07 February 2014

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Dear Hamish

Carmichael Coal Project
Response to IESC Advice

Please find below our response to the key conclusions included in the IESC Advice to decision maker on coal mining project relating to the Carmichael Coal Project dated 12 December 2013.

1 Relevant Data and Information: Key Conclusions

1.1 Groundwater Flow Conceptualisation

1.1.1 IESC Comment:

There are important data gaps, especially in the deeper groundwater systems, most notably hydraulic head information, which bring into question the conclusions being drawn about groundwater flow directions. The groundwater flow interpretation contained within the draft SEIS appears to be based primarily on shallow groundwater monitoring. This interpretation is not considered to be consistent with expected groundwater flow for deeper formations, given regional geology and accepted regional groundwater flow directions within the Great Artesian Basin (GAB).There is insufficient data provided in the draft SEIS to substantiate the proponent's groundwater flow conceptualisation.

1.1.2 GHD Response

Data gaps

Available groundwater level data for each of the geological units present at the site are presented in Figures 2 to 8 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). At the time of publication of the SEIS, some 82 groundwater level monitoring bores had been installed by Adani within the proposed Mine Area. A further two monitoring bores have been installed since. This significant investment in monitoring in the Carmichael Coal Project Mine Area compares favourably with the recently approved Galilee Coal Project where a network of 21 piezometers was installed during the EIS process (Heritage Computing Pty Ltd, 2013).

A breakdown of the number of groundwater monitoring network bores currently installed in each hydrogeological unit present within the Carmichael Coal Project Mine Area is presented in Table 1.

Table 1 Monitoring Piezometers by Strata – Carmichael Coal Project Mine Area

Groundwater Unit	Number of Boreholes
Quaternary Alluvium	2
Tertiary Clay	3
Dunda Beds	7
Rewan Group	7
Permian Overburden (Bandanna Formation)	11
AB Coal Seams (Bandanna Formation)	16
Permian Interburden (predominantly Bandanna Formation)	11
D Seams (Colinlea Sandstone)	14
Older Permian Strata (predominantly Colinlea Sandstone)	13
Total	84

The basis of the IESCs statement that there is a lack of hydraulic head information in deeper units is not clear. As shown in Table 1 and in Figures 2 to 8 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6), bores have been installed in each unit present within the site, including 13 monitoring locations in the Permian strata underlying the coal seams at the site, which is present at depths of over 500 m below ground close to the western boundary of the site. If anything, (as shown in Table 1), the number of monitoring bores generally increases with depth. This is predominantly a reflection of the limited extent of some of the shallower units. The Dunda Beds and Rewan Group are, for instance, only present towards the west of the Mine Area. This groundwater monitoring network is therefore considered to be sufficient to confirm groundwater flow directions in all hydrogeological units throughout the proposed Mine Area.

Outside of the proposed Mine Area, where land access and other constraints prevent extensive groundwater monitoring bore installation, increased reliance is inevitably placed on data available from public data sources, predominantly the Queensland State Groundwater Database. Nevertheless, as shown in Table 2 and in Figures 2 to 8 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6), Adani has also installed four further monitoring boreholes (HD01, HD02, HD03A and HD03B) in the area between the Doongmabulla Springs and the western boundary of the Mine Area. The Groundwater Monitoring Plan provides commitments to undertake further monitoring to track the development of any impacts and confirm groundwater level flow directions in this important area.

Table 2 Monitoring Piezometers by Strata – Off Lease Monitoring Bores

Groundwater Unit	Number of Boreholes
Quaternary Alluvium (HD03B)	1
Clematis Sandstone (HD02)	1
Dunda Beds (HD01, HD03A)	2

Other than the bores installed recently by Adani, data on groundwater levels in the GAB area to the west of the Mine Area are limited to three registered bores, which are thought to be installed into the Clematis Sandstone (see Figure 2 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6)).

Groundwater flow conceptualisation

As discussed in Section 2.4.2 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6), prior to undertaking the project, given the observed dip of the strata present, it was expected that groundwater flow, particularly in the GAB units to the west of the mine area, would be towards the south west (i.e. in line with the dip). This is the dominant groundwater flow direction within central parts of the GAB elsewhere in Queensland. Importantly, however, within these central parts of the basin, regional boundary conditions, the dip of the strata and the general topographic slope all act to encourage flow in a south west direction. Conversely, the Carmichael Coal Project forms part of the Belyando River surface water catchment which drains towards the east and north and hence, in this marginal part of the basin, the dip of the strata and the topography act to encourage flow in different directions. The majority, if not all, of the available groundwater level data for the project area suggest that groundwater flow, in both the Triassic aged GAB units and the underlying Permian age strata, is towards the Carmichael and/or the Belyando River (i.e. in line with the topography). There is little or no evidence of a south-westerly flow component within any of the units monitored.

Groundwater level data for the three registered bores to the west of the Mine Area (RN90621, RN16897 and RN69443) suggest groundwater flow in a generally northerly direction within the Clematis Sandstone in this area (i.e. in line with the topography). Given that the Clematis Sandstone is the uppermost reliable aquifer unit in this area, few water bores penetrate into the underlying Permian-age Colinlea Sandstone. However, a recent study undertaken by the DNRM (see Attachment 1) has identified some data on approximate groundwater levels in the Colinlea Sandstone, which have been derived from Drill Stem Tests (DST) stored in the Queensland Petroleum Exploration Database (QPED). This data also suggests flow within the Colinlea Sandstone in a generally north easterly direction, again in line with the regional topography.

Whilst this finding was not necessarily expected, a number of other areas close to the margins of the GAB are characterised by topographically 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 should be stressed, however, that whilst the available groundwater level data and the associated conceptual model suggest topographically driven flow, the numerical groundwater model has been set up such that flow **can occur** in a south westerly direction. All the modelled strata dip in this direction and the south western boundary of the model has been simulated using a MODFLOW General Head Boundary condition (**not a No-Flow boundary as suggested by the IESC**) such that flow within the more permeable aquifer units can exit the model towards the south west. In no way have modelled groundwater flow directions been 'forced' to comply with the conceptual model of topographically controlled flow.

The available groundwater level data, which generally indicate flow towards the Carmichael and/or the Belyando Rivers, has quite properly been used for calibration targets and to set boundary elevations in some cases. The fact that the numerical model has been able to replicate the observed flow directions, without recourse to unrealistic flow parameters, is considered to provide further supporting evidence that the conceptual model of topographically controlled flow is accurate. The results of the independent assessment undertaken by the DNRM (see Attachment 1) also tend to confirm this groundwater flow conceptualisation.

It may be that weathering, leading to a complete loss of structure and cementation, plays an important role in promoting topographically driven, rather than structurally controlled groundwater flow, at least within the relatively shallow weathered horizons. Once topographically driven flow has been established within the generally more permeable near surface weathered strata, it would be theoretically possible for flow in the deeper, generally less permeable, fresh bedrock to persist in the opposite direction. However, this is considered unlikely, especially given the general lack of obvious routes for groundwater discharge (e.g springs or other similar features) to the south west of the Mine Area.

Further discussion of model boundary conditions, in response to the IESC's comments relating to "Application of appropriate methodologies", is provided in Section 2.1.2.

It is noted that URS in their peer review of the numerical groundwater model included in the SEIS (URS, 14 October 2013, see SEIS Appendix K7) suggested that additional consideration of groundwater flow patterns outside of the Mine Area be included as flow within the Galilee Basin sediments (west to east) is contrary to the dip of the geology. To address this, additional groundwater level data and refined groundwater contours across the Mine Areaarea were presented in Section 2.3 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). This additional information has now also been reviewed by URS (see Attachment 2) who conclude that:

"The groundwater flow patterns presented in the SEIS report, based on site specific data, provide an accurate depiction of groundwater flow across the site, which has been simulated in the numerical groundwater model.

Groundwater flow patterns are recognised to be contrary (perpendicular) to geological dip due to a combination of factors including geological setting (pinching-out of units), topography, aquifer hydraulic parameters, recharge and extraction."

Independent reviews conducted by the DNRM and URS therefore both conclude in favour of the groundwater flow conceptualisation presented in the SEIS.

1.2 Rewan Group

1.2.1 IESC Comment

Rewan Formation: The current groundwater model assumes the Rewan Formation will respond uniformly as an aquitard. However, the Committee questions this assumption based on variability in the hydraulic conductivity field data. Further data collection and assessment of the Rewan Formation is necessary. In addition, more data is needed to predict the effect of potential subsidence induced fracturing in the Rewan Formation on leakage rates from the GAB to the coal seam. Information on the degree of groundwater connectivity between the coal seams and the GAB is essential to understand the potential impacts of this project.

1.2.2 GHD Response

Note that the current formal stratigraphic name for the Rewan Formation is the Rewan Group (Australian Stratigraphic Names Database, Geoscience Australia, http://dbforms.ga.gov.au/www/geodx.strat_units.int, website accessed on the 30 January 2014). GHD responses therefore refer to the Rewan Group whereas the IESC refer to the Rewan Formation.

The current 'best estimate' of the predicted impacts of the Project are based on the calibrated values for the Rewan Group, since these are the values which result in an optimal fit to the available data.

As previously discussed at some length in Section 3.6.1 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6) calibration of the groundwater model returned optimal horizontal and vertical hydraulic conductivity for the Rewan Group of 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 the relatively small number of tests undertaken for the project. The calibrated values are, however, well within the 5th and 95th percentile range of 8.3×10^{-6} to 5.1×10^{-2} m/d calculated from the substantial regional data set for the Rewan Group 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).

Nevertheless, it is recognised that the hydraulic properties of the Rewan Group, like other units in the area, are highly variable, both laterally and vertically. A detailed sensitivity analysis was therefore undertaken to quantify groundwater impacts, based on a wide range of possible hydraulic conductivity values for the Rewan Group. The results of this sensitivity analysis are reported in Section 3.6.1 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). Hydraulic conductivity values for the Rewan Group as high as 1×10^{-2} m/d horizontally and 1×10^{-3} m/d vertically were considered which are towards the upper end of:

- the range of values for the Rewan Group calculated from regional data sets (QWC, 2012); and
- a typical range for sandstone of 2.6×10^{-5} to 5.2×10^{-1} m/d, as identified by Domenico & Schwartz (1990).

Hence, under the ‘worst case scenario’ considered for the sensitivity analysis, the groundwater modelling assumes that the Rewan Group will respond uniformly as a **fractured sandstone aquifer**. The IESCs comment that “the current groundwater model assumes the Rewan Formation will respond uniformly as an aquitard” therefore appears to give no recognition to the sensitivity analysis work completed.

As reported in Section 3.6.1 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6), sensitivity analysis results suggest that maximum drawdown impacts at the Doongmabulla Springs could be up to around 1 m in the event that the actual vertical hydraulic conductivity of the Rewan Group was $1x10^{-3}$ m/d (i.e. around two orders of magnitude higher than the calibrated value) and close to zero if the lower bound value 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.

Consideration of the potential for faulting within the Rewan Group

The IESC has also made the comment that the groundwater model does not take into consideration the potential for faulting within the Rewan Group . It should be noted however that, where the Rewan Group is present within the predicted maximum 150-160 m thick free draining fracture zone that may develop above the proposed longwall panels, the modelled vertical hydraulic conductivity value used for predictive purposes has been increased by a factor of 10. Hence for the ‘worst case’ scenario considered in the sensitivity analysis, the final post-development horizontal and vertical hydraulic conductivity of the Rewan Group, in the area immediately above the proposed longwall panels, have been assumed to be $1x10^{-2}$ m/d. This value is almost at the upper end of values considered realistic for sandstone of $2.6x10^{-5}$ to $5.2x10^{-1}$ m/d as identified by Domenico & Schwartz (1990).

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 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). This log shows 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 be characterised by significantly lower vertical hydraulic conductivity values than $1x10^{-2}$ m/d and hence also significantly limit the effective vertical hydraulic conductivity of the Rewan Group. Where further representative data were collected (e.g. by undertaking laboratory core testing from a number of elevations within the Rewan Group and/or further analysis of downhole geophysics information) it is therefore considered highly unlikely that the maximum vertical hydraulic conductivity, before or after mining, in any vertical sequence would approach the ‘worst case’ scenario hydraulic conductivity values already considered in the sensitivity analysis. The value of further data collation in this area is therefore considered to be negligible since the impacts of extreme values for the hydraulic conductivity of the Rewan Group have already been assessed.

1.3 Springs

1.3.1 IESC Comment

Springs: The source aquifer for the Mellaluka Springs Complex has not been determined, and as such it is not possible to accurately predict impacts from mining on these Springs. For both the Mellaluka and Doongmabulla Springs Complexes there is insufficient information on ecology and water chemistry, particularly in relation to potential seasonal variability, to design scientifically appropriate management *and mitigation strategies. The Committee has little confidence in the capacity of the groundwater flow conceptualisation and groundwater flow model to predict the impact on these Spring Complexes.*

1.3.2 GHD Response

Mellaluka Springs – source aquifer

Adani has committed to undertaking a detailed program of ongoing ecological and hydrogeological monitoring at both the Mellaluka (and Doongmabulla) spring complexes, as outlined in the Groundwater Dependent Ecosystem Management Plan, in order to confirm the source aquifer for the Mellaluka Springs.

