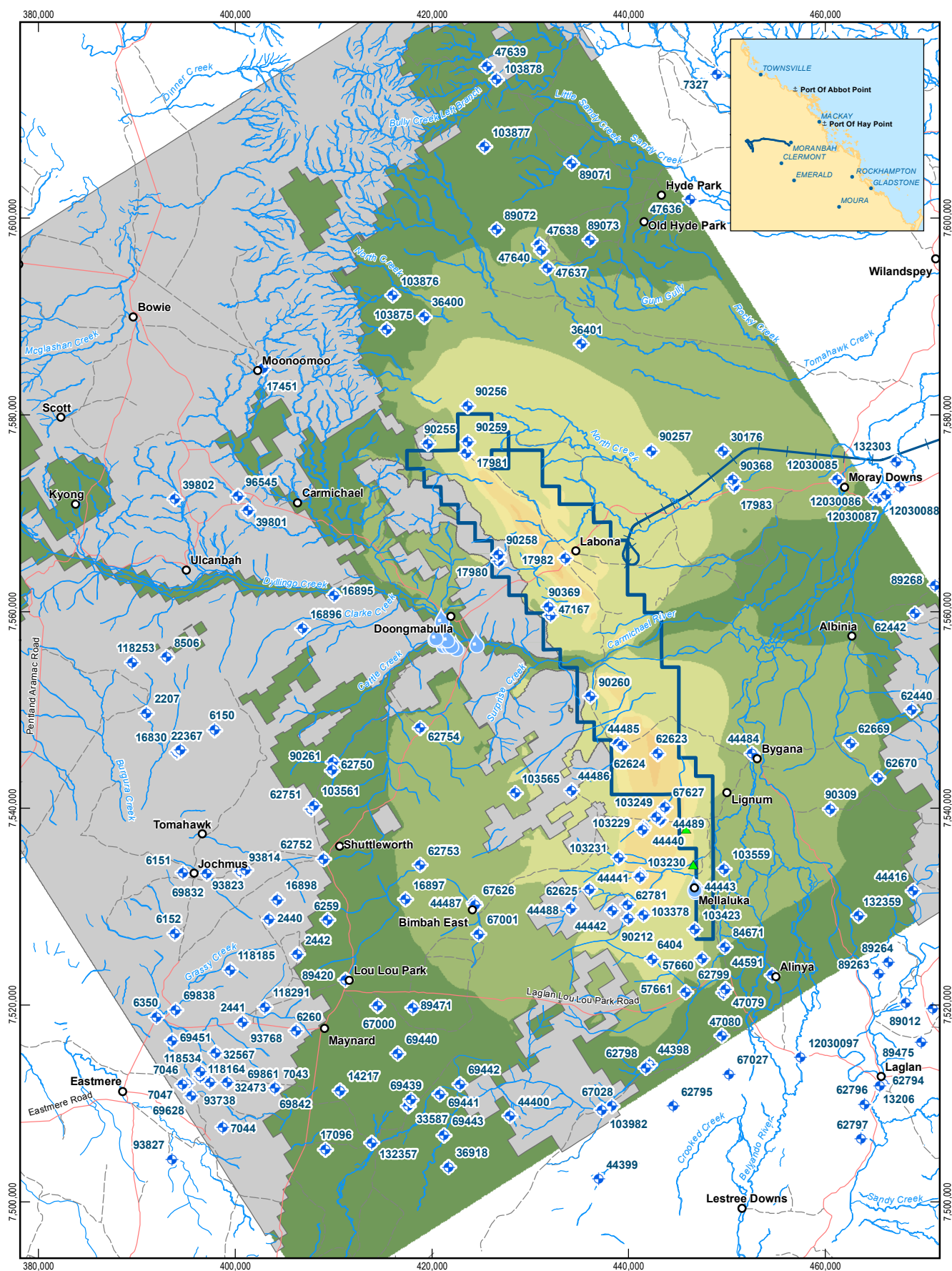


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Tertiary-age Strata
Drawdowns - Year 2129

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.13



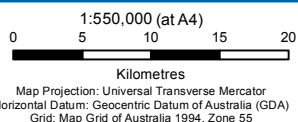
LEGEND

- Homestead
- Spring
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- Local Road
- Track
- Watercourse
- Project (Rail)
- Project (Mine)

Tertiary-age Strata Drawdown (m)

- | | | |
|-----------|-------------|-------------|
| 0 - 0.2 | 20.0 - 50 | 200.0 - 250 |
| 0.2 - 1 | 50.0 - 100 | 250.0 - 300 |
| 1.0 - 10 | 100.0 - 150 | 300.0 - 350 |
| 10.0 - 20 | 150.0 - 200 | |

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

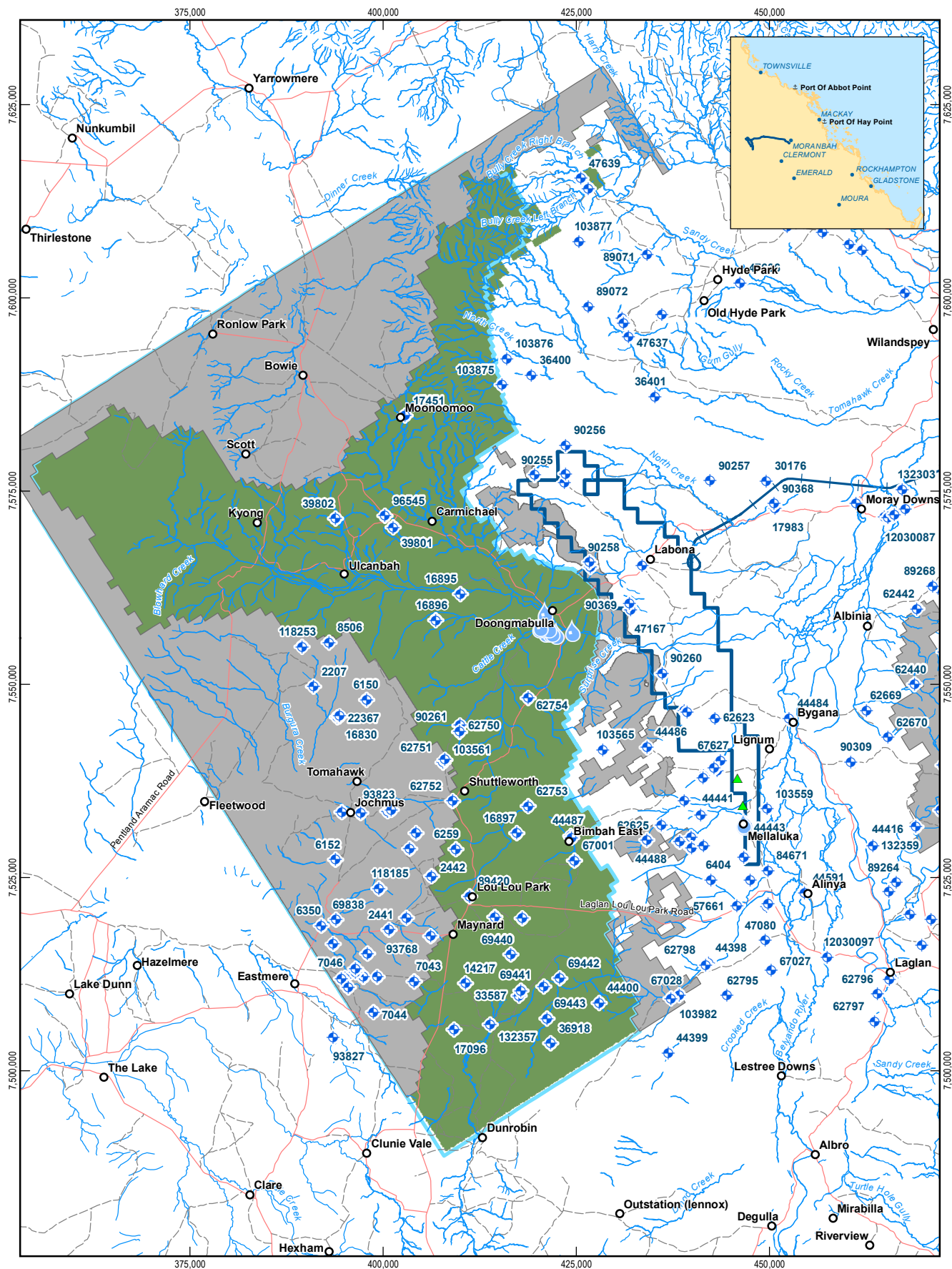


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision A
Date 04-10-2013

Predicted Tertiary-age Strata Drawdowns - Post-Closure (Long Term) Figure A.14



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent
- Clematis Sandstone Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

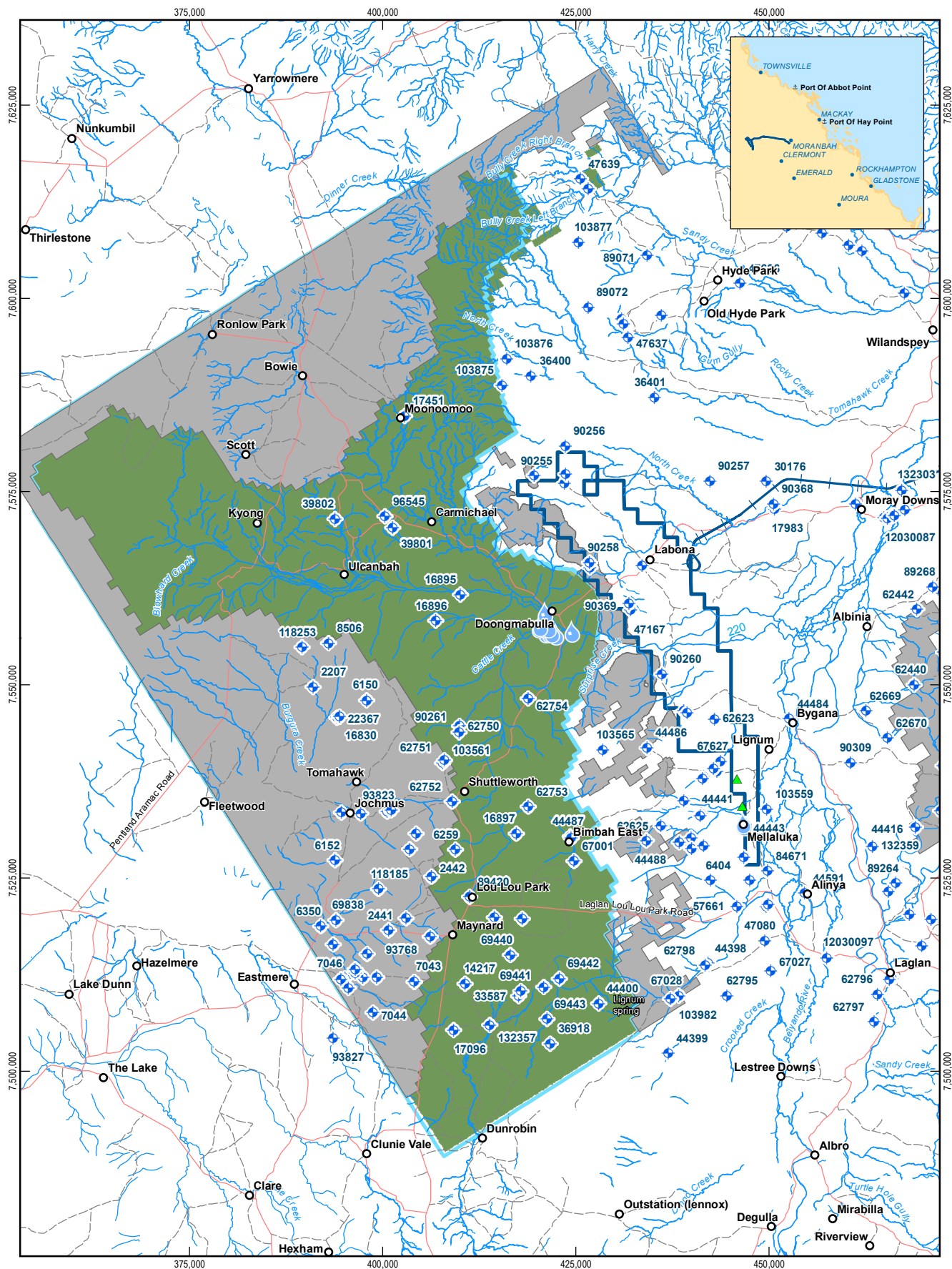


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Clematis Sandstone Drawdowns - Year 2019