The current uncertainty regarding the source aquifer of the Mellaluka Springs is a result of the general lack of any historic information relating to these springs and the unusual hydrogeological setting. The springs are located outside of the GAB and in a topographically very flat area. Outcrop geology in the area is dominated by Tertiary-age clay and hence there are few obvious local areas with the necessary elevation and permeability to sustain discharge from these springs. As shown in the conceptual cross section developed for the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6, see Figure 10)) the most likely recharge area for these springs is considered to be subdued sandstone dominated ridge areas which are present to the west of the Mine Area and have been mapped as Dunda Beds at outcrop. However, the Dunda Beds are not thought to be present at the springs themselves and hence recharge to these outcrop areas must first pass through the underlying Permian age strata before discharging to surface via fractures (or similar) in the overlying Tertiary-age clay. Possible alternative conceptual models for the source of the Mellaluka Springs include:

- A possible source within the Tertiary-age deposits; and
- Direct discharge from the Colinlea Sandstone based on the apparent south-north groundwater flow direction evident in regional scale data collated by the DNRM (see Attachment 1).

It should be noted that the current conceptual model for the Mellaluka spring source (i.e. recharge to the Triassic-age Dunda Beds discharging via the Permian–age Colinlea Sandstone) is effectively a 'worst case' model from a drawdown impact point of view. Substantially less impact is likely if it is assumed that the springs are fed by groundwater discharge from within the near-surface, Tertiary-age units.

Additional data gathering

It is recognised that further time series groundwater level, groundwater quality and ecology data are required to confirm the source of the Mellaluka springs in particular and also to assist with definition of appropriate management and mitigation strategies. Adani have therefore committed to a program of ongoing ecological and hydrogeological monitoring at both the Mellaluka and Doongmabulla spring complexes. Additional groundwater monitoring boreholes are also proposed in the area between the proposed mineworkings and the Mellaluka spring complex to confirm the geological setting in this area and hence provide further information on potential connectivity with the mine. Further detail of the proposed spring monitoring program and additional boreholes is provided in the Groundwater Dependent Ecosystem Management and Groundwater Monitoring plans. Data collected during these investigations will be used to confirm:

- The most likely source of each spring;
- Baseline ecological and hydrogeological conditions;
- The sensitivity of each individual spring vent to groundwater level drawdown impacts; and
- Appropriate mitigation and management measures.

Predicted Impacts

The committees concerns around the capacity of the model to predict impact at the Mellaluka and Doongmabulla spring complexes appear to be related predominantly to the groundwater flow direction conceptualisation and modelled boundary conditions which are discussed and addressed in Sections 1.1.2 and 1.2.2. The modelling so far undertaken is considered to be highly conservative in a number of ways including:

- Adoption of a 'worst case' conceptual model for flow to the Mellaluka Springs; and
- Drawdown impacts quoted are for the source aquifer and hence no allowance has been made for attenuation of impacts by the potentially highly variable strata which separate the source aquifer from the springs themselves.

Furthermore, as part of the sensitivity analysis previously reported in Section 3.5 and 3.6 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6), spring drawdowns have also been calculated for a wide range of different possible parameter values. It is therefore considered highly unlikely that actual impacts will exceed predicted drawdowns based on the 'worst case' parameter values considered in the sensitivity analysis.

1.4 Ecological Impacts

1.4.1 IESC Comment

Ecological Impacts: Additional information to quantify the likelihood and extent of ecological impacts e.g. to riparian vegetation, as a result of changes to surface and groundwater systems would be beneficial to inform the development of mitigation and management measures.

1.4.2 GHD Response

The ecological impact assessment as a result of changes to surface and groundwater systems has been adequately described within the SEIS. A number of additional technical studies were conducted post EIS based on the findings and identified knowledge gaps from the EIS (relevant technical studies are listed in Attachment 3).

These targeted SEIS technical studies (in addition to the EIS technical studies), provide information on the existing environment and enabled the likelihood and extent of potential ecological impacts as a result of changes to surface and groundwater systems within and adjacent to the Project Area to be adequately described (relevant impact assessment reports are listed in Attachment 3).

Post SEIS, a flood inundation duration assessment report has further assessed the ecological impacts as a result of changes to the surface water systems due to the proposed levees and bridge crossing.

The revised impact assessment reports have informed the development a number of environmental management plans and strategies which detail appropriate mitigation and management measures (relevant management plans are listed in Attachment 3 and include management plans relating to Groundwater Dependent Ecosystems (GDE) and Black Throated Finch). The GDE Management Plan includes sub-plans for the Doongmabulla spring complex, Mellaluka spring complex, Carmichael River and the waxy cabbage palm.

These post SEIS management plans also bring together information from various SEIS reports and provide a summary of potential impacts, mitigation and management measures, monitoring requirements and corrective measures for predicted Project impacts on black throated finch and GDEs (Doongmabulla spring complex, Mellaluka spring complex, Carmichael River and waxy cabbage palms).

Adani have committed to carrying out an extensive program of ecological and hydrogeological monitoring at the Doongmabulla and Mellaluka spring complexes and the Carmichael River as detailed in the GDE management plan and surface and groundwater monitoring plans to provide additional information on the surface and groundwater systems.

Mitigation of post-closure impacts will be further refined following monitoring of groundwater and surface water during operation. Opportunities to offset ongoing, post-closure impacts would be dependent upon the relevant regulatory and policy instruments at the time of closure - however opportunities may exist for securement and management of other waterways in the catchment.

1.5 Cumulative Impacts

1.5.1 IESC Comment

Cumulative Impacts: The proponent undertook a limited cumulative impact assessment including four other proposed projects in the region. There are, however, additional relevant proposed projects which should be included in the cumulative impacts assessment, including the China Stone Coal Project. These proposed developments extend over 300 km in length within the Galilee Basin and comprise some of the largest coal mines in Australia. On this basis, the Committee considers that information on cumulative impacts should be commensurate with the scale of all proposed developments.

1.5.2 GHD Response

The cumulative impact assessment included within the EIS and SEIS has been undertaken in accordance with the project Terms of Reference (TOR) and consultation with the Co-ordinator Generals Office who confirmed that the cumulative impact assessment should be limited to information about other relevant regional projects in the public domain (i.e. excluding potential future projects such as the China Stone Coal Project).

Whilst GHD and Adani are aware of the China Stone Coal Project, there is very limited information relating to this development in the public domain and hence it is not possible at this stage to quantify accurately the combined impacts of the Carmichael Coal and China Stone Coal projects on groundwater resources.

Notwithstanding this, the key potential cumulative impacts resulting from new mining within the Galilee Basin have been identified and commitments have been proposed in response. These commitments include:

- A minimum 1 km (500m from the centreline) wide Carmichael River buffer area to maintain east west connectivity; and
- A commitment by Adani to contribute to development of a basin-scale groundwater flow model, to assess the cumulative impacts of all proposed coal mining activities in the area.

2 Application of appropriate methodologies: key conclusions

2.1 Numerical Groundwater Model

2.1.1 IESC Comment

Numerical Groundwater Model: The Committee is not confident that the proponent's groundwater model will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine. The Committee does not have confidence in the model's predictions for the potential groundwater impacts to the Doongmabulla and Mellaluka Spring Complexes and the Carmichael River. The Committee has significant concerns in relation to the use of no flow boundaries at most of the edges of the model domain and the truncation of the Clematis Sandstone (and other geological formations) on the western side in the numerical model. It appears that surface water catchment boundaries have been used to define the overall model domain, for both shallow and deeper groundwater systems. It is not good practice to employ model boundary conditions such as no flow boundaries without justification and validation. The use of no flow boundary conditions in a groundwater flow model can have profound effects on its predictions. Due to these unjustified and unvalidated assumptions, the Committee does not consider that the numerical model provides a reasonable prediction of the impacts of the development.

2.1.2 GHD Response

Truncation of the Clematis Sandstone

Given that the Clematis Sandstone and other GAB units to the south of the Mine Area potentially extend to the Queensland State border and around 200 km to the west, it is not practicable to produce a groundwater model which includes the full extent of the Clematis Sandstone whilst retaining sufficient detail in and around the Mine Area to accurately quantify impacts on local surface water courses. Truncation of the GAB units to the south and west of the Mine Area is therefore necessary. In this case the active model area extends to the hydrological divide between the catchments of the Belyando River and Lake Galilee catchments.

Model boundaries and extent

As previously discussed in Section 1.1 and as reported in Section 5.4.2 of the SEIS Mine Hydrogeology Report, MODFLOW General Head Boundary (GHB) conditions (rather than the no-flow boundary conditions) have been applied around the outer edge of the active model area, in all areas where significant lateral flow into and out of the model area is considered likely. GHB conditions have not been applied to low permeability aquitard units such as the Rewan Group since lateral flow into and out of such units is typically expected to be minimal. Further information showing the GHB cells in each layer, in the form of screen shots from the actual groundwater model, is provided as Attachment 4.

As shown in Attachment 4 GHB conditions have been applied in the south western boundaries of the model area along the edge of the Belyando River catchment in the Clematis Sandstone (model layer 4), Dunda Beds (model layer 5) and the more permeable parts of the Permian-aged units (model layers 9 and 11) to allow lateral flow into / out of the remainder of the GAB to the south west. As reported in Section 5.4.2 of the SEIS Mine Hydrogeology Report, the elevation of these boundaries was derived from interpolated observed groundwater level data. Prior to undertaking the modelling work, and given the dip of the strata, it was expected that groundwater flow would exit the model in this direction. However, as previously discussed in Section 1.1.2 the available groundwater level data for the Clematis Sandstone suggest flow in a generally northerly direction in the area and the model replicates this flow direction. Flow in the Clematis Sandstone and the other main aquifer units present in this area is still able to leave the model domain to the south west, although reference to modelled groundwater level contours in this area suggest limited flow across this boundary. In no way, therefore, have modelled groundwater flow directions been ‘forced’ to comply with the conceptual model of topographically controlled flow.

As the IESC comments do not include any references to the SEIS documentation, the source of confusion about boundary conditions is not known, although it may have been caused by a lack of clarity in Figure 29 of the SEIS Mine Hydrogeology Report. This figure does show the location of modelled GHB cells, although due to the large area covered by the map and the small size of the cells it is recognised that these boundary cells are difficult to make out.

2.2 Regional Faults

2.2.1 IESC Comment

Regional Faults: The conceptual model would benefit from an assessment of regional faults. The proponent’s groundwater model does not take into consideration the influence of faulting within the Rewan Formation. The Committee notes that faults have been identified on the eastern boundary of the Galilee Basin within the Rewan Formation in other project proposals, but their potential role on groundwater flow processes has not been considered in this project.

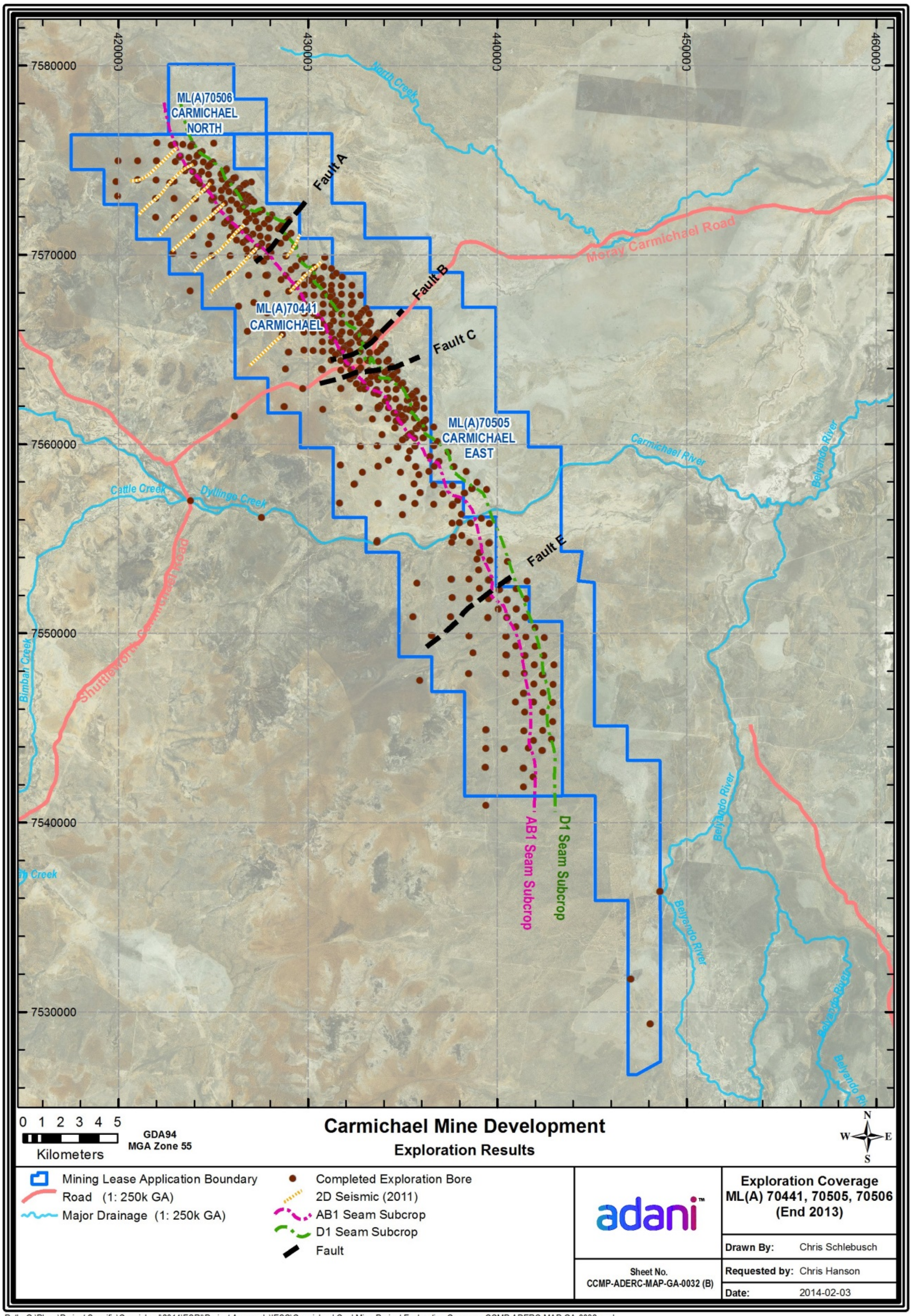
2.2.2 GHD Response

Some studies (including the Queensland Carbon Geostorage Initiative Atlas, 2009) suggest the presence of a number of faults close to the boundary between the Galilee Basin and the Drummond Basin to the east (i.e. to the north and east of the proposed mining area). This information was considered in overall geological assessments for the Carmichael Coal Project, and by independent geologists acting as Competent Persons under JORC 2012, who have undertaken JORC Resource modelling assessments. JORC assessments have been undertaken by Xenith Consulting (Turner, 2013), and also more recently by ROM Resources (Mark Biggs, 2014), who are currently preparing an updated resource assessment (see Attachment 5). Following overall assessment of the publically available regional geology reports and maps, together with JORC resource modelling by these recognised independent geologists, it is concluded that there is a general absence of any significant faults in the area. This conclusion is based on structural geological interpretation to a JORC 2012 compliant standard, which is underpinned by a significant density of drilling and seam interpretation throughout the area as shown in Figure 1.

High quality 2D seismic which has been interpreted along the lines shown in Figure 1, demonstrates no significant regional fault structures intersecting these lines.

The level of geological interpretation based on successive comprehensive exploration campaigns and geological modelling since Adani purchased the EPC from Linc Energy in 2010 is considered to provide for a substantially higher level of structural geological understanding, and fault interpretation and relative displacements, when compared with existing regional interpretations.

The JORC Coal Resources Estimate for the project (Turner, 2013), suggests the presence of only four minor faults in the coal strata, with vertical throws between 20 m and 40 m, trending in a general east - west direction (see Figure 1). This interpretation has recently been substantiated by Mark Biggs, ROM resources (see Attachment 5) based on additional drilling data provided by Adani from the 2013 drilling program.



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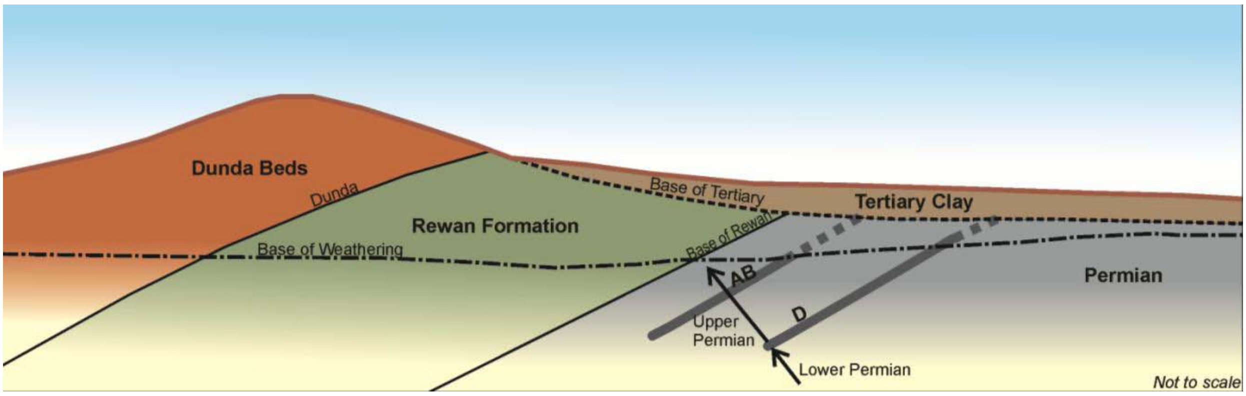
A cross section of the stratigraphic sequence through the Project area is shown in Figure 2. As is shown, the Tertiary sediments are composed of unconsolidated to semi-consolidated sediments approximately 50 m in thickness towards the east of the Mine Area, thinning to zero in the west. The Dunda Beds and Rewan Group overlay the Permian coal sequence in the west, with overburden thicknesses of approximately 300 m to 400 m.

Figure 2 – Geological Cross Section of the Carmichael Coal Project Area



Given that the Rewan Group is around 250 m thick at the western boundary of the proposed Mine Area a throw of 40 m would still result in an effective aquitard thickness of 210 m. There is no evidence in the geological data set of any faults with sufficient throw to, for example, bring the Dunda Beds or the overlying Clematis Sandstone into contact with the underlying Permian-age units on the other side of a faulted contact.

On this basis, no direct simulations of hypothetical faulting of the Rewan Group or other strata have been undertaken. However, as discussed in Section 1.2.2, a detailed sensitivity analysis has been undertaken to quantify groundwater impacts based on a wide range of possible hydraulic conductivity values for the Rewan Group. The results of this sensitivity analysis are reported in Section 3.6.1 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). Hydraulic conductivity values for the Rewan Group of as high as $1x10^{-2}$ m/d horizontally and $1x10^{-3}$ m/d vertically were considered for the Rewan Group, increasing post mining to $1x10^{-2}$ m/d horizontally and vertically in the area immediately overlying the underground mine workings. Hence under the 'worst case' Rewan Group hydraulic conductivity scenario considered for the sensitivity analysis, the groundwater modelling assumes that the Rewan Group will respond uniformly as a fractured sandstone **aquifer**. This is akin to assuming that the Rewan Group is heavily faulted and fractured throughout the area, such that it ceases to function as an aquitard. Impact predictions based on this 'worst case' scenario suggest that maximum impacts at the Doongmabulla Springs could be up to around 1 m compared to up to around 0.2 m drawdown based on the calibrated or 'best estimate' parameter set.

2.3 Subsidence Fracturing

2.3.1 IESC Comment

Subsidence Fracturing: The assessment of the height of the subsidence fracture zone above longwall mining was not based on local site data nor with due consideration of multi-seam mining. The draft SEIS notes that these factors are significant and may result in underestimation of the fracture zone height above longwall mining. Likewise the connectivity of the fracture network and the relative increase in hydraulic conductivity of strata within this zone needs verification. Subsidence fracture zone height and hydraulic connectivity could have implications for the GAB and surface water resources.

2.3.2 GHD Response

The height of the free draining fracture zone used for modelling purposes has been extracted from a detailed project-specific study carried out by the MSEC (MSEC, 2013). This study included a detailed literature review to identify other estimates and models of the height of the free-draining fracture zone. Unfortunately, as there are no active longwall operations in the Galillee Basin, none of the examples and models identified are directly applicable to the Carmichael Coal Project. In any case, as the authors identify, the height of the free draining fracture zone appears to be dependent on a range of site-specific factors, including the longwall panel width, the seam thickness extracted, the thickness and geomechanical properties of the overlying strata, the presence of faults and natural jointing, the presence of low permeability layers that can restrict the vertical flow of groundwater, and in some cases the bulking and compaction factors of the goafed material (MSEC, 2013). MSEC used a number of different models to predict the height of the free draining fracture zone above the uppermost extracted seam at the Carmichael Coal project. Estimates ranged from 58 to 160 m above the extracted seam. Recognising that these estimates are based on single seam extraction, MSEC recommended adoption of the upper bound estimate of 160 m, based on the model developed by Klenowski (ACARP C5016, 2000). In terms of the enhanced permeability factors which apply within this free draining fracture zone, MSEC recommended adoption of the factors calculated by Guo et el (ACARP C14033, 2007). Given the range of factors which govern development of the fracture zone and the highly variable nature of the overlying strata, verification of the predicted height of fracturing and the enhanced permeability factors can only be provided by monitoring of subsidence, groundwater levels and permeability at selected horizons both before and after mining.

MSECs recommendations, with regard to both the predicted height of the free draining fracture zone and expected vertical permeability factors, were adopted for the groundwater modelling work completed by GHD and reported in the Section 5 of the SEIS Mine Hydrogeology Report (SEIS Appendix K1).

No direct simulations of the sensitivity of model prediction to potential variations in the height of the free draining fracture zone have been undertaken to date. However, given that other models identified by MSEC resulted in free draining fracture zones of as low as 58 m above the extracted seam. The 160 m value recommended by MSEC is considered to be conservative and close to worst case. Furthermore, and as discussed in Section 1.2.2 ‘worst case’ predictions of impacts on the Doongmabulla spring complex and GAB are based on vertical hydraulic conductivity values for the Rewan Group of 1×10^{-2} m/d inside of the free draining fracture zone and 1×10^{-3} m/d outside. Given the large number of low-permeability clay, claystone or siltstone horizons logged within the Rewan Group, the chances of the bulk vertical hydraulic conductivity of this formation approaching 1×10^{-3} even in a scenario where the full thickness of the Rewan Group is fractured by longwall mining operations is considered remote. For instance Domenico & Schwartz (1990) quote maximum upper bound values for fractured siltstone of $1x10^{-3}$ m/d and $4x10^{-4}$ m/d for clay (i.e. values which are the same or lower than the 'worst case' values for the Rewan Group which have already been considered).

It should also be noted that, as shown in Figure 2, the Clematis Sandstone (GAB aquifer) does not directly overlie the Permain units to be mined / altered thus any subsidence effects would be in the Rewan Group units closest to the Permian strata and not the overlying Clematis Sandstone or Dunda Beds.

3 Reasonable values and parameters in calculation: key conclusions

3.1 Numerical Groundwater Model Boundaries

3.1.1 IESC Comment

The Committee supports URS's peer review recommendation on the need to "validate the location and type of boundaries in the model, emphasising suitability, impact on model results/predictions, and assumptions used when selecting the model boundaries."

3.1.2 GHD Response

Further detail on model boundaries in the critical south western part of the model is provided in Section 2.1.2. The sensitivity of model predictions to General Head Boundary (GHB) conductance is reported in Section 3.6.3 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). As expected, given the distance of the model boundaries from the proposed Mine Area, sensitivity analysis results suggest that the predicted impacts are not sensitive to the conductance or elevation of the defined GHB cells.

The IESC's concerns with regard to modelled boundaries appear to be related to a mis-interpretation of the boundaries applied. This was clarified previously in Section 2.1.2.

3.2 Field Data and Rewan Group

3.2.1 IESC Comment

The proponent's field data needs to be further integrated into the groundwater model to establish an appropriate set of values and ranges for model layers, in particular, hydraulic conductivity parameters for the Rewan Formation. Sensitivity analysis of the groundwater model confirms that the integrity of the Rewan Formation plays a critical role in controlling impacts to the GAB and the Doongmabulla Springs Complex. This role may also extend to include ecological communities supported by discharge from the GAB, the groundwater dependent Waxy Cabbage Palm and other threatened species in the region.

Rewan Formation: On-site measurements of hydraulic conductivity values for the Rewan Formation ranged across several orders of magnitude, consistent with the variable lithology presented from drilling logs. These variations in local geology, including the potential for faulting, deep weathering or lateral gradation into the Warang Sandstone, may increase the permeability of the Rewan Formation. The implications of this contrasting behaviour for regional groundwater processes need to be further explored.