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.15



Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

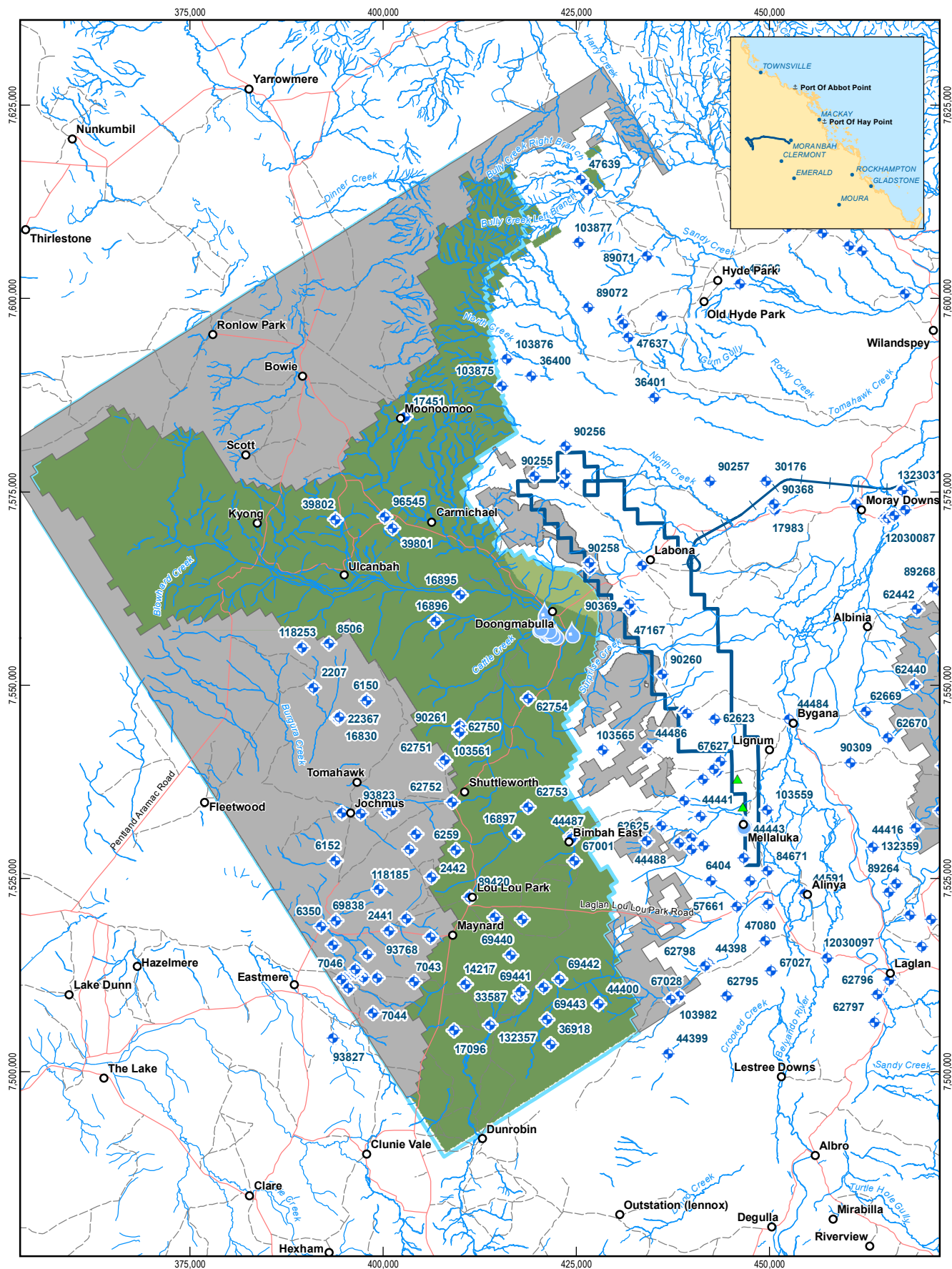


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Clematis Sandstone Drawdowns - Year 2039

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.16



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent
- Project (Rail)
- Project (Mine)

Clematis Sandstone Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

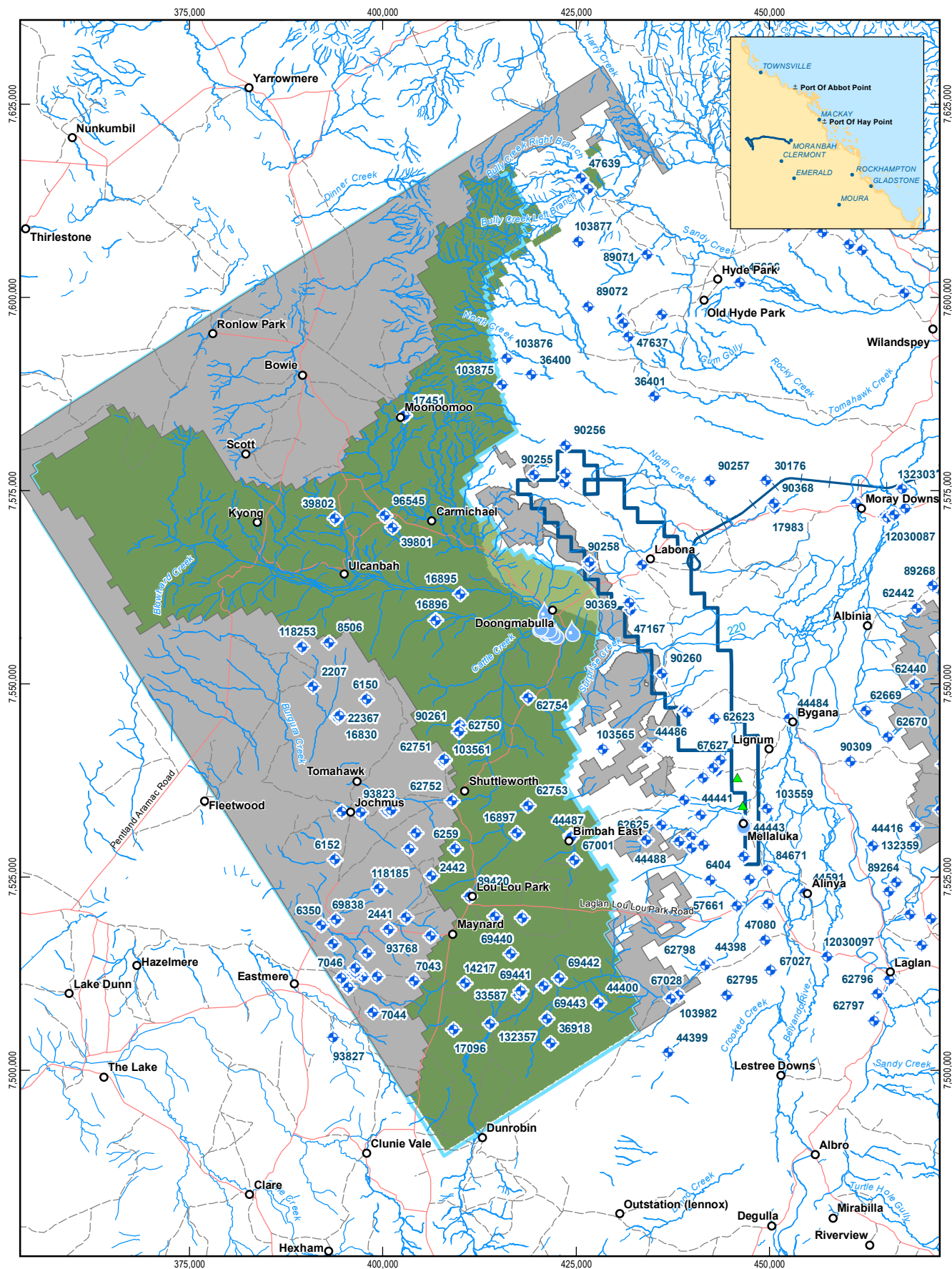


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Clematis Sandstone Drawdowns - Year 2071

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.17



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ⊕ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis
- Sandstone Extent
- Clematis Sandstone Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

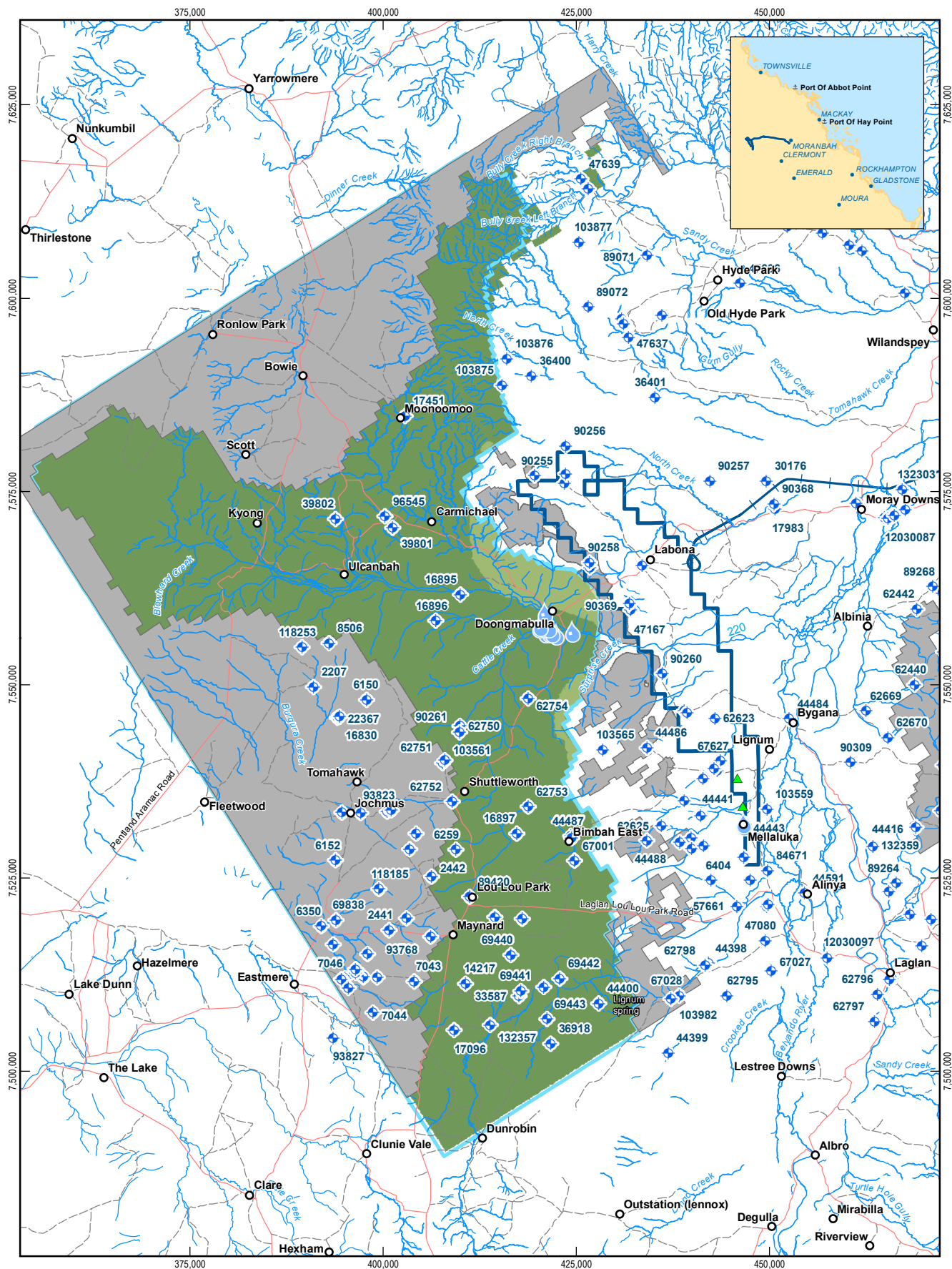


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Clematis Sandstone Drawdowns - Year 2092

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.18



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ⦿ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis
- Sandstone Extent
- Project (Rail)
- Project (Mine)