3.2.2 GHD Response

Again, the IESCs comments appear to give no recognition to the detailed sensitivity analysis work reported in Sections 3.5.1 and 3.6.1 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). Impacts on the Carmichael River, GAB groundwater resources and the Doongmabulla and Mellaluka spring complexes have been assessed based on a wide range of possible alternative parameter sets for the Rewan Group and all other modelled units, in addition to the 'best estimate' prediction, which is based on the calibrated parameter set. The parameter ranges adopted for sensitivity analysis purposes were derived based on a range of information sources including site specific field test results, regional data sets and other relevant modelling studies. In particular, horizontal hydraulic conductivity values of up to $1x10^{-2}$ m/d ($1x10^{-3}$ m/d vertically) have been considered for the Rewan Group. The maximum hydraulic conductivity values for the Rewan Group considered in the sensitivity analysis are therefore:

- More than two orders of magnitude higher than the calibrated hydraulic conductivity of the Rewan Group which are $7.4x10^{-5}$ m/d (horizontal) and $7.4x10^{-6}$ m/d (vertical);
- At least as high as the values for the Rewan Group calibrated in other known modelling studies undertaken in the Galilee Basin;
- Around one order of magnitude higher than the maximum hydraulic conductivity of 1.7×10^{-4} m/d returned by tests undertaken on unweathered strata within the Rewan Group;
- At the upper bound of the range of values quoted for siltstone by Domenico & Schwartz (1990) who suggest values of between $9x10^{-7}$ and $1x10^{-3}$ m/d; and also
- Towards the upper end of a typical range for sandstone of $2.6x10^{-5}$ to $5.2x10^{-1}$ m/d (Domenico & Schwartz, 1990)

The 'worst case' scenario run therefore effectively covers a range of possible scenarios, since even where the Rewan Group is highly faulted (by either mining induced fracturing or natural processes) or grades into the Warang Sandstone, it is considered highly unlikely to be characterised by hydraulic conductivity values which exceed the range of values already modelled.

It is recognised that higher values of hydraulic conductivity than those considered in the modelling can be returned by tests undertaken in horizons where the Rewan Group has been weathered. Hence, as previously reported in Section 2.2.8 of the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6) 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. However, detailed information derived from the extensive exploration drilling undertaken in the Mine Area also suggests:

- Only partial weathering of the Rewan Group over 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. In fact, given the dip of the strata, little or no weathering of the Rewan Group is anticipated throughout the area to the west of the Mine Area. It was therefore not considered appropriate or realistic to apply field test values for weathered strata to the full thickness of the modelled Rewan Group.

4 Specific Comments

The IESC advice letter also includes some 46 specific comments. An individual response to each of these comments is provided in Attachment 6.

5 References

Biggs, M., 2014, A Short Review of Regional Structure in the Region of the Carmichael Coal Deposit, Central Queensland, ROM Resources for Adani Mining Pry Ltd.

Domenico, P.A. and Schwartz, F.W., 1990, Physical and Chemical Hydrogeology, John Wiley & Sons Inc.

GHD, 2012. Queensland Water Commission, Report for QWC17-10 Stage 2 Surat Cumulative Management Area Groundwater – Model Report.

GHD, 2013. Carmichael Coal Mine and Rail Project SEIS, Report for Mine Hydrogeology Report prepared for Adani Mining Pty Ltd.

Guo, H., Adhikary, D. P. and Gabeva, D., 2007. Hydrogeological Response to Longwall Mining, ACARP project C14033. CSIRO Exploration and Mining Report P2007/692.Houlsby, 1976, Routine Interpretation of the Lugeon Water-Test, p303 – 313.

Heritage Computing, 2013. Galilee Coal Project Groundwater Assessment for Waratah Coal Pty Ltd.

Klenowski, G. (2000). The Influence of Cracking on Longwall Extraction, , ACARP Research Project No. C5016, August 2000.

MSEC, Mine Subsidence Engineering Consultants, 2012. Carmichael Project – Subsidence Prediction Report. Report Number: MSEC575, Revison 02.

MSEC, Mine Subsidence Engineering Consultants, 2013. Carmichael Project – Revised Subsidence Prediction and Impact Assessment Report. Report Number: MSEC627, Revision 01.

The Queensland Carbon Geostorage Initiative (QCGI), 2009. Potential for carbon geostorage in the Taroom Trough, Roma Shelf and the Surat, Eromanga and Galilee Basins, Preliminary Report, Geological Survey of Queensland, Department of Mines and Energy, Queensland.

QWC, 2012. Underground Water Impact Report for the Surat Cumulative Management Area.

Turner, T., 2013, Adani Mining Pty Ltd JORC Coal Resource Estimate – Carmichael Coal Project.

URS, 2013. Report Adani Carmichael Coal Project Numerical Groundwater Model Peer Review.

Regards,
GHD Pty Ltd

Keith Phillipson
Principal Hydrogeologist
(07) 3316 3468

Attachments:

1. Groundwater Flow Direction Carmichael Coal Project, DNRM, December 2013;
2. Memo from URS, Mark Stewart
3. Technical studies relevant to the ecological impact assessment
4. Modelled General Head Boundary Cells
5. Memo from Mark Biggs
6. Response to specific IESC comments

7. GHD Memo responding to IESC Comment 3c;
8. GHD Memo providing calculations in support to response to IESC Comment 18f

Attachments

Attachment 1. Groundwater Flow Direction Coal Project, DNRM, December 2013

17/12/2013

Groundwater Flow Direction
Carmichael Project Area

GHD, acting for Adani have generally conceptualised a south to north groundwater gradient at the southern end of the model area and a west to east groundwater gradient in the middle of the mine area. They also have a north west to south east gradient in the north of the modelled area.

When officers of DNRM first saw these contours there were concerns about how well this represented what was actually occurring in the area.

Generally in the eastern Galilee Basin area it had been conceptualised that formation outcrops occurring in north-south strips adjacent the Great Dividing Range acted as groundwater intake beds after which each formation dipped from east to west. Therefore groundwater flow would be from east to west. The GHD conceptualisation is investigated further below.

Clematis Sandstone
The shape of the contours change to some extent from one aquifer to another with the gradient in the Clematis Sandstone being more pronounced south to north in the southern half of the model area with gradients all then heading towards the low created by the Doongmabulla springs as represented by the head in monitoring bore HD02.

The south to north gradient is shown in Figure 1 (Figure 2 from the Adani SEIS Appendix K6 groundwater addendum). Data from three landholder bores and monitoring bore HD02 are used by GHD to demonstrate a south to north gradient and west to east gradient towards the Doongmabulla springs complex. Note that HD02 is located adjacent the most easterly spring in the complex.

In the south (west of South Galilee, Galilee, Alpha and Kevins Corner) recharge occurs through outcrops of the Clematis Sandstone. Groundwater heads in the Clematis in the intake beds in these areas is as high as 350 metres above sea level Australian Height Datum (AHD). Ground level elevation is about 450 metres AHD in these areas. From here groundwater will move west down dip away from the recharge area. To the north there are less and less areas where the Clematis Sandstone outcrops (often covered by clayey Tertiary sediments), thus minimising opportunities for recharge. Because groundwater generally moves from areas where recharge is occurring to areas where recharge is not occurring, the poor recharge conditions in the north have the effect of encouraging a south to north groundwater flow as well as the east to west groundwater flow.

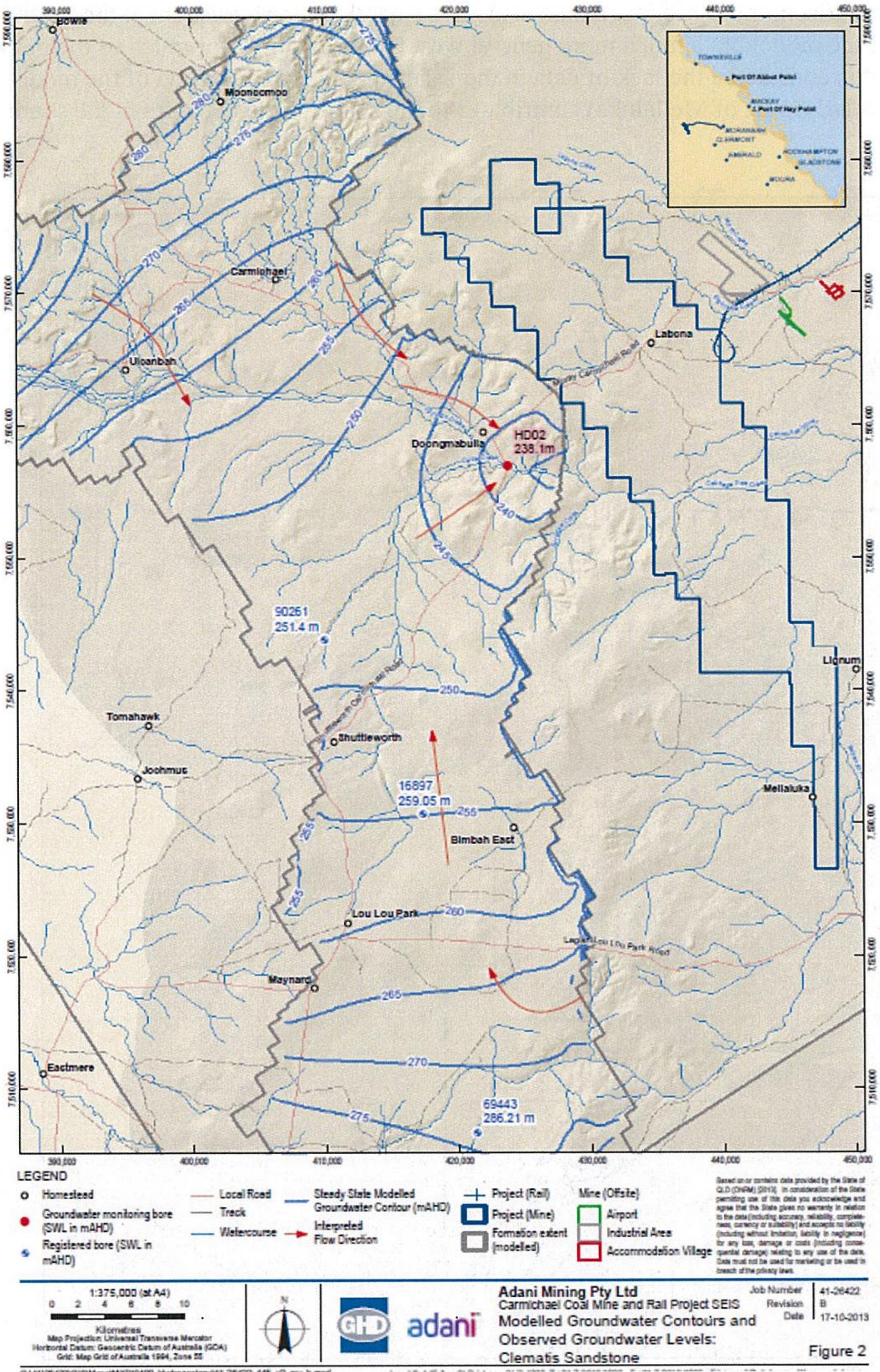
There are then areas around Carmichael where the Clematis Sandstone either outcrops (in some limited areas) or is found at shallow depth, at low ground elevations. For example at monitoring bore HD02, the ground elevation is 240 metres AHD. In this area (Doongmabulla spring complex) groundwater in the Clematis Sandstone is flowing out at points where the groundwater head in the aquifer is higher than the ground level elevation and a path (eg fractures) exists to the surface. The source for the Doongmabulla springs is the Clematis Sandstone. The springs and the Carmichael

River are a discharge area for the Clematis Sandstone aquifer encouraging a local low in the groundwater heads of the Clematis Sandstone aquifer in this area.

Hence we have a groundwater gradient lowering from the south to the north and from the west to the east, resulting in discharge to the Doongmabulla Springs and the Carmichael River. The data supports the GHD conceptualisation.

Attachment 1

Figure 1

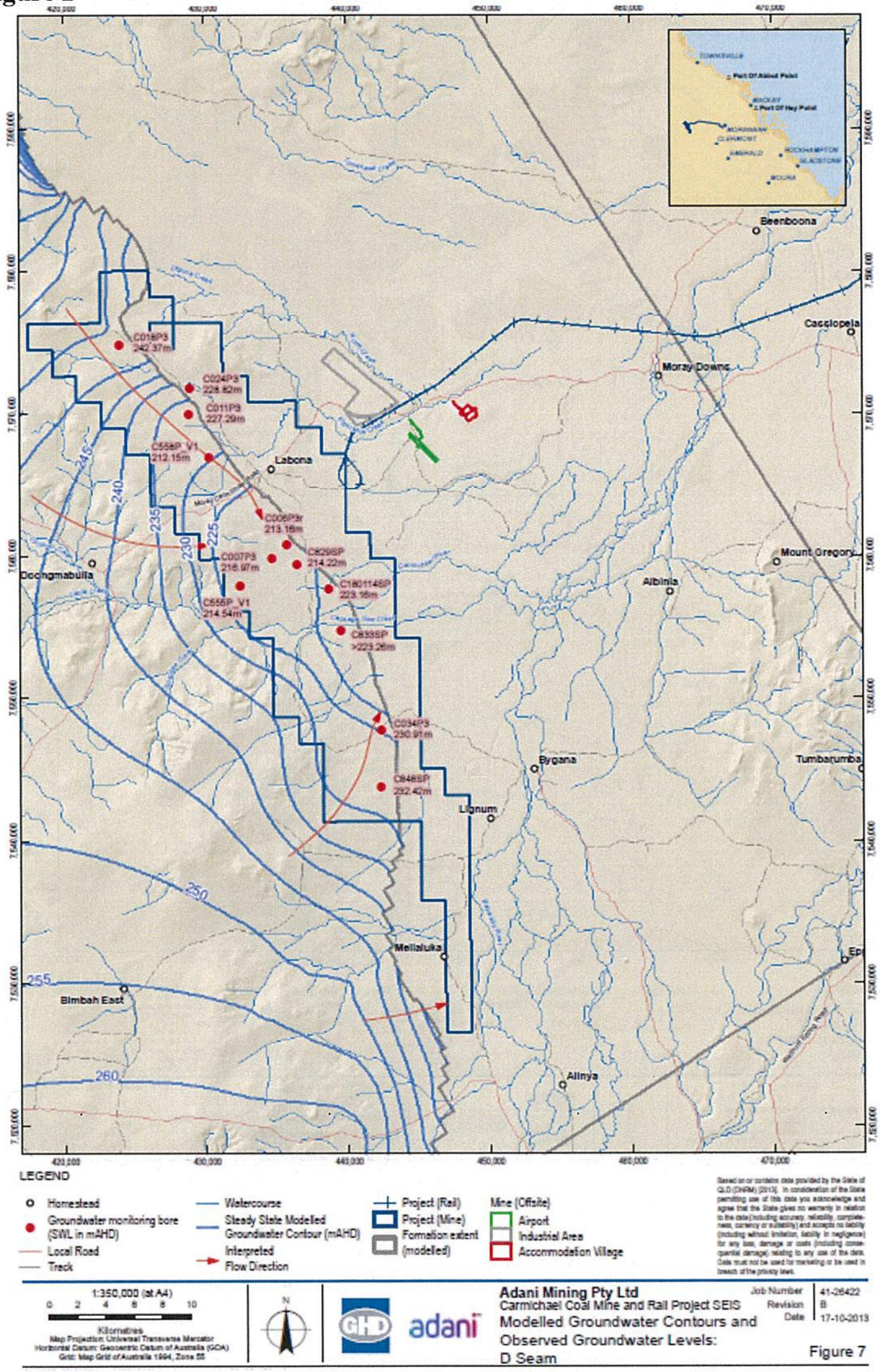


Attachment 1

Colinlea Sandstone

In comparison, the D seam contours also have a south to north gradient at the southern end of the model but a much more general west to east gradient for much of the model area. It is considered the lack of data in the D seam at the southern end of the model (particularly west of Mellaluka) contributes to the shape of the contours in the south.

Figure 2



Attachment 1

In recent times, DNRM officers have been looking at regional groundwater issues associated with all mines being investigated in the eastern Galilee Basin area from South Galilee (adjacent Alpha township) in the south to Carmichael in the north (with specific details of China Stone, north of Carmichael still yet to be seen).

Of particular interest here is that DNRM have investigated sources of data to assist in understanding groundwater heads in the Colinlea Sandstone and Bandanna formation in areas well west of the proposed mine areas.

Some such data was able to be sourced from old drill stem tests carried out in petroleum exploration wells in the area.

Drill stem tests can often provide poor quality information and often these poorer quality tests can easily be identified and discounted. However even in the better tests there remain significant measurement uncertainties. Bearing this in mind any data obtained from these tests can be taken as a guide only.

Within the dataset available for the petroleum exploration wells in the area, data from four wells was selected where the tests were carried out in the Bandanna Formation or Colinlea Sandstone and the data appeared accurate enough to utilise.

Wells chosen were as follows:

Table 1 Petroleum Exploration Wells used for Drill Stem Head Data

Name	GWDB RN	Tested Interval (m)	Formation
Lake Galilee No.1	22367	1010 - 1063	Colinlea Sandstone
Thunderbolt No.1	22595	886 - 915	Bandanna Formation
Carmichael No.1	-	918 - 929	Colinlea Sandstone
Coreena No.1	22658	742 - 783	Colinlea Sandstone

After collecting all the data and allowing a conversion for the units that data was originally collected in, temperature affect of pressure and reference points (where the data was measured from), Table 2 provides a summary of data collected.

Attachment 1

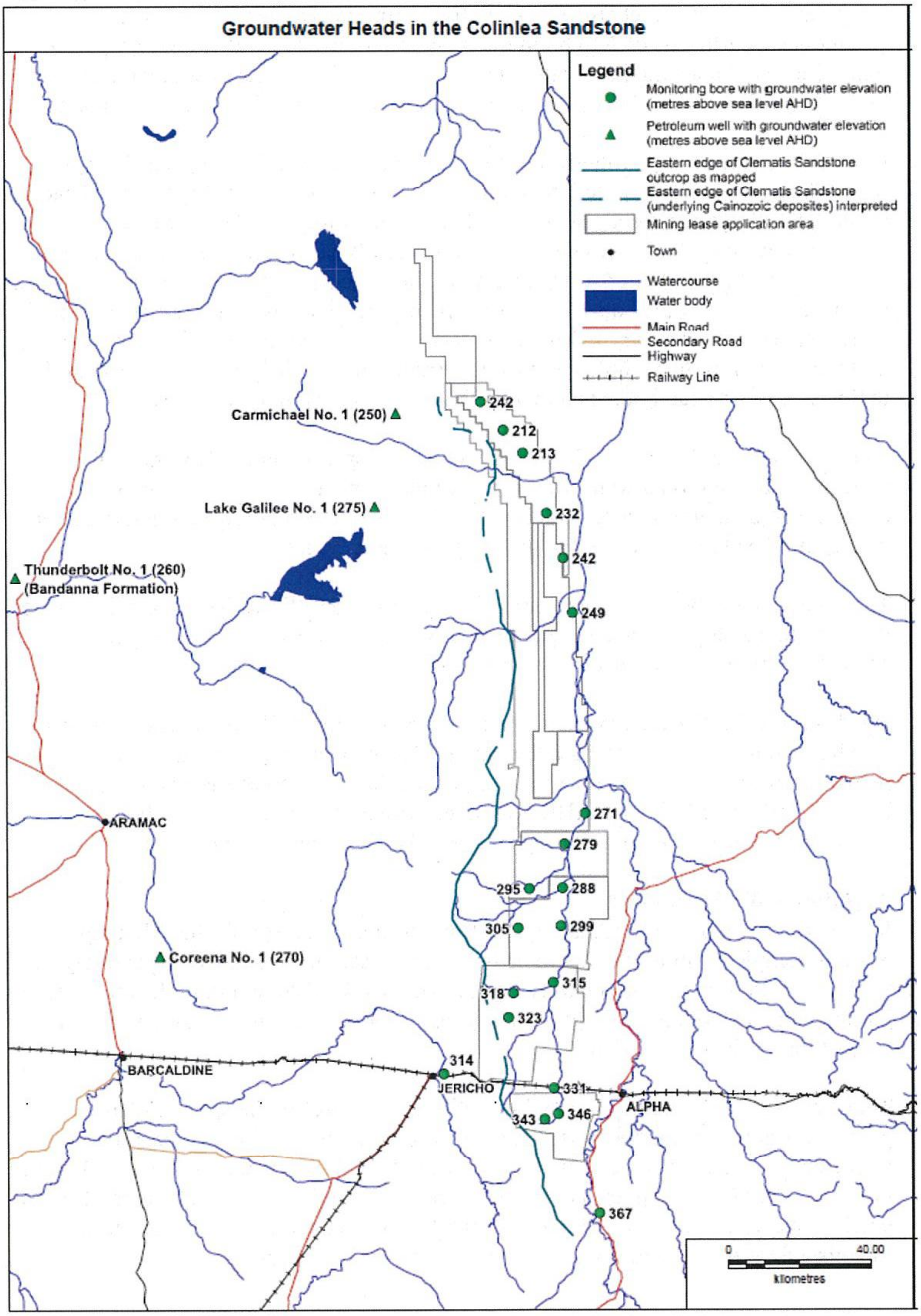
Table 2 Calculation of Approximate Heads using Drill Stem Test Data

Well Name	Maximum Head Recorded (psia)	Adjustment for measurement in a vacuum (psia issue)	Adjustment for temperature	Depth at which head measured below Kelly Bushing (m)	Depth of Head below Kelly Bushing (m)	Elevation of Kelly Bushing (m AHD)	Approximate Elevation of Head (m AHD)
Carmichael No.1 (1995)	1274.9	1274.9 – 14.7 = 1260.2 psi (887.5m)	887.5 – 10 = 877.5 m	922	922 – 877.5 = 44.5	293.8	249.3 round off to 250
Lake Galilee No.1 (1964)	1445	1445 – 14.7 = 1430.3 (1007.3m)	1007.3 – 10 = 997.3 m	1016	1016 – 997.3 = 18.7	293.9	275.2 round off to 275
Thunderbolt No.1 (1967)	1329	1329 – 14.7 = 1314.3 (925.6m)	925.6 – 10 = 915.6 m	885.6	885.6 – 915.6 = -30	232	262 round off to 260
Coreena No.1 (1970)	1118	1118 – 14.7 = 1103.3 psi (777 m)	777 – 10 = 767 m	751.3	-15.7	254	269.7 round off to 270

Attachment 1

Data available from monitoring of the Colinlea Sandstone in the southern mine areas and other private bores in the area was then used in combination with the drill stem test data to produce figure 3.

Figure 3



From this it can be seen that the highest recorded heads in the area are south of Alpha adjacent Alpha Creek. It is conceptualised by DNRM that in this area, south of Alpha township, there is a 40 km section of Alpha creek which overlies and recharges alluvium and Tertiary sediments which in turn overlie the Colinlea Sandstone. Alpha Creek in this area therefore appears to provide recharge to the Colinlea Sandstone acting as a significant recharge source to that formation in the Galilee Basin. Additionally north east of Jericho in the western half of the Galilee Coal proposed mine site area it appears that shallow porous Tertiary sediments overlie the Bandanna Formation and may similarly provide useful recharge to that formation in that area.

From this southern area groundwater flow directions are south to north and east to west. The south to north direction is in line with declining surface topography heading north in the Belyando creek catchment. Despite declining groundwater level elevations heading north, groundwater heads actually become closer and closer to ground level. Just south of Carmichael mine site, a number of artesian bores are noted to exist in a line north to south. Whilst many of these bores were initially considered to be sourced from Tertiary sediments it is now considered likely that they are taking groundwater from the Colinlea Sandstone. Part of the confining layer for this aquifer in this area of artesian bores is likely to be very clayey Tertiary sediments.

At the southern end of Carmichael, the Mellaluka springs complex exists. It also appears to source groundwater from the Colinlea Sandstone. From here there continues to be a groundwater gradient to a point just north of the Carmichael River where an unexplained low area or groundwater 'hole' exists.

The topographically low area of Carmichael where the Colinlea Sandstone is close to outcrop appears to provide a discharge area for the Colinlea Sandstone as the Mellaluka Springs complex demonstrates.

By observing the few approximate heads available in the drill stem holes, support can also be seen for a west to east gradient at the Carmichael area. Note that the petroleum wells some 30 km west of Carmichael have a groundwater elevation of between 250 and 275 metres AHD compared with 212 to 242 metres AHD at Carmichael. The data then generally supports the GHD conceptualisation.

Additional Work required

It is however important for Adani to confirm the source aquifer for the Mellaluka Springs complex. Initially the proponent had suggested that the source was likely to be the early Permian strata (underlying the Colinlea Sandstone) but in the more recent groundwater addendum report it has been suggested that it is more likely to be the base of the Colinlea Sandstone.

They have made estimates of drawdown of 2 to 18 metres in the springs with a predicted figure of 9 metres based on the source being the Colinlea Sandstone. Unfortunately there is no layer in the model for the geological unit below the D seam in the Colinlea (which appears to be the source) and the layer representing the D seam pinches out well west of the Mellaluka springs. Hence once the source has been established by Adani, additional modelling work will be required.

In addition the proponent must ensure that the artesian monitoring bores that they have constructed in the area of the Mellaluka Springs complex are constructed in a manner which ensures that accurate groundwater heads can be monitored.

All of these issues have been raised in DNRM's response to the SEIS for Carmichael.

A. Bleakley

Attachment 2. Memo from URS, Mark Stewart

URS

Memorandum

Attachment 2

Date:	6 February 2014
To:	Hamish Manzi
From:	Mark Stewart
Subject:	Peer Reviewer Comments on the Carmichael Coal Project Groundwater Conceptualisation

Further to our Peer Review of the Carmichael Coal Project (CPP) numerical model (URS report ref. 42627082, dated 14 October 2013) and the outcomes of your Independent Expert Scientific Committee (IESC) advice workshop, URS has compiled a memorandum on the CPP groundwater flow patterns included in the SEIS conceptualisation.

Objective

An action item from the IESC advice workshop (15 January 2014) included the request for URS to provide commentary on the conceptualisation for inclusion in the formal response to the IESC. URS were requested to provide comment on the flow direction discussions and conceptualisation.