Clematis Sandstone Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

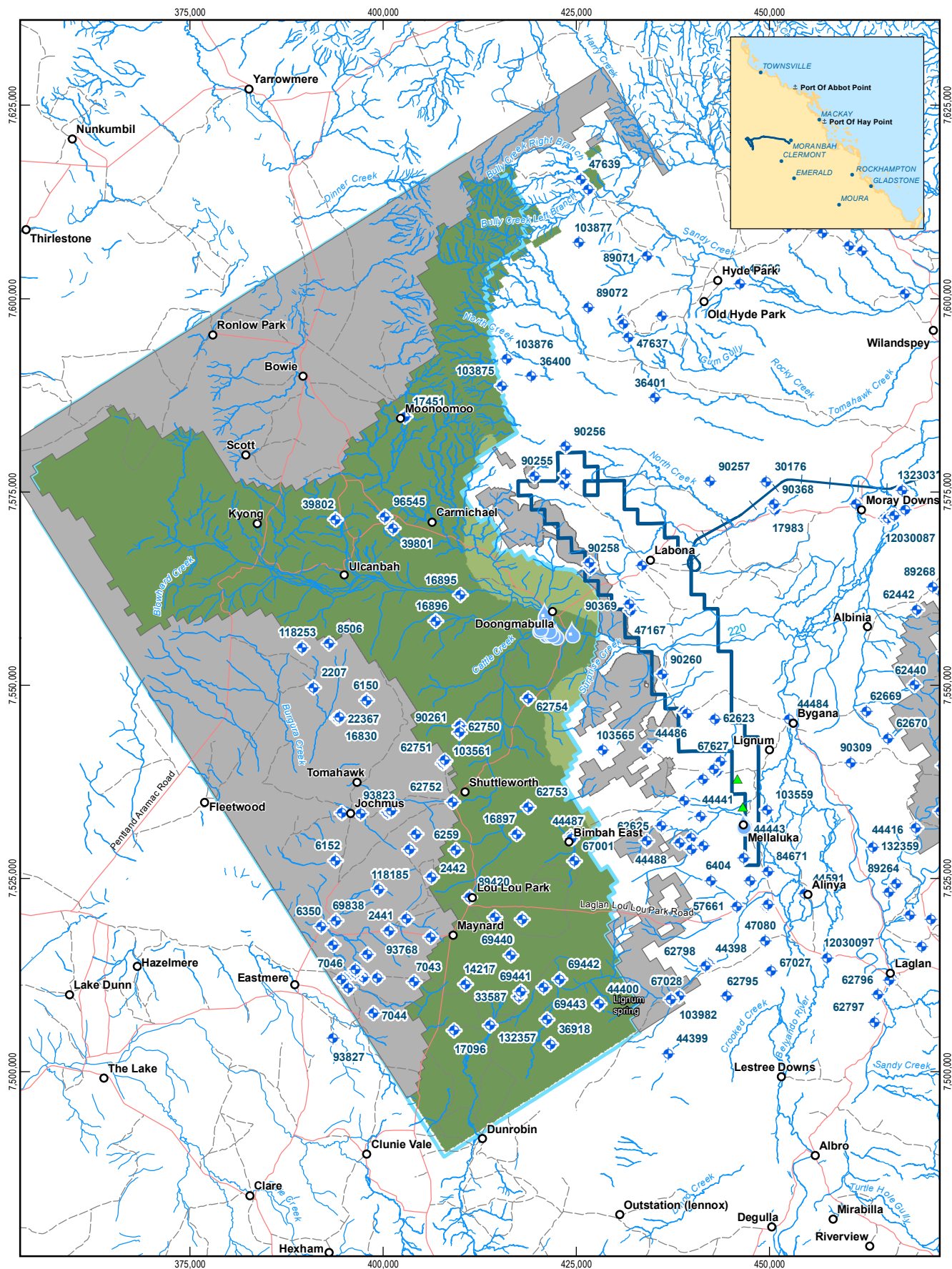


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Clematis Sandstone Drawdowns - Year 2109

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.19



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis Sandstone Extent
- Clematis Sandstone Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

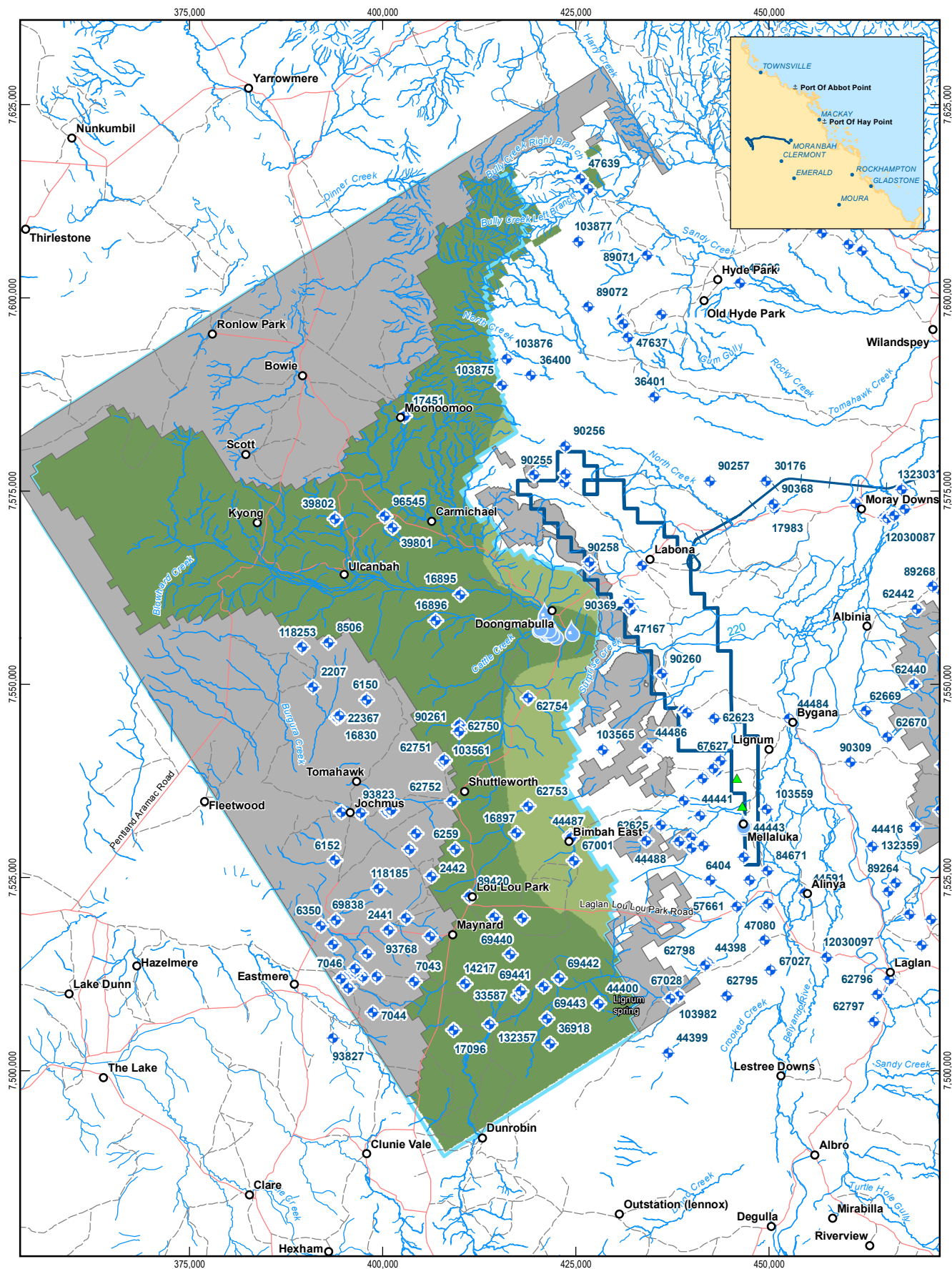


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Clematis Sandstone Drawdowns - Year 2129

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.20



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Clematis
- Sandstone Extent
- Clematis Sandstone Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

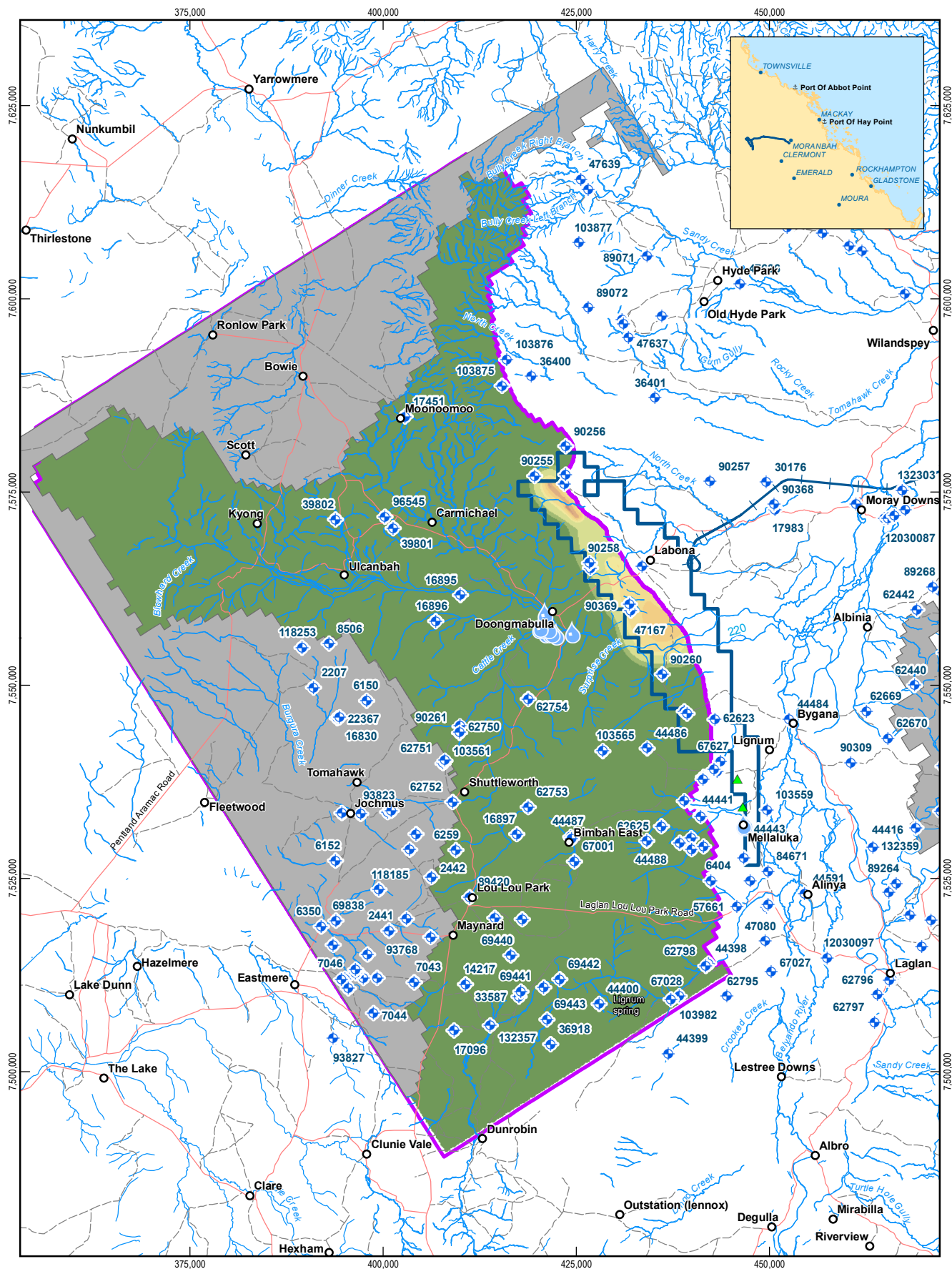


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision A
Date 04-10-2013

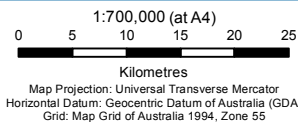
Predicted Clematis Sandstone Drawdowns - Post-Closure (Long Term) Figure A.21



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB
- Coal Seam AB Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

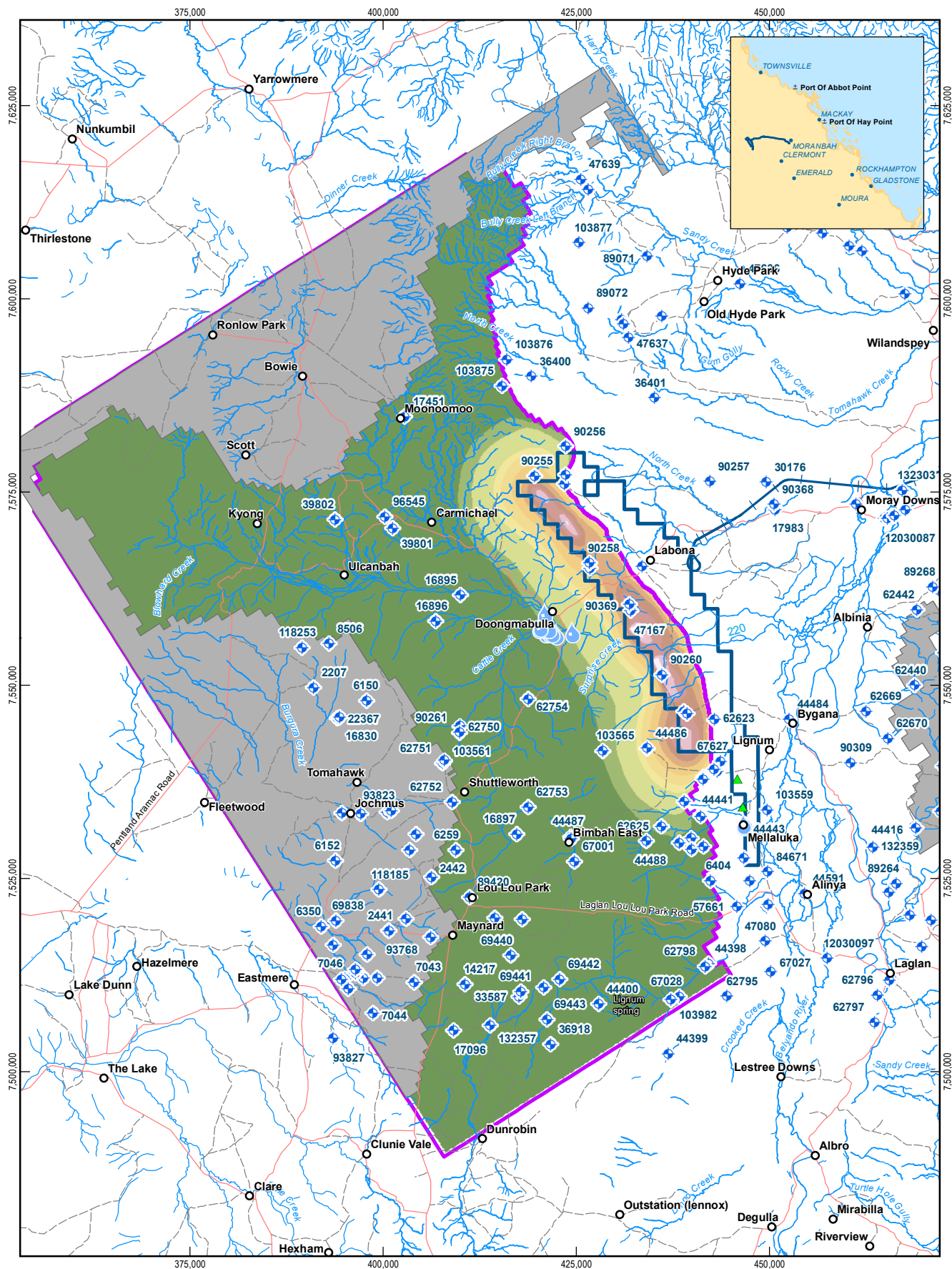


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam AB
Drawdowns - Year 2019

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.22



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB
- Coal Seam AB Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

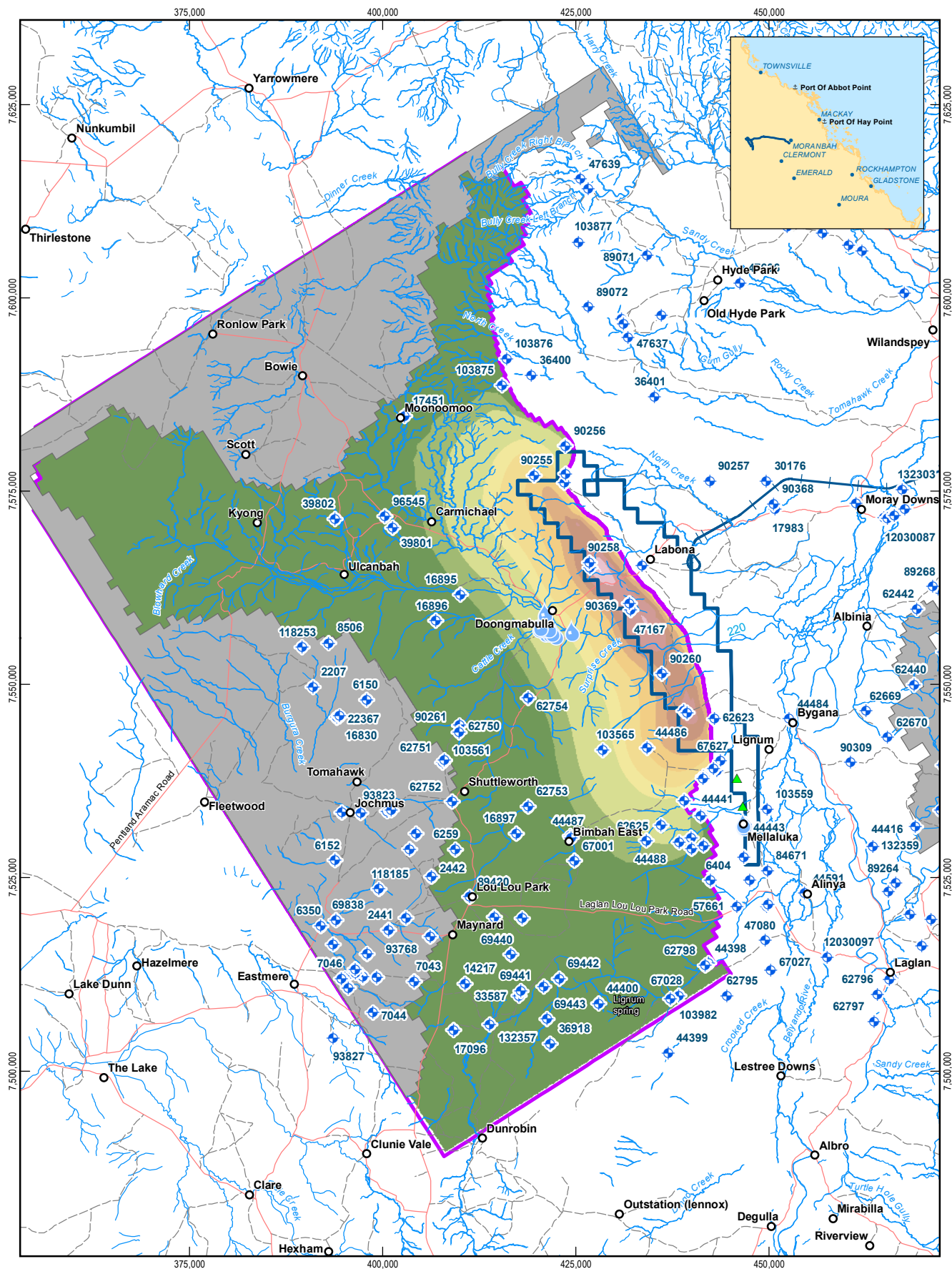


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam AB
Drawdowns - Year 2039

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.23



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring

- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB

Coal Seam AB Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

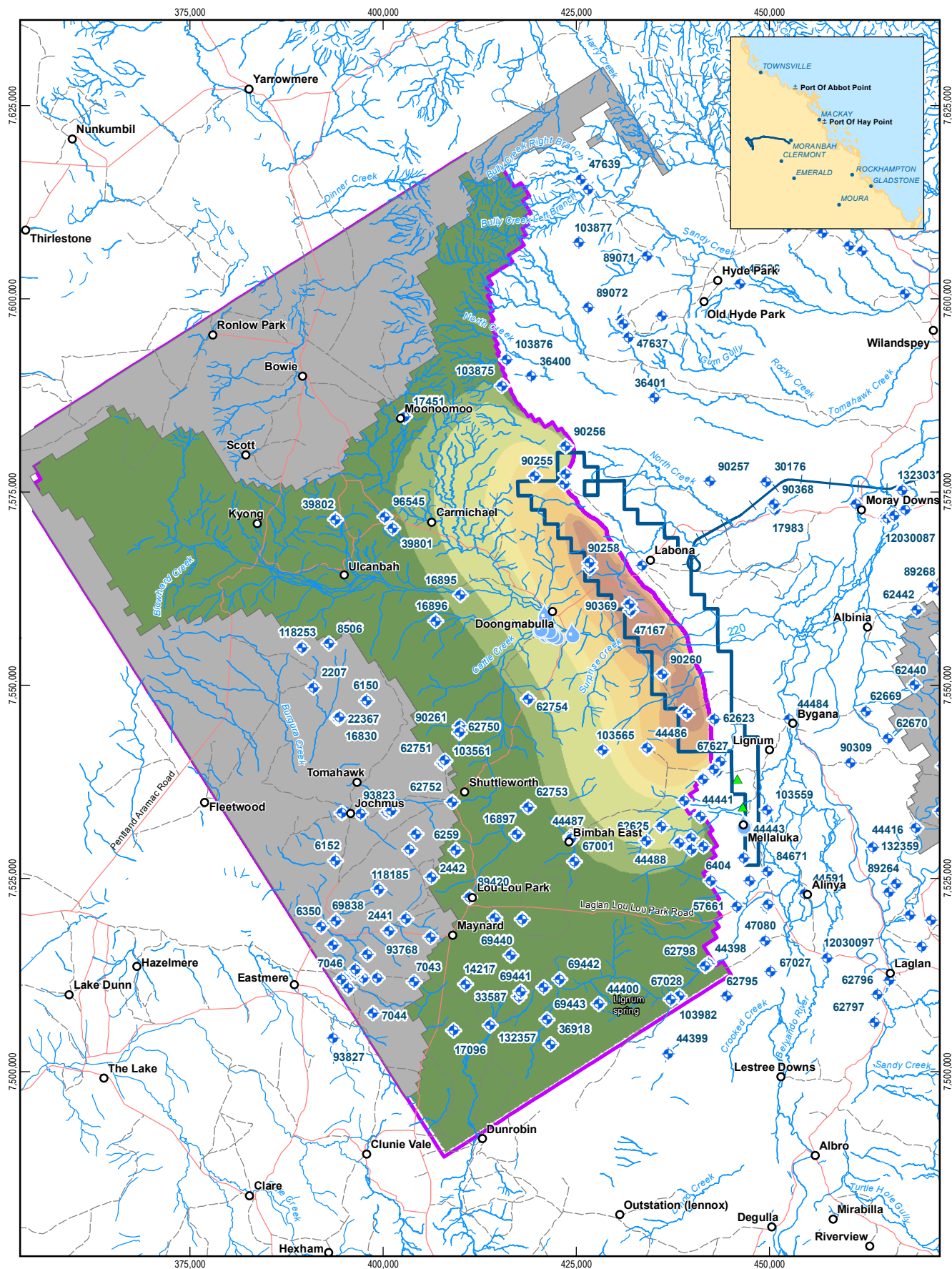


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam AB
Drawdowns - Year 2071

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.24



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB
- Coal Seam AB Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRm) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