Peer Review Comment

The IESC in their “Advice to decision maker on coal mining project” document (dated 12 December 2013) included the comment that the independent peer review of the groundwater model undertaken by URS also notes that the model flow direction is at odds, and is not consistent, with the regional flow direction and geology.

In our peer review of the numerical groundwater model I had ask that additional discussion regarding flow patterns, on and adjacent to the mine lease, be included as these flows are contrary to the dip of the geology.

I considered, based on my experience in the Galilee Basin that the different flow directions in the Galilee Basin units and GAB units may assist in the conceptualisation of groundwater divide(s), and the recognised groundwater low point north of the Carmichael River.

Additional Information

Additional groundwater level data and refined groundwater contours across the mine lease application area were compiled in the SEIS hydrogeology submission.

The groundwater flow contours for the underlying Permian-age (Galilee Basin) strata are in line with the topography, flowing from north west to south east across the northern part of the Mine Area and from southwest to northeast through the southern part of the mine lease area.

It was considered by GHD in their reporting that the groundwater extraction (and low recharge) has a marked influence on groundwater flow patterns around the Labona Homestead.

Based on a review of groundwater studies conducted along the eastern boundary of the Galilee Basin it is noted that the similar groundwater flow patterns perpendicular (south to north) in the Galilee Basin sediments (which dip east to west) has been recorded along the eastern edge of the Galilee Basin at Kevin’s Corner, Alpha, Galilee (previously China First), and South Galilee coal projects.

Groundwater flow in the Great Artesian Basin (GAB) sediments, namely the Rewan Group and Clematis Sandstone are considered to mimic topography as conceptualised in the SEIS. The flow patterns presented in the SEIS for the Clematis Sandstone were considered and validated by the Department of Natural Resources and Mines (DNRM) in their report entitled, "Groundwater Flow Direction Carmichael Project Area", dated 17 December 2013.

It is noted that the groundwater flow in this GAB unit does not follow the generalised GAB flow patterns to the west or southwest (simplified conceptualised groundwater flow for the entire GAB from recharge beds in the Great Dividing Range in the east to discharge springs in the west and southwest). This is discussed below.

Flow Patterns

GHD in their Mine Hydrogeology Report Addendum (Appendix K6) constructed five groundwater level contour plots for the Permian Age units monitored across the CPP. The groundwater level contours, constructed using the regional scale numerical model, for each of the Permian-age strata, including Permian overburden, AB seam, Permian interburden, D seam, and Permian below D seam. (Appendix K6 Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8).

All five contour plots indicate groundwater flow in line with the topography from northwest to south east across the northern part of the Mine Area and from southwest towards the northeast in the southern part of the Mine Area.

The groundwater flow in the Galilee Basin sediments monitored on site is considered to be governed by:

- Topography;
- Groundwater flow within the more permeable altered / weathered near horizontal (low dip) upper horizons and coal seams along the eastern edge of the Galilee Basin; and
- The groundwater low, identified to the north of Carmichael River, considered to be related to groundwater extraction.

The flow within the Permian units along the eastern edge of the Galilee Basin (east of the Great Dividing Range), perpendicular to the dip of the strata (strata dips east to west) is recognised in Kevin's Corner, Alpha, Galilee, and South Galilee coal projects, as conceptualised in the South Galilee Coal Project (RPS Aquaterra, 2012), where flow in the Permian is to the north along the eastern edge of the Galilee Basin (Figure 1). This conceptualisation is validated in DNRM report, which considers flow within the Colinlea Sandstone across the eastern edge of the Galilee Basin.

It is considered by URS that another factor that influences the flow patterns within the Galilee Basin sediments, and several of the GAB units, is the pinching-out of these units at depth (and to the west) as indicated on the regional cross-section (Figure 2) derived from the Galilee Basin Operators Forum report (RPS, 2012). This cross-section is generated from available bore logs in the DNRM registered groundwater bore database.

The Permian coal bearing units are confined on three sides, above by the Rewan Group and Tertiary saprolite, below by the Early Permian sediments and to the west where the units pinch-out. The potentiometric pressures within these Permian units have equalised across the basin, resulting in the potentiometric pressures recorded in monitoring bores across the CPP area. The groundwater resources are recharged in the topographic highs (to the southwest and northwest) resulting in groundwater flow in the near horizontal (shallow dip on the eastern side of the Great Dividing Range) and more permeable (coal) units.

URS

Memorandum

Attachment 2

Figure 1 Conceptual Groundwater Model – South Galilee Coal Project (RPS Aquaterra, 2012)

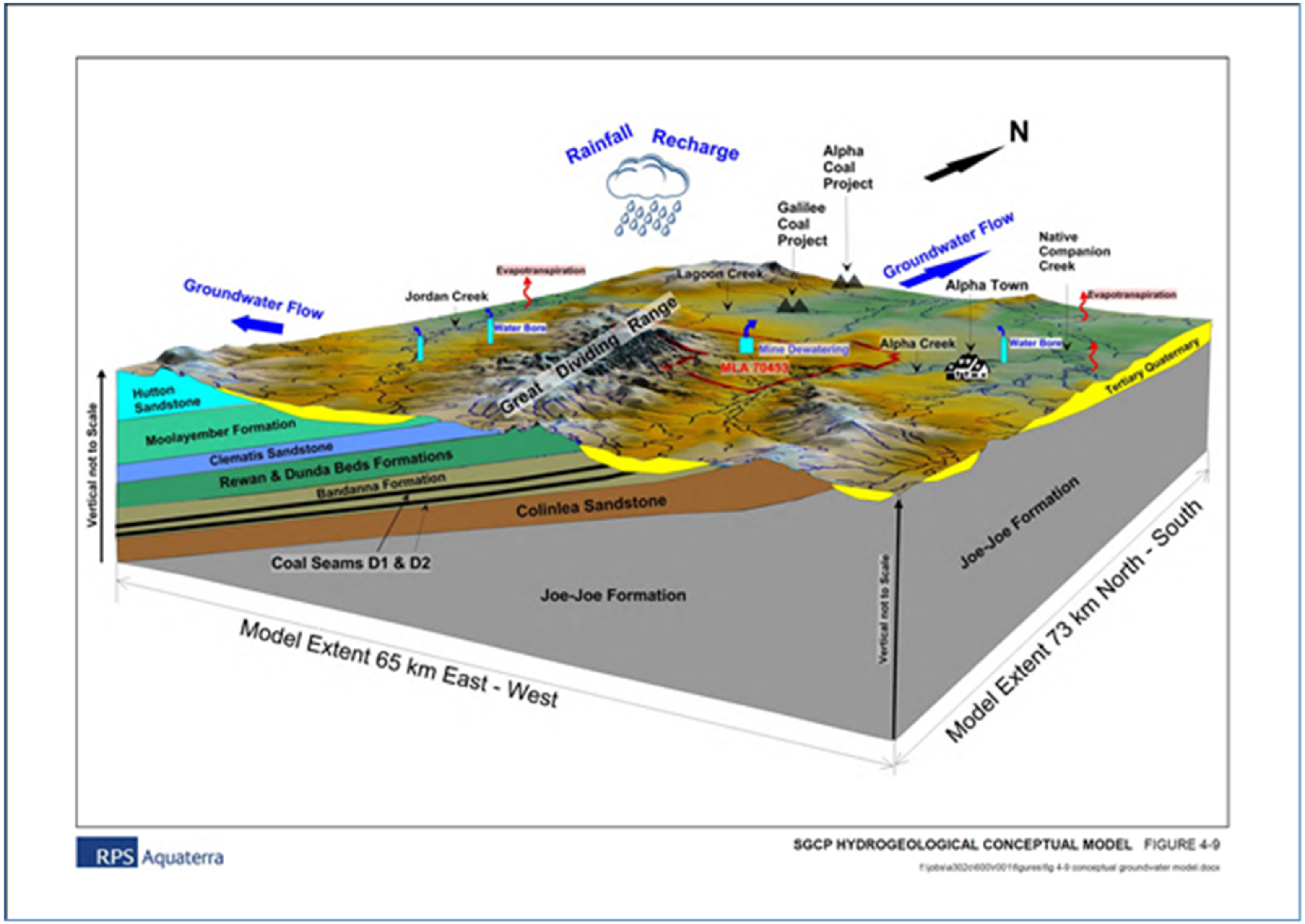
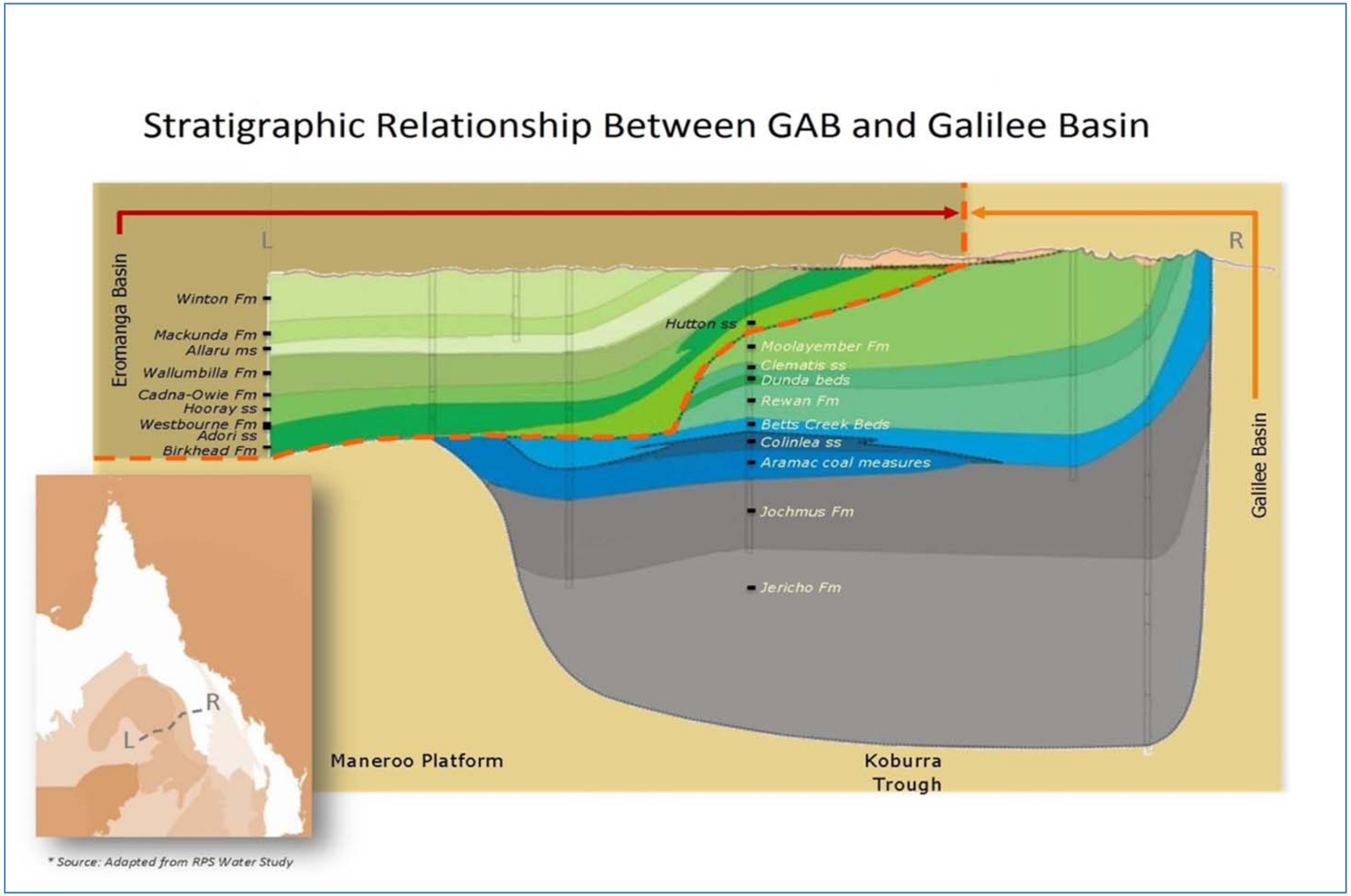