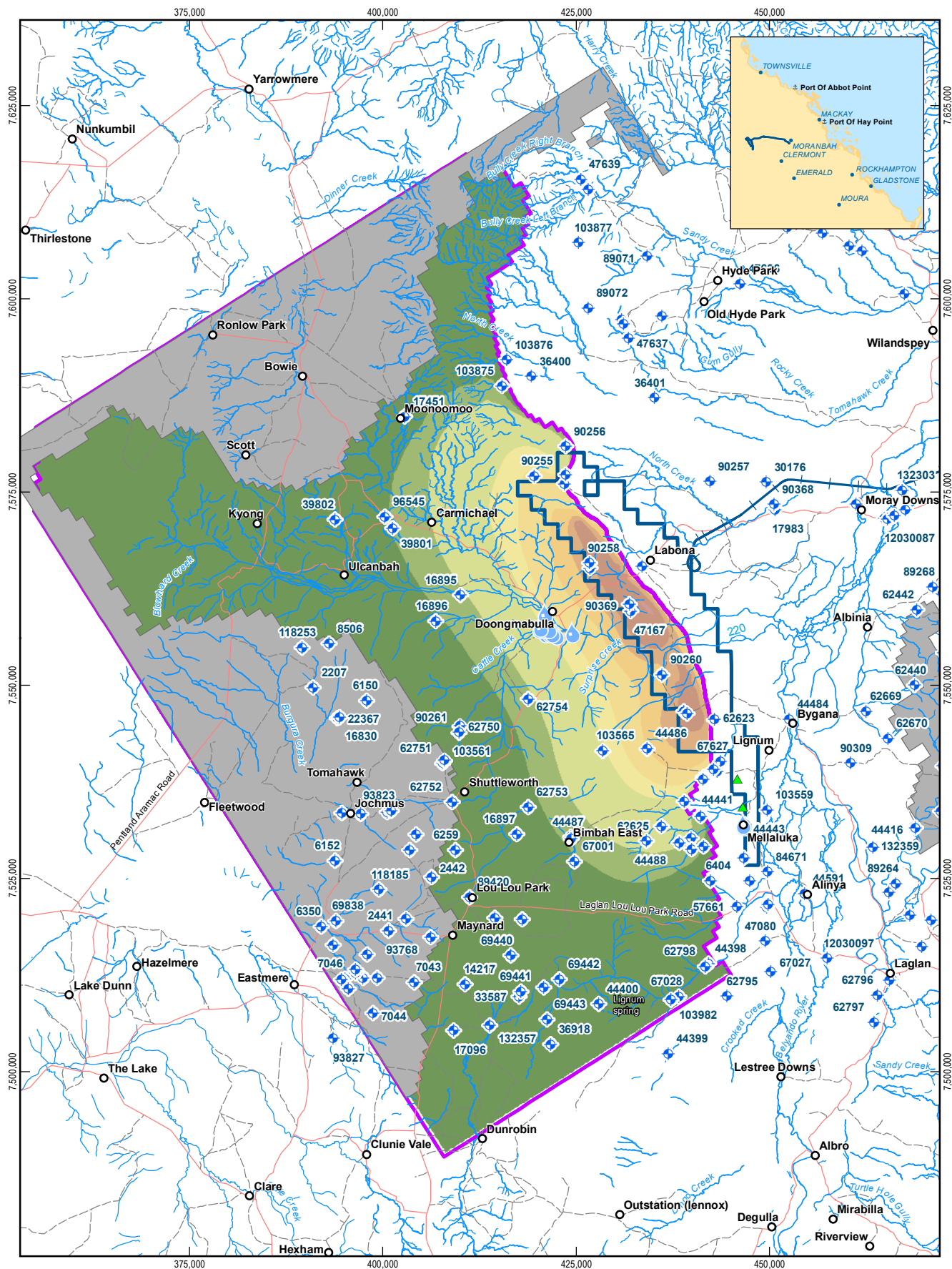


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam AB
Drawdowns - Year 2092

Job Number 41-26422
Revision A
Date 04-10-2013

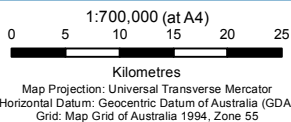
Figure A.25



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB
- Coal Seam AB Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

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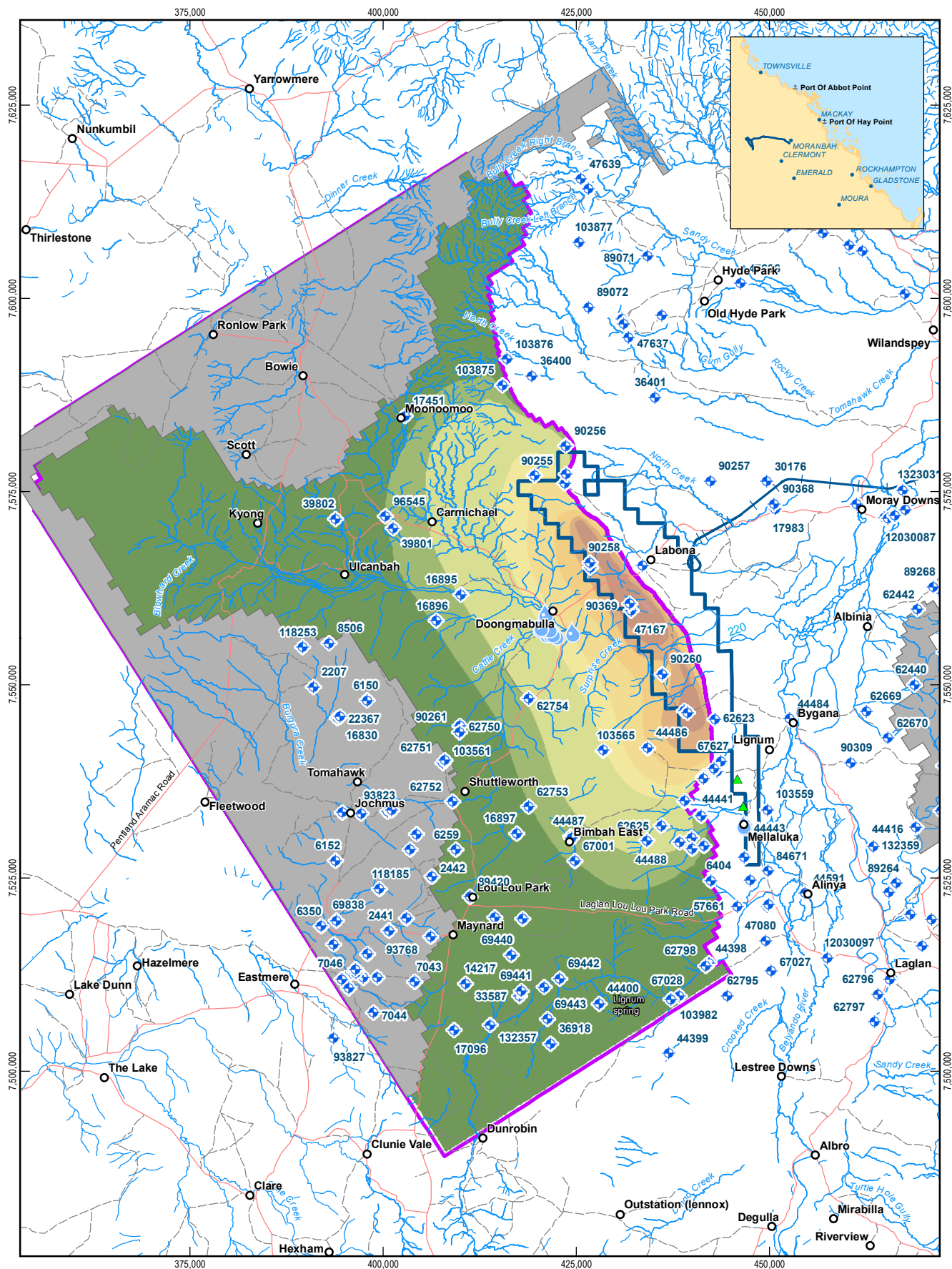


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Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam AB
Drawdowns - Year 2109

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.26



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring

- Local Road
- Track
- Watercourse

Limit of Coal Seam AB

Coal Seam AB Drawdown (m)	
0 - 0.2	20.0 - 50
0.2 - 1	50.0 - 100
1.0 - 10	100.0 - 150
10.0 - 20	150.0 - 200
200.0 - 250	250.0 - 300
300.0 - 350	

- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55



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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam AB
Drawdowns - Year 2129

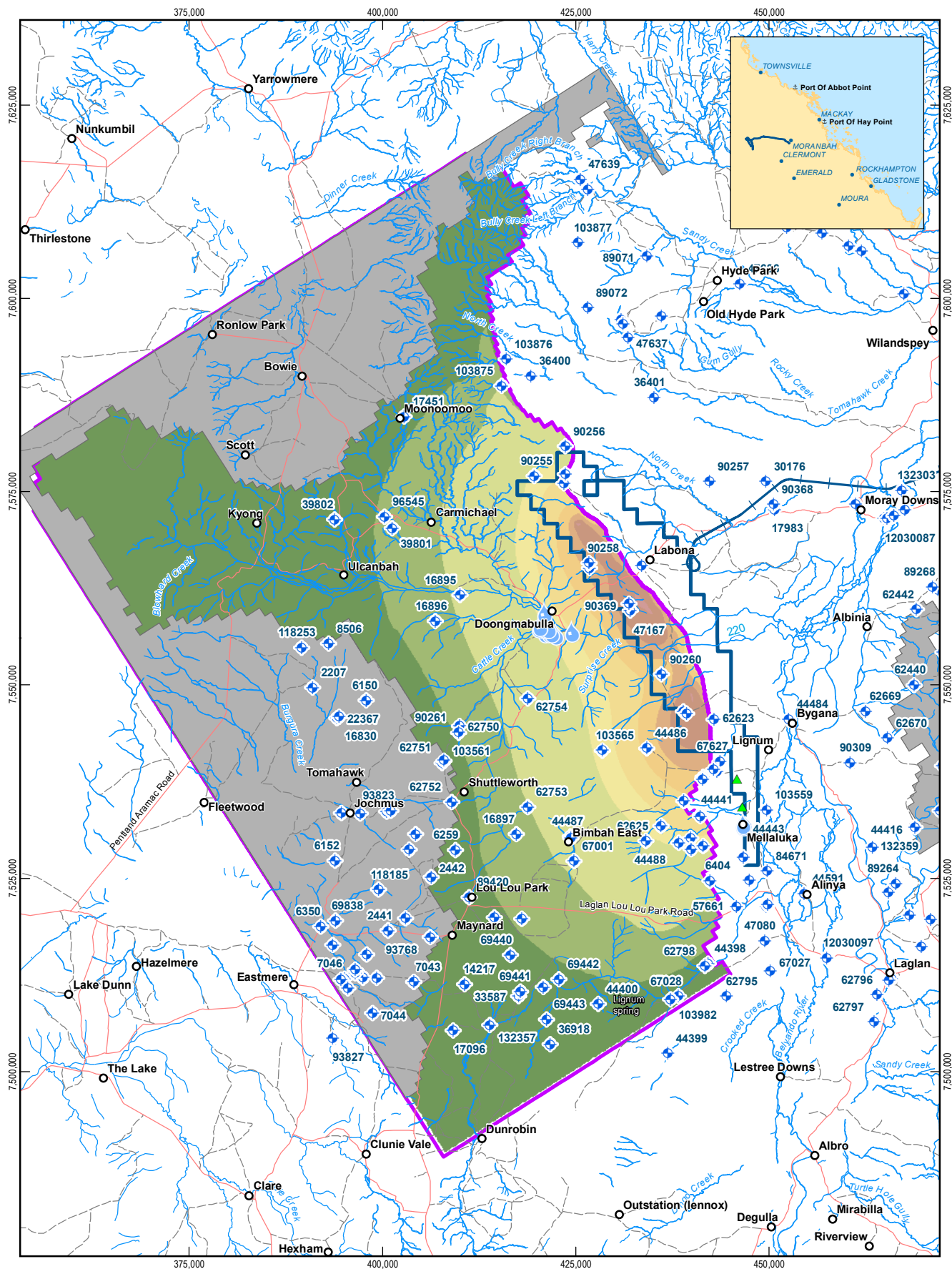
Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.27

G:\41\26422\GIS\Maps\MXD\0400_Hydrogeology\41-26422_436_rev_a.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

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Data Source: DME: EPC 1690 (2010)/EPC 1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Homestead, Locality, Road, Spring Locations, Watercourse (2007); GHD: Monitoring Bore, Interpreted Groundwater Level Contour (2012), Limit of Coal Seam AB (2013); DNRm: Streams (2012); Registered Groundwater Bore (2010); Adani: Project Rail 1 (Opt1 Rev2) & 2 (Opt9 Rev3) (2013). Created by: BW, MS



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam AB

Coal Seam AB Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

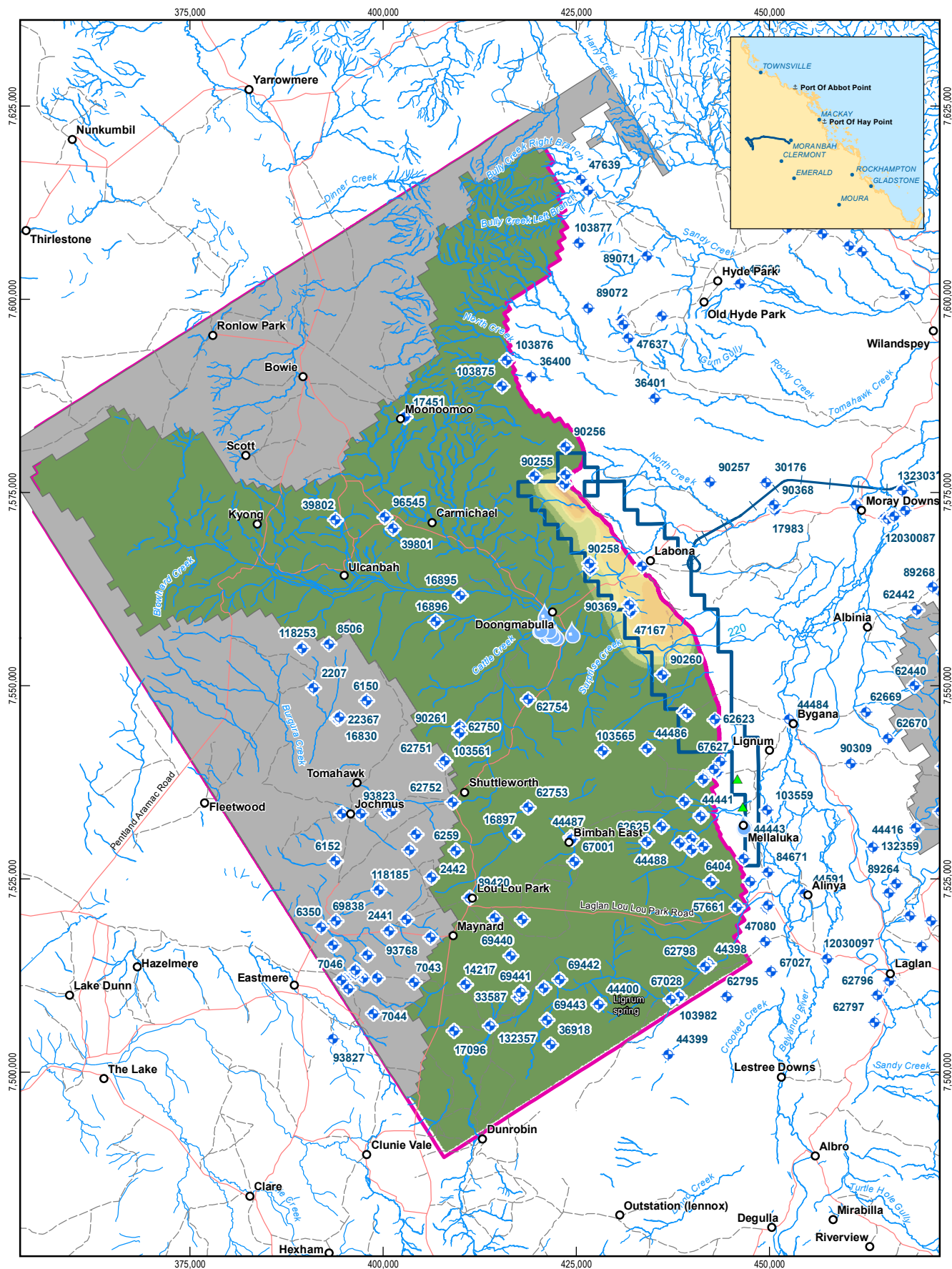


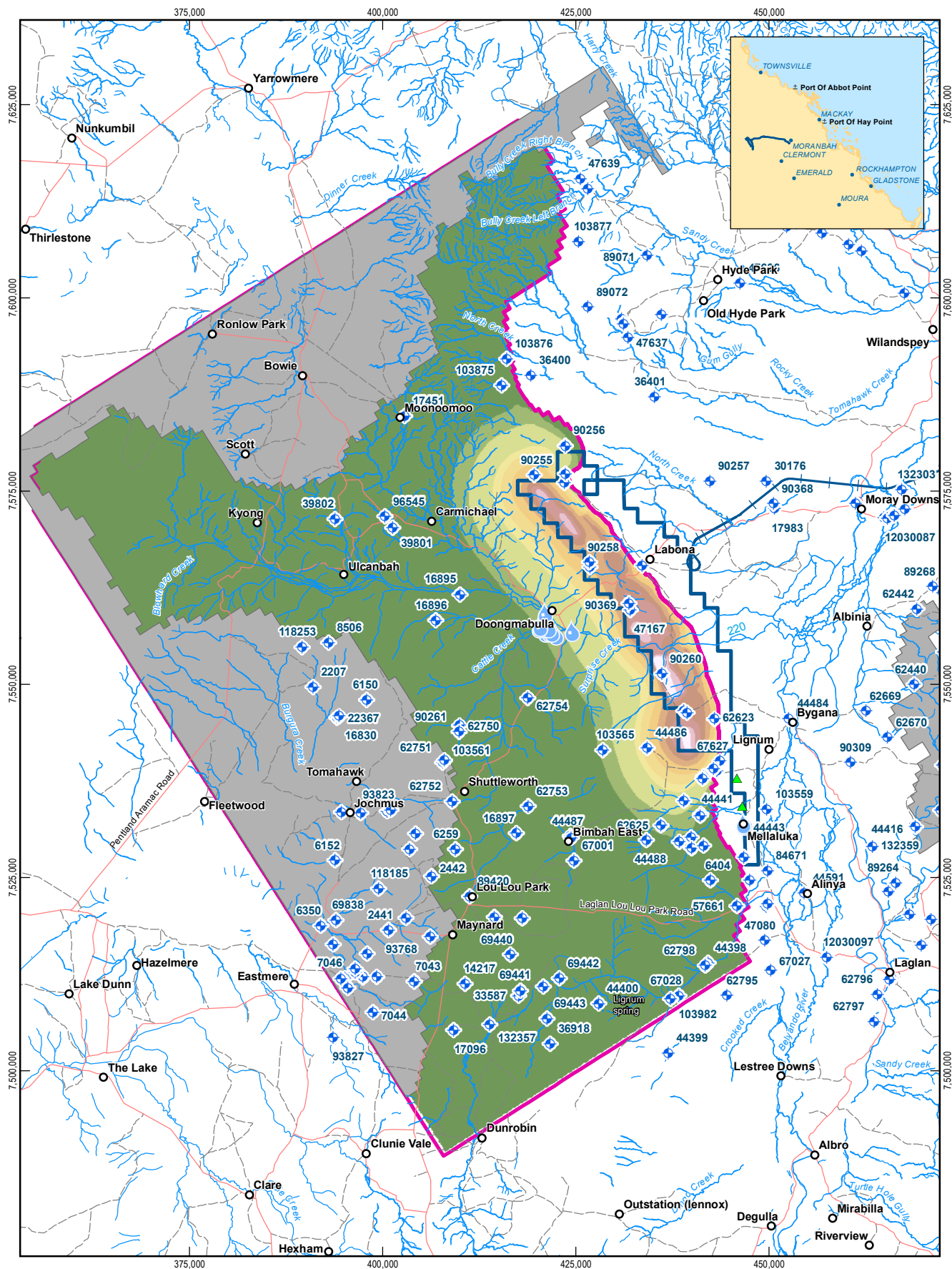
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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision A
Date 04-10-2013

**Predicted Coal Seam AB
Drawdowns - Post-Closure (Long Term) Figure A.28**





LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring

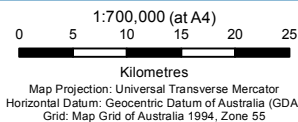
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

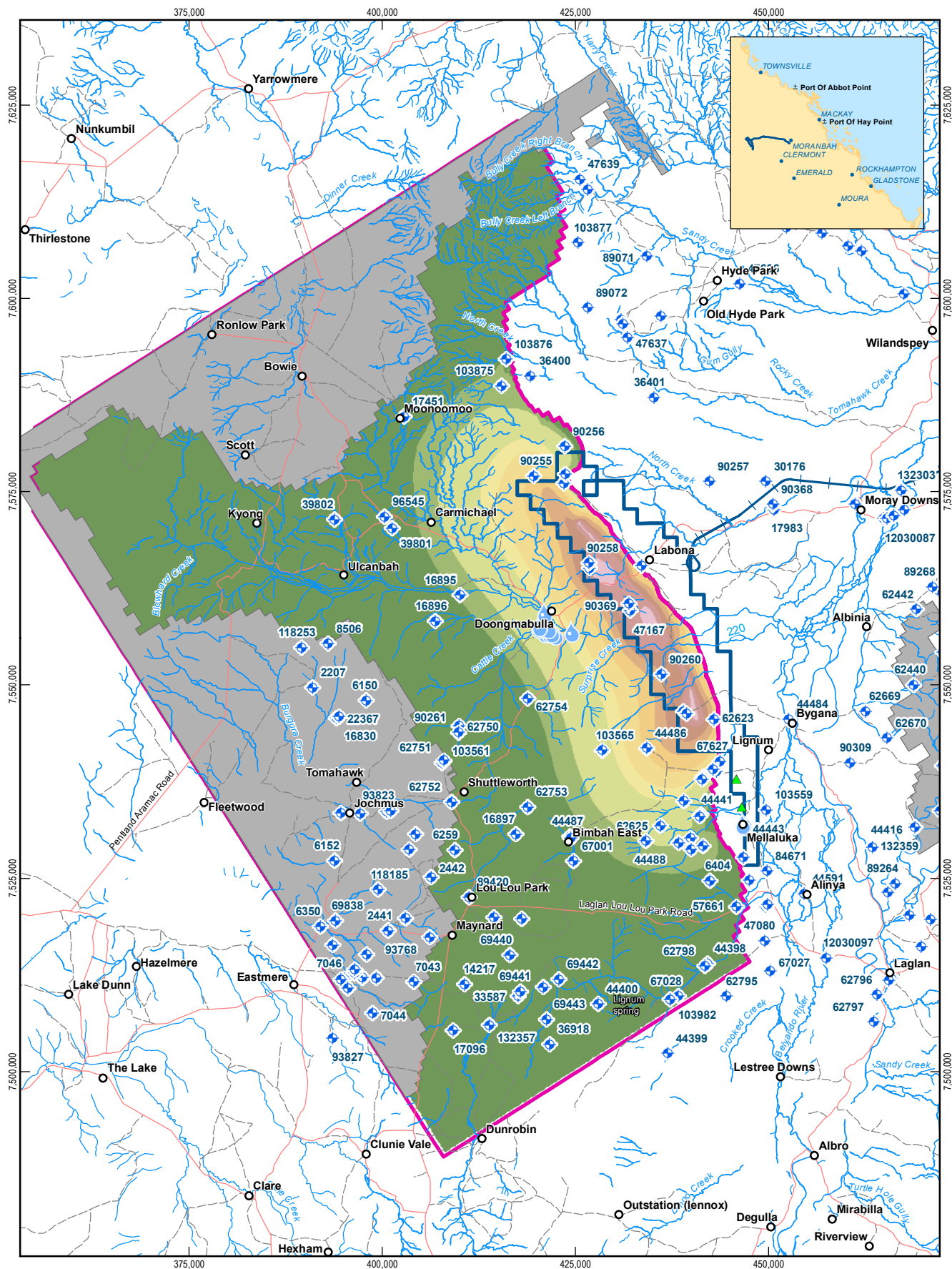


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Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam D
Drawdowns - Year 2039

Job Number: 41-26422
Revision: A
Date: 04-10-2013

Figure A.30



LEGEND

- Homestead
- Spring (Geoscience Australia)
- Registered Groundwater Bore
- Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D
- Coal Seam D Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

Based on or contains data provided by the State of QLD (DNRM) (2013). In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:700,000 (at A4)
0 5 10 15 20 25
Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