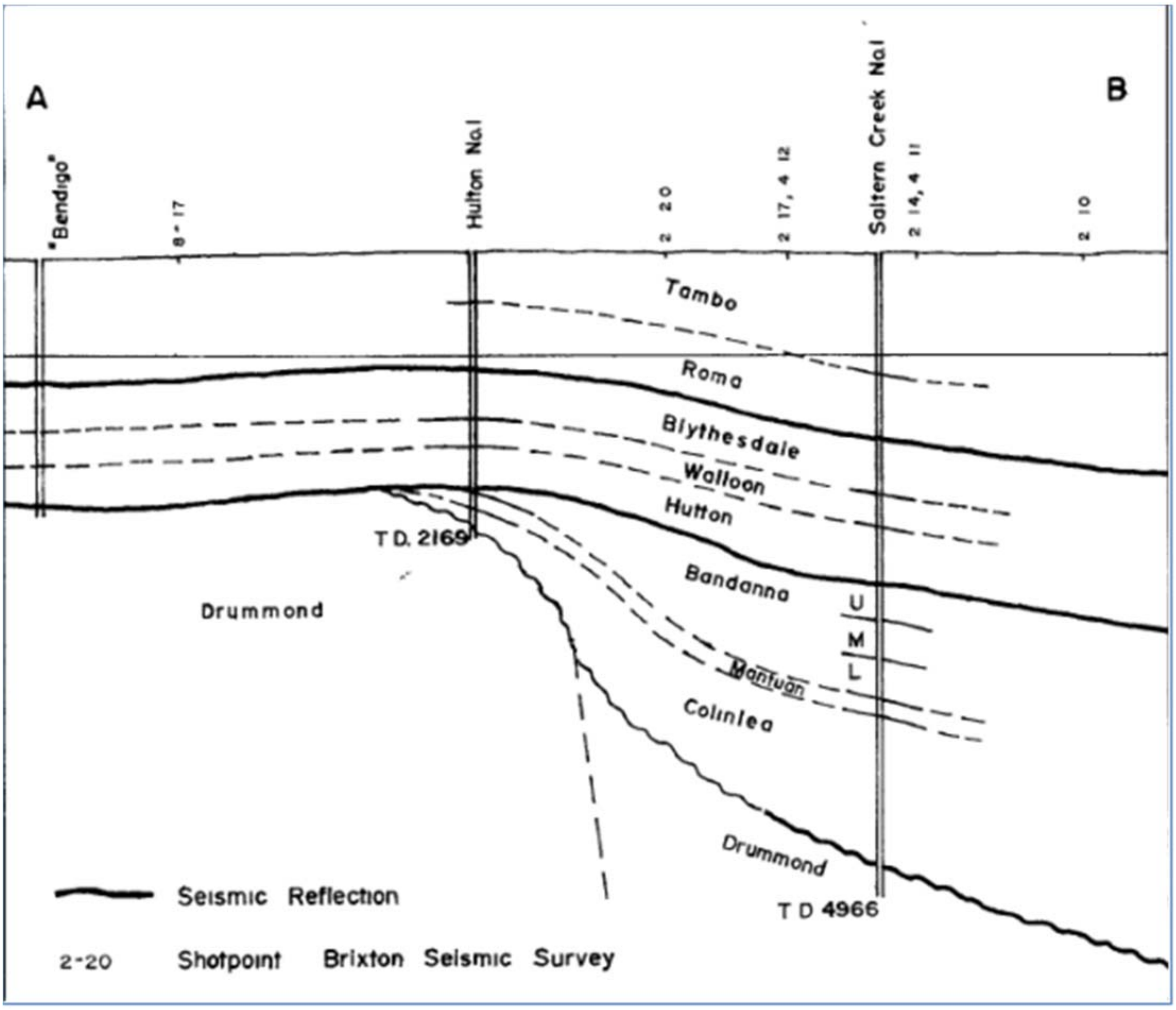
Figure 2 Relationship of the GAB to the Galilee Basin



Consideration of Figure 2 and cross-sections generated by Mott and Associates (1990) (Figure 3), and the cross-section on the 1:250,000 Muttaburra Geological Map, indicate that the GAB sediments, namely the Rewan Group, Clematis Sandstone, and Moolayember Formation also pinch-out and do not extend across the entire GAB. Note also the Precipice Sandstone and Evergreen Formation are missing from the typical GAB sequence.

This truncation of these GAB sediments, similar to the Permian Galilee Basin units, influences groundwater flow patterns in the outcrop areas as potentiometric pressures within these GAB units have equalised across the basin, i.e. no discharge to the west.

Figure 3 Geological cross-section from Mott and Associates, 1990



The confining of the GAB units above, below and to the west results in potentiometric surface flows, within the more permeable near surface weathered / altered zone, which mimic the topography.

The confining pressure and high recharge (relative to the other units) in the Clematis Sandstone is considered to result in the Doongmabulla spring complex, as deliberated in the DNRM document.

Comments

The groundwater flow patterns presented in the SEIS report, based on site specific data, provide an accurate depiction of groundwater flow across the site, which has been simulated in the numerical groundwater model.

Groundwater flow patterns are recognised to be contrary (perpendicular) to geological dip due to a combination of factors including geological setting (pinching-out of units), topography, aquifer hydraulic parameters, recharge and extraction.

References

GHD, 2013. Carmichael Coal Mine and Rail Project SEIS Mine Hydrogeology Report Addendum

Mott and Associates, 1990. Well Completion Report Hulton No.1. Queensland Digital Exploration Report No.1468

RPS Aquaterra, 2012. South Galilee Coal Project (SGCP) Groundwater Assessment and Modelling. Report ref. A302C\600\R001e

RPS Australia East Pty Ltd, 2012. Galilee Basin Report on the Hydrogeological Investigations. Report Number PR102603-1

URS, 2013. Report Adani Carmichael Coal Project Numerical Groundwater Model Peer Review.

Attachment 3. Technical studies relevant to the ecological impact assessment

Attachment 3

Additional SEIS technical studies included:

- Volume 4, Appendix J2, BTF On-site Monitoring Survey Report

In discussion with the DSEWPaC (now DotE) and the Black-throated Finch Recovery Team, Adani committed to the development and implementation of an additional monitoring program, to gain a better understanding of the population size, seasonal movements and key habitats and potential nesting areas used by the black-throated finch, both at the Mine site and adjacent Moray Downs and Bygana properties. The purpose of this report is to present the results of the first phase of targeted black-throated finch monitoring undertaken in the Study Area.

- Volume 4, Appendix J3, Doongmabulla and Mellaluka Springs Report

This report provides a description of the aquatic and terrestrial flora, fauna and habitat values of both the Doongmabulla Springs complex and the Mellaluka Springs complex.

- Volume 4, Appendix J4, Population Survey of Waxy Cabbage Palm Report

The primary purpose of this document was to report the findings of a targeted population survey of waxy cabbage palms within the Study Area.

- Volume 4, Appendix J5, Offsite Infrastructure Ecological Assessment

This report presents a summary of the existing ecological values within the Offsite infrastructure area, based on the results of desktop and field investigations.

- Volume 4, Appendix J8, Great Barrier Reef Wetland Protection Areas

This report provides a description of the three GBR WPAs within the Study Area in terms of the Queensland Wetland Definition and Delineation Guidelines wetland criteria, hydrology, biota (flora and fauna) and soils. The wetlands were described using desktop information and field surveys conducted in May 2013.

- Volume 4, Appendix K1, Mine Hydrogeology Report

This report provided updated groundwater modelling based on the revised Mine Plan and additional information gathered Post EIS.

- Volume 4, Appendix K2, Water Balance Report

This report provides a further refinement of the water balance that was developed as part of the EIS. It is expected that this water balance will be further developed and refined during future design phases and that the final water balance will ultimately form an integrated part of the Water Management Plan (WMP) for the mine.

- Volume 4, Appendix K3, Mine Water Quality Report

This report provides an update of surface water quality assessment of the Project (Mine). A combination of desktop and field assessments were undertaken to describe the existing surface water resources that may be affected by the Carmichael Coal Mine and Rail Project in the context of environmental values.

- Volume 4, Appendix K4, Flood Mitigation and Creek Diversion Design Report

Flood modelling of the proposed Carmichael Coal Mine and Rail Project was undertaken for the Carmichael River corridor and for minor waterways intersecting the mine through the north and the south. The purpose of this study is to inform the SEIS Mine Hydrology Report and to make recommendations for flood mitigation works.

Attachment 3

The SEIS revised impact assessment reports included:

- Volume 4, Appendix H, Matters of National Environmental Significance Report

This report brings together assessments of impacts on matters of national environmental significance (NES) from the EIS and SEIS technical reports (e.g. water resources, flora and fauna, cultural heritage and cumulative impacts etc.) to produce a stand-alone assessment in a format suited for assessment under the EPBC Act.

Relevant sections to surface and groundwater include:

Section 4 Potential impacts on listed threatened species and ecological communities
4.8 GAB springs including potential impacts, management and mitigation measures, residual impacts and impact significance.
Section 6 Potential impacts on water resources, including changes in flows and flooding.

- Volume 4, Appendix I1, Revised Subsidence Assessment Report

This report outlines the predicted subsidence and the potential impacts on the natural features and items of surface infrastructure. Relevant sections to surface and groundwater include:

Section 6 Potential impacts on surface infrastructure
6.1 Streams

- Volume 4, Appendix J1, Updated Mine Ecology Report

This report brings together a number of key baseline ecological assessments from the EIS, namely terrestrial and aquatic ecological assessments and additional SEIS technical studies for the Springs (Appendix J3), surveys of the offsite infrastructure areas (Appendix J5), surveys for waxy cabbage palm (Appendix J4), surveys of black throated finch (Appendix J2), investigations of mapped Great Barrier Reef Wetland Protection Areas (Appendix J8), updated Mine hydrogeology (Appendix K1 and K6) and Mine hydrology (Appendix K5).

Relevant sections to surface and groundwater include:

Section 3 Potential impacts and mitigation – construction
3.10 Alteration of surface water regime
Section 4 Potential impacts and mitigation – operation
4.11 Alteration of surface water regime
4.12 Impact of altered groundwater regime on groundwater-dependent ecosystems

- Volume 4, Appendix J5, Offsite Infrastructure Ecological Assessment

The report presents a review of potential impacts that construction and operation of the Project (Offsite) may have on the ecological values of the Study Area and outlines measures to manage and mitigate those potential impacts.

Relevant sections to surface and groundwater include:

Section 4 Potential impacts and mitigation – construction phase
4.8 Loss of aquatic and riparian habitat
4.9 Degradation of water quality and aquatic habitat
Section 5 Potential impacts and mitigation measures – operation phase
5.6 Degradation of water quality and aquatic habitats

- Volume 4, Appendix K1, Mine Hydrogeology Report

This report provides an updated groundwater modelling and impact assessment based on the revised Mine Plan and additional information gathered Post EIS. The report also addresses submissions received on the Hydrogeology Report, Appendix R of the Project EIS (GHD, 2012) and provides further information and comments as requested by the Coordinator-General.

Relevant sections include:

Section 5 Groundwater modelling
5.6 Model predictions – operational phase
5.6.6 Predicted groundwater level impacts – operational phase
5.6.7 Predicted groundwater flow impacts – operational phase
5.7 Model predictions - post closure

Attachment 3

5.7.4 Predicted groundwater level impacts – post closure
5.7.5 Predicted groundwater flow impacts – post closure
Section 6 Potential impacts and mitigation measures – construction phase
Section 7 Potential impacts and mitigation measures – operational phase
7.1 Overview
7.1.4 Potential for indirect impacts on the Great Artesian Basin
7.1.5 Potential impact on local spring systems
7.1.6 Potential impacts on surface water flows
7.1.7 Potential impacts on riparian vegetation
7.4 Potential impacts related to stream diversions
7.6 Management, mitigation and monitoring activities – operational phase
Section 8 Potential impacts and mitigation measures – post closure
8.2 Potential impacts related to creation of voids
8.2.2 Potential for indirect impacts on the Great Artesian Basin
8.2.3 Potential for impacts on local springs
8.2.4 Potential for impacts on surface water flows
8.4 Management, monitoring and mitigation measures – post closure

- Volume 4, Appendix K6 Mine Hydrogeology Report Addendum

An addendum to Appendix K1 developed in response to comments received from a number of agency consultees including the DNRM, DEHP, DotE and URS, who conducted a peer review of the numerical groundwater flow modelling component of the SEIS Hydrogeology report.

- Volume 4, Appendix K5, Updated Mine Hydrology Report

This report specifically focuses on the impacts of the change in flow patterns and regime and the water users affected by the Project (Mine).
Relevant sections include:

Section 2 Potential impacts and mitigation measures – Construction phase
Section 3 Potential impacts and mitigation measures – Operation Phase
3.3 Impacts on determined watercourses
3.4 Impacts on flooding
3.5 Impacts on seasonal flow
3.10 Impacts relating to groundwater
3.11 Total impact Carmichael River surface flow
3.13 Management, mitigation and monitoring activities – operational phase

SEIS Management Plans included:

- Volume 4, Appendix I2, Draft Subsidence Management Plan

The Subsidence Management Plan has been developed as part of the SEIS to provide control, mitigation and management measures for subsidence impacts from the underground operations of the mine on State Significant Biodiversity Values and matters of National Environmental Significance.