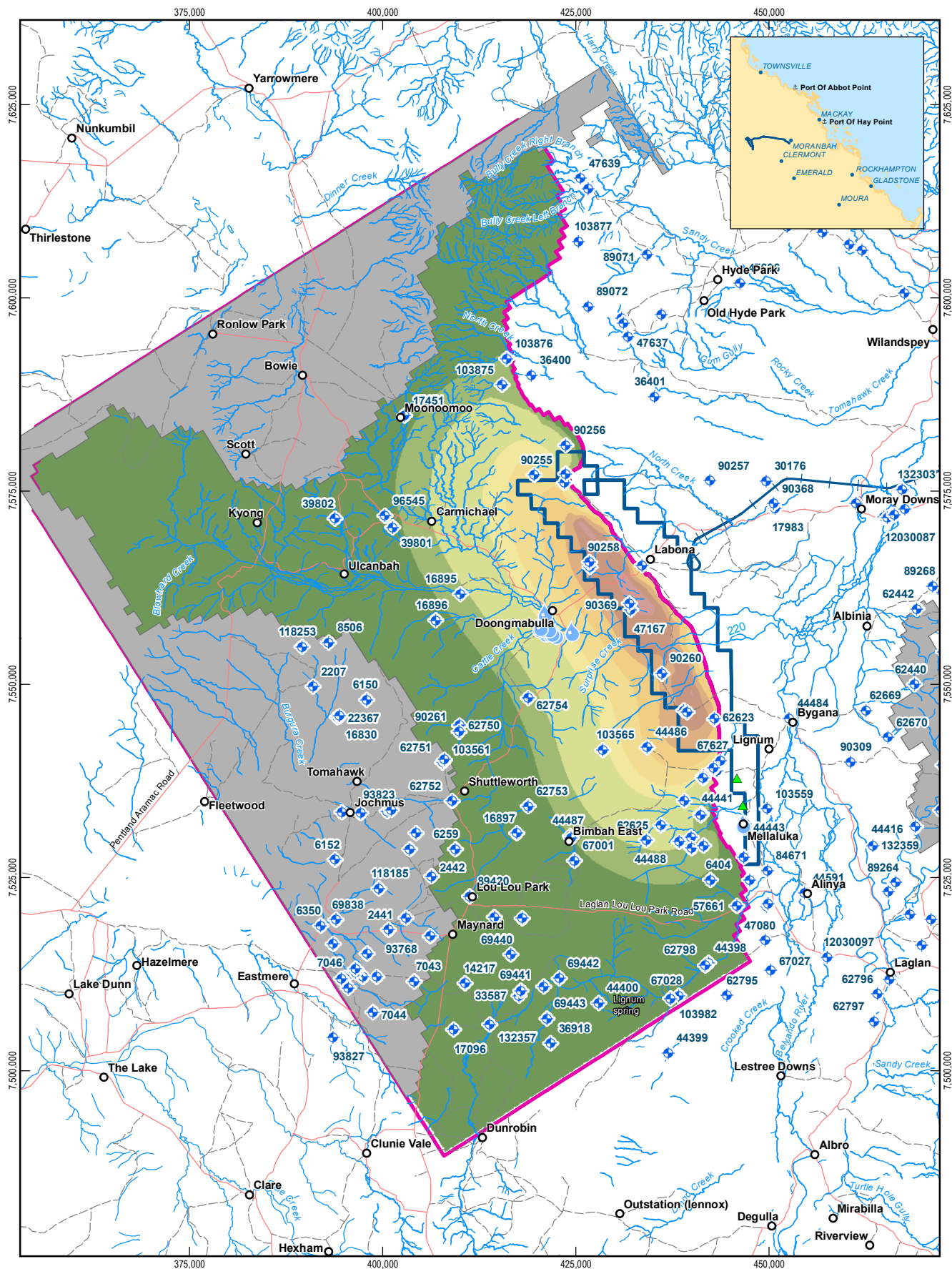


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Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam D
Drawdowns - Year 2071

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.31



LEGEND

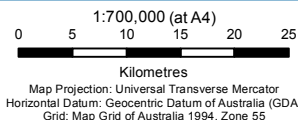
- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring

- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)	
0 - 0.2	20.0 - 50
0.2 - 1	50.0 - 100
1.0 - 10	100.0 - 150
10.0 - 20	150.0 - 200
200.0 - 250	250.0 - 300
250.0 - 300	300.0 - 350

- Project (Rail)
- Project (Mine)

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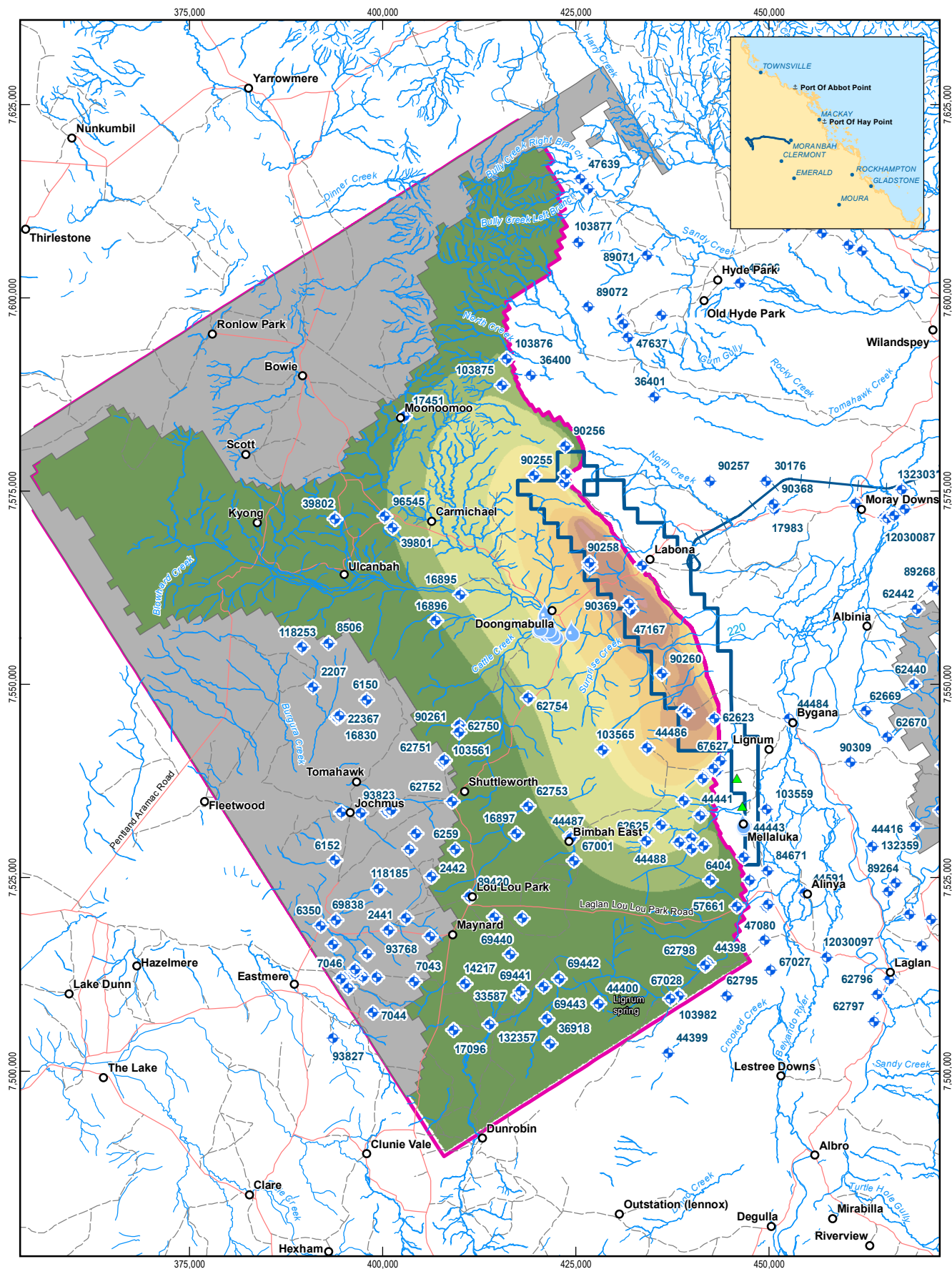


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam D
Drawdowns - Year 2092

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.32



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D
- Coal Seam D Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

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1:700,000 (at A4)
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Kilometres
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

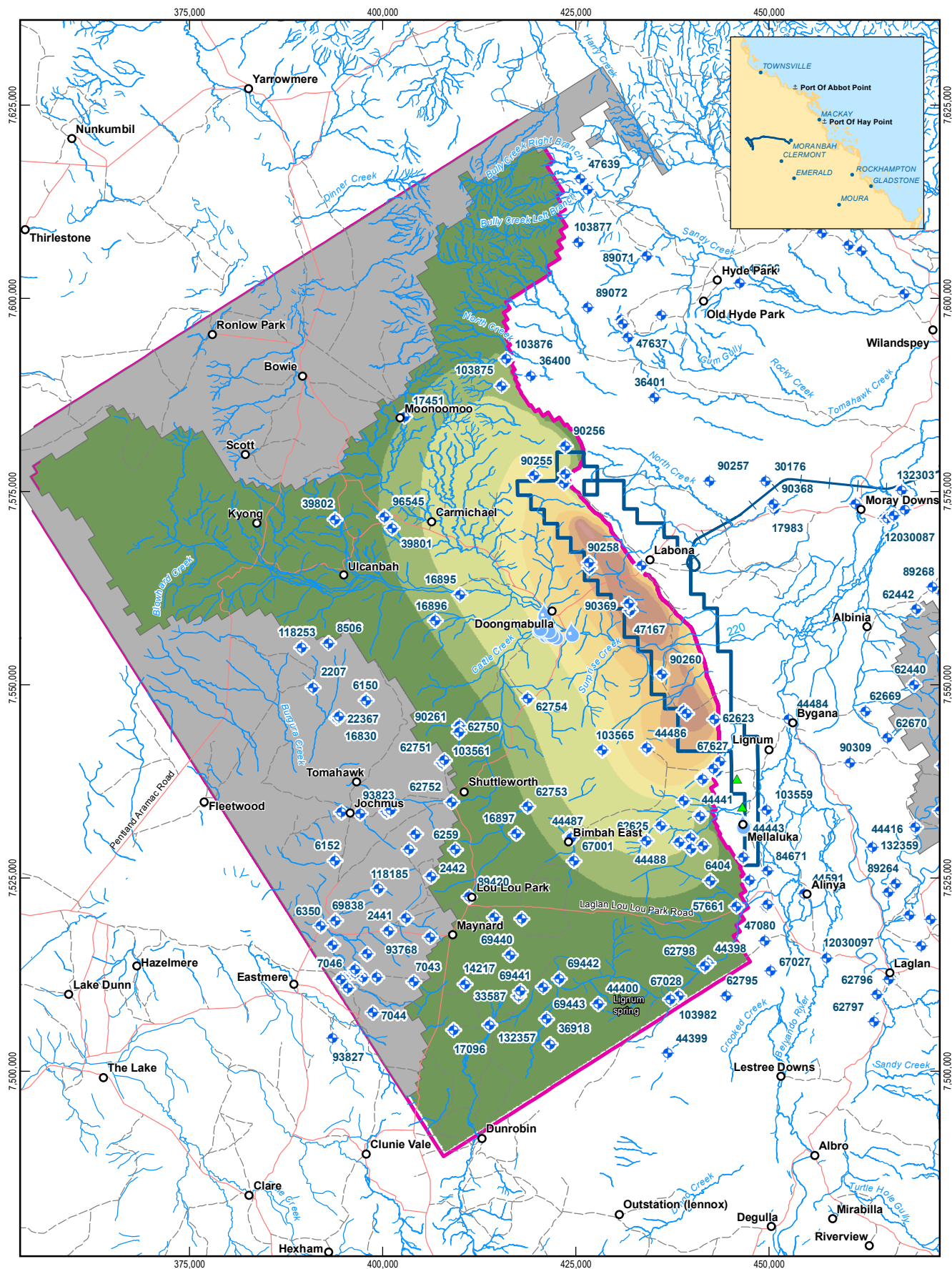


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam D
Drawdowns - Year 2109

Job Number 41-26422
Revision A
Date 04-10-2013

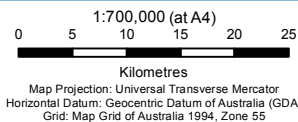
Figure A.33



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D
- Coal Seam D Drawdown (m)
 - 0 - 0.2
 - 0.2 - 1
 - 1.0 - 10
 - 10.0 - 20
 - 20.0 - 50
 - 50.0 - 100
 - 100.0 - 150
 - 150.0 - 200
 - 200.0 - 250
 - 250.0 - 300
 - 300.0 - 350
- Project (Rail)
- Project (Mine)

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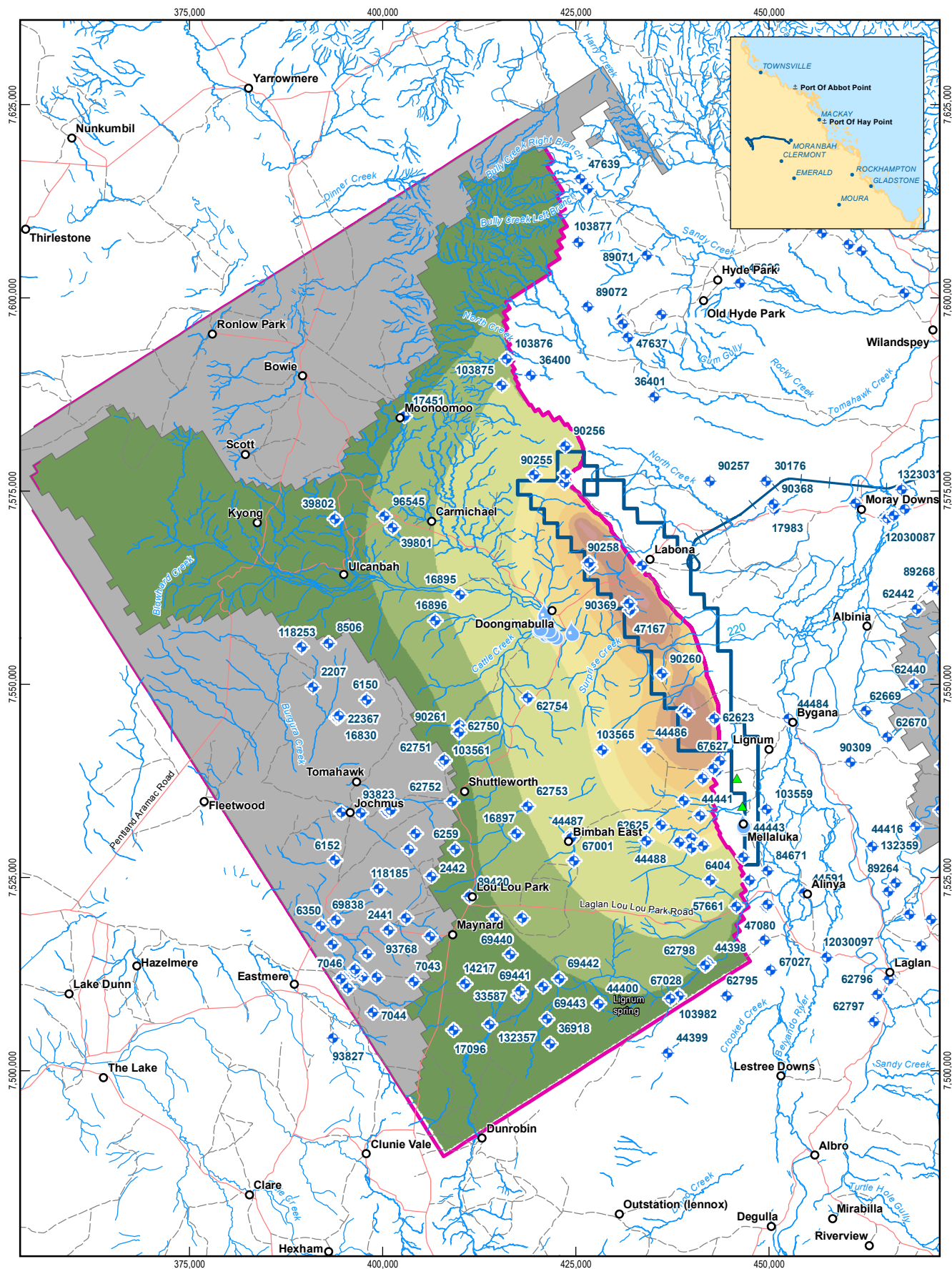


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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam D
Drawdowns - Year 2129

Job Number 41-26422
Revision A
Date 04-10-2013

Figure A.34



LEGEND

- Homestead
- Spring (Geoscience Australia)
- ◆ Registered Groundwater Bore
- ▲ Spring

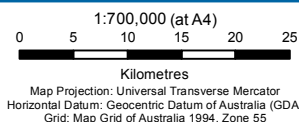
- Local Road
- Track
- Watercourse
- Limit of Coal Seam D

Coal Seam D Drawdown (m)

- 0 - 0.2
- 0.2 - 1
- 1.0 - 10
- 10.0 - 20
- 20.0 - 50
- 50.0 - 100
- 100.0 - 150
- 150.0 - 200
- 200.0 - 250
- 250.0 - 300
- 300.0 - 350

- Project (Rail)
- Project (Mine)

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS
Predicted Coal Seam D Drawdowns
- Post-Closure (Long Term)

Job Number 41-26422
Revision A
Date 04-10-2013

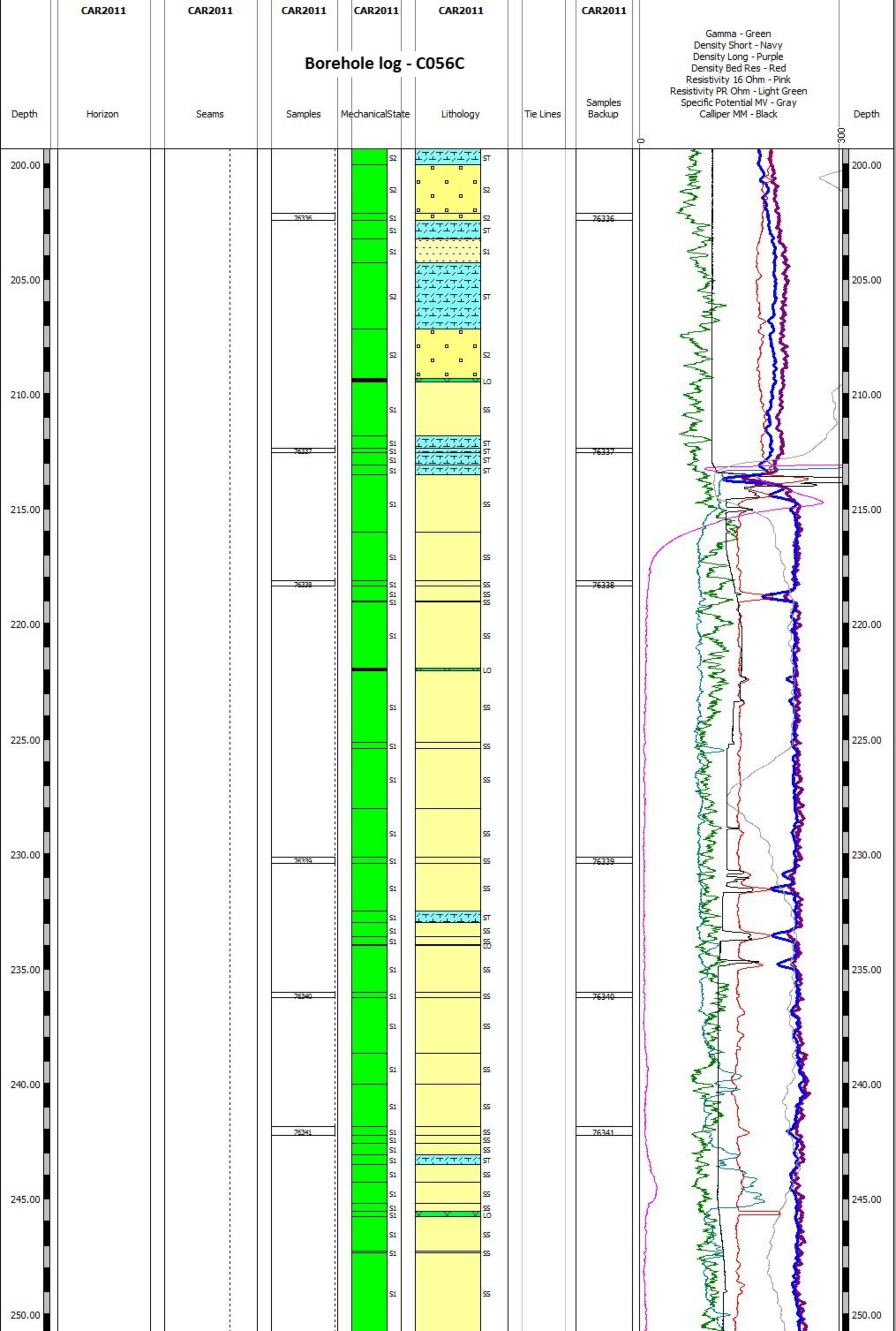
Figure A.35

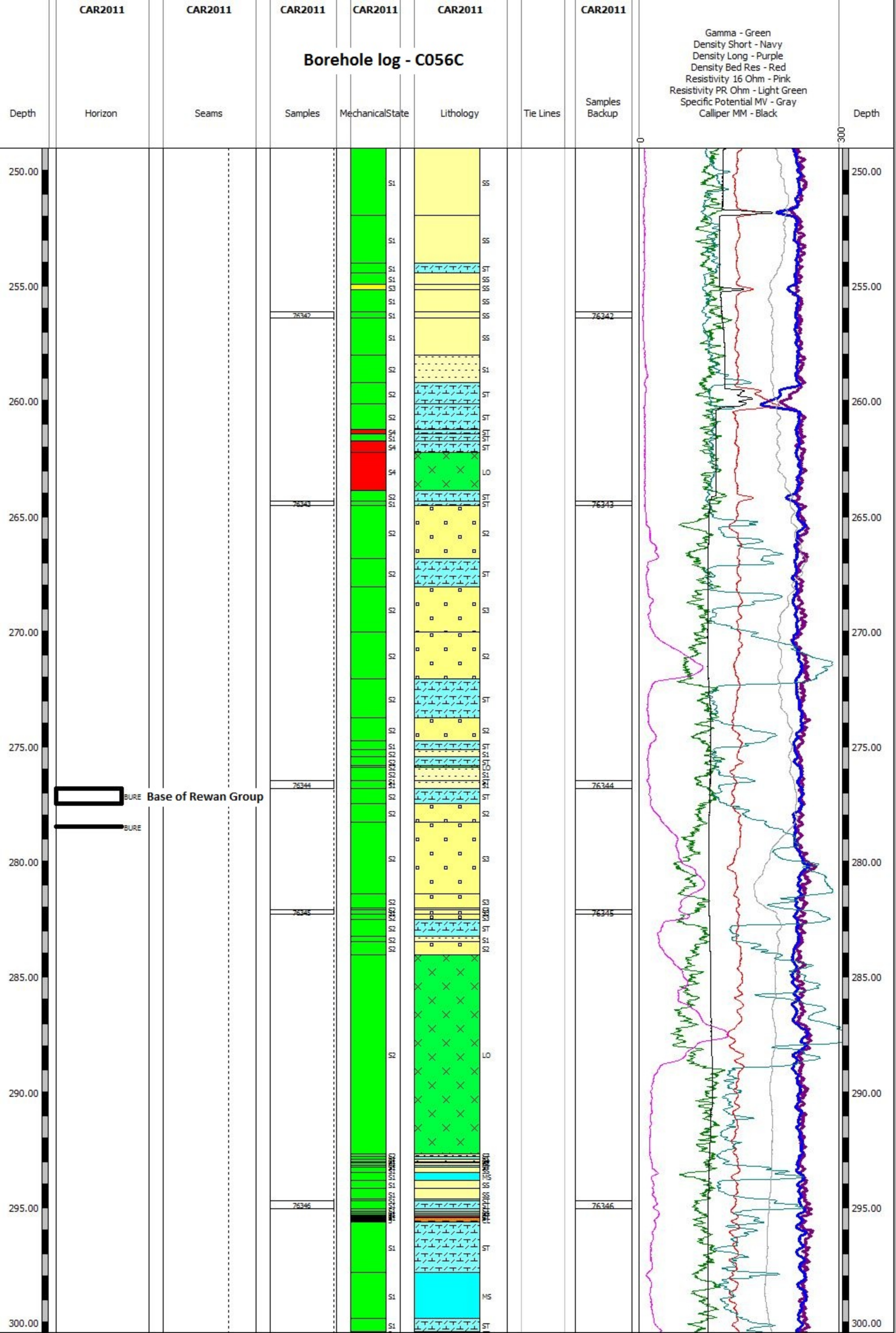
Appendix B – Typical Borehole Log Rewan Group

[illegible]

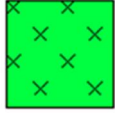
[illegible]

[illegible]





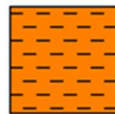
Lithology Legend



Loss associated with sample (LO)



Soil (SO)



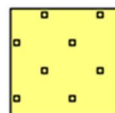
Silt (SL)



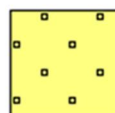
Sandstone (SS)



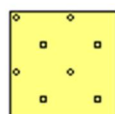
Very fine grained Sandstone (S1)



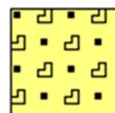
Fine grained Sandstone (S2)



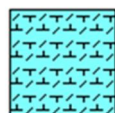
Fine to medium grained Sandstone (S3)



Medium grained Sandstone (S4)



Coarse to very coarse grained Sandstone (S5)



Siltstone (ST)



Claystone (CY)

GHD

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	Ruth Brown / Luca Traverso	K Phillipson		P Bradley	On file	18/10/2013
0	Ruth Brown / Luca Traverso	K Phillipson		P Bradley		21/10/2013

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