Relevant sections to surface and groundwater include:

Section 5 Subsidence impact assessments on Great Artesian Basin and vegetation and fauna
Section 6 Impact assessment methodology and outputs
Section 7 Proposed control
Section 8 Performance, monitoring, management and reporting

- Volume 4, Appendix Q1, Environmental Management Plan – Mine

The EMP (Mine) reflects the findings and recommendations of studies undertaken for the EIS and SEIS, and provides a framework for management of identified impacts and implementation of recommendations made. Relevant subplans include:

9. Surface Water
10. Groundwater
13. Terrestrial Ecology
14. Aquatic Ecology

- Volume 4, Appendix Q2, Environmental Management Plan – Offsite

Attachment 3

The EMP (Offsite) reflects the findings and recommendations of studies undertaken for the EIS and SEIS, and provides a framework for management of identified impacts and implementation of recommendations made. Relevant subplans include:

> *9. Surface Water*
> *10. Groundwater*
> *12. Terrestrial Ecology*
> *13. Aquatic Ecology*

- Volume 4, Appendix R1, Mine Closure and Rehabilitation Strategy

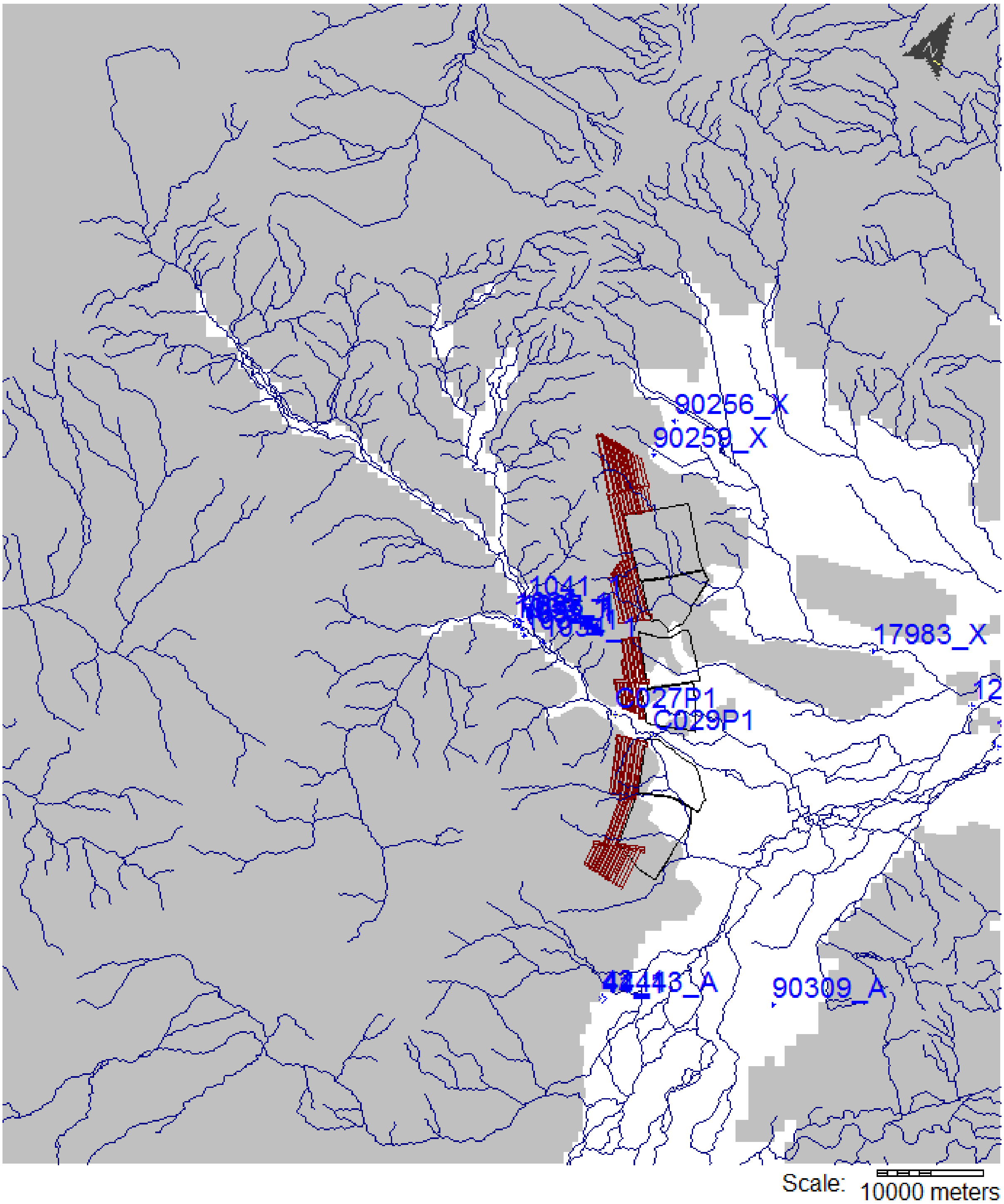
The closure and rehabilitation strategies implement the management controls and methods outlined in the Carmichael Coal Mine and Rail Project Environmental Management Plan (EMP). The closure and rehabilitation strategy will evolve over time as activities progress and additional technical studies and investigations are completed. Relevant sections to surface and groundwater include:

- *Chapter 4 Preferred rehabilitation strategy*
  - *4.1 Domains*
    - *4.1.6 Stream diversions*
    - *4.1.8 Carmichael River corridor*
- *Chapter 5 General rehabilitation activities*
  - *5.2 Environmental management*
    - *5.2.3 Surface water management*
    - *5.2.4 Groundwater management*
    - *5.2.5 Revegetation*
- *Chapter 6 Final landform strategy*
  - *6.6 Stream diversions*
  - *6.8 Carmichael River corridor*
- *Chapter 7 Monitoring and maintenance*
  - *7.1 Surface water and groundwater*
  - *7.4 Rehabilitation monitoring*

Attachment 4. Modelled General Head Boundary Cells

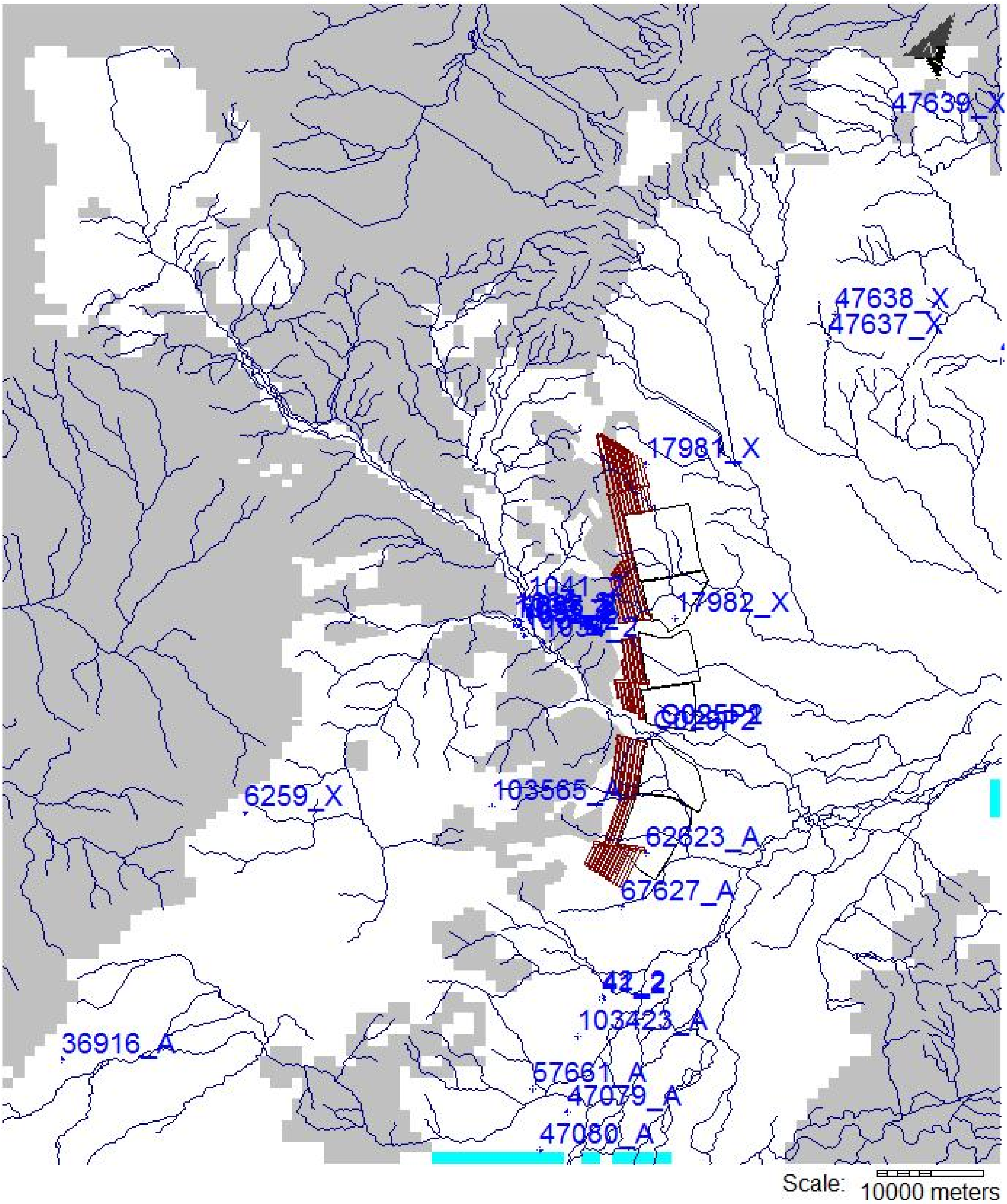
Attachment 4

Figure 1 General Head Boundaries – Model Layer 1 (Quaternary Alluvium)



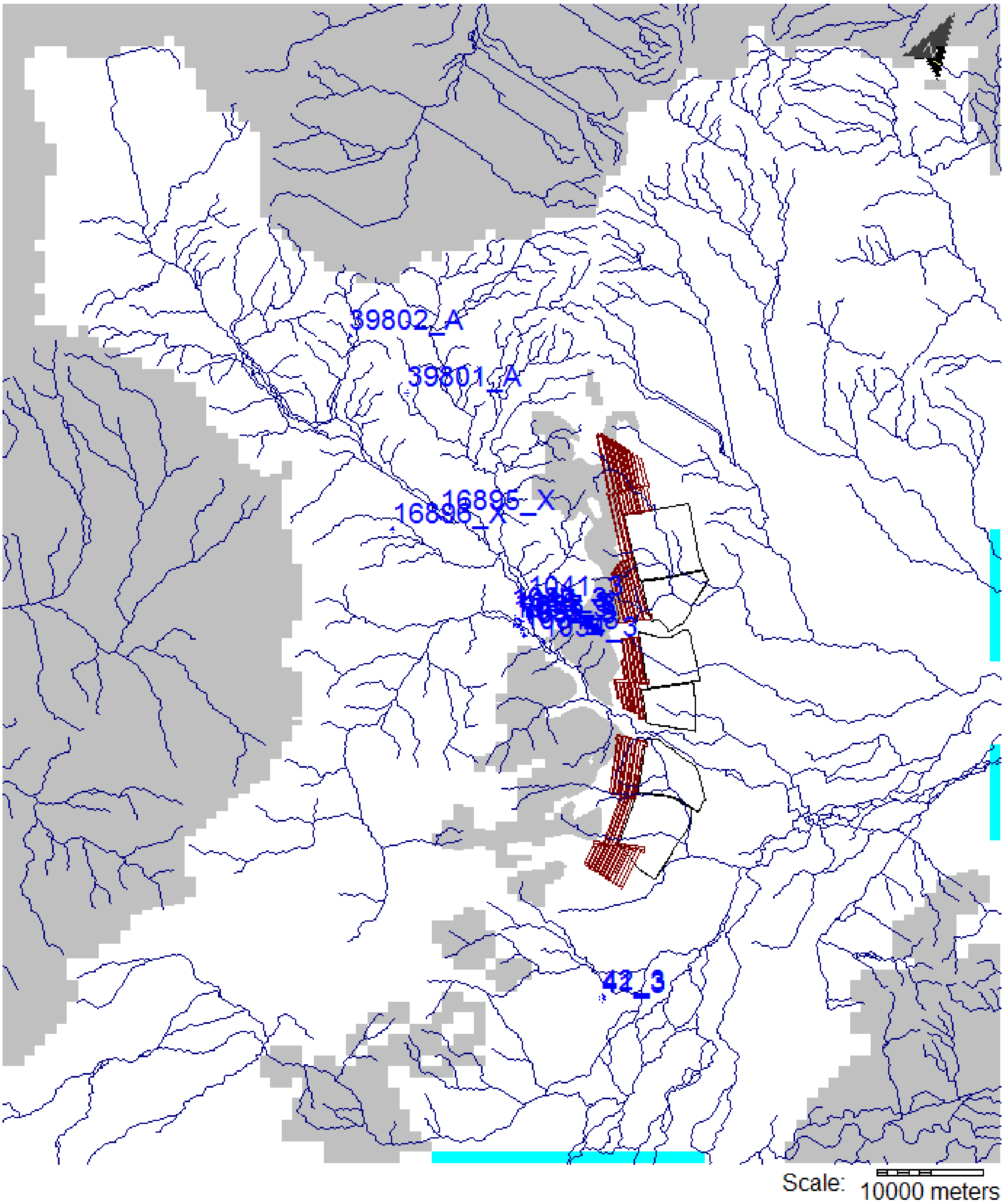
Attachment 4

Figure 2 General Head Boundaries – Model Layer 2 (Tertiary Units)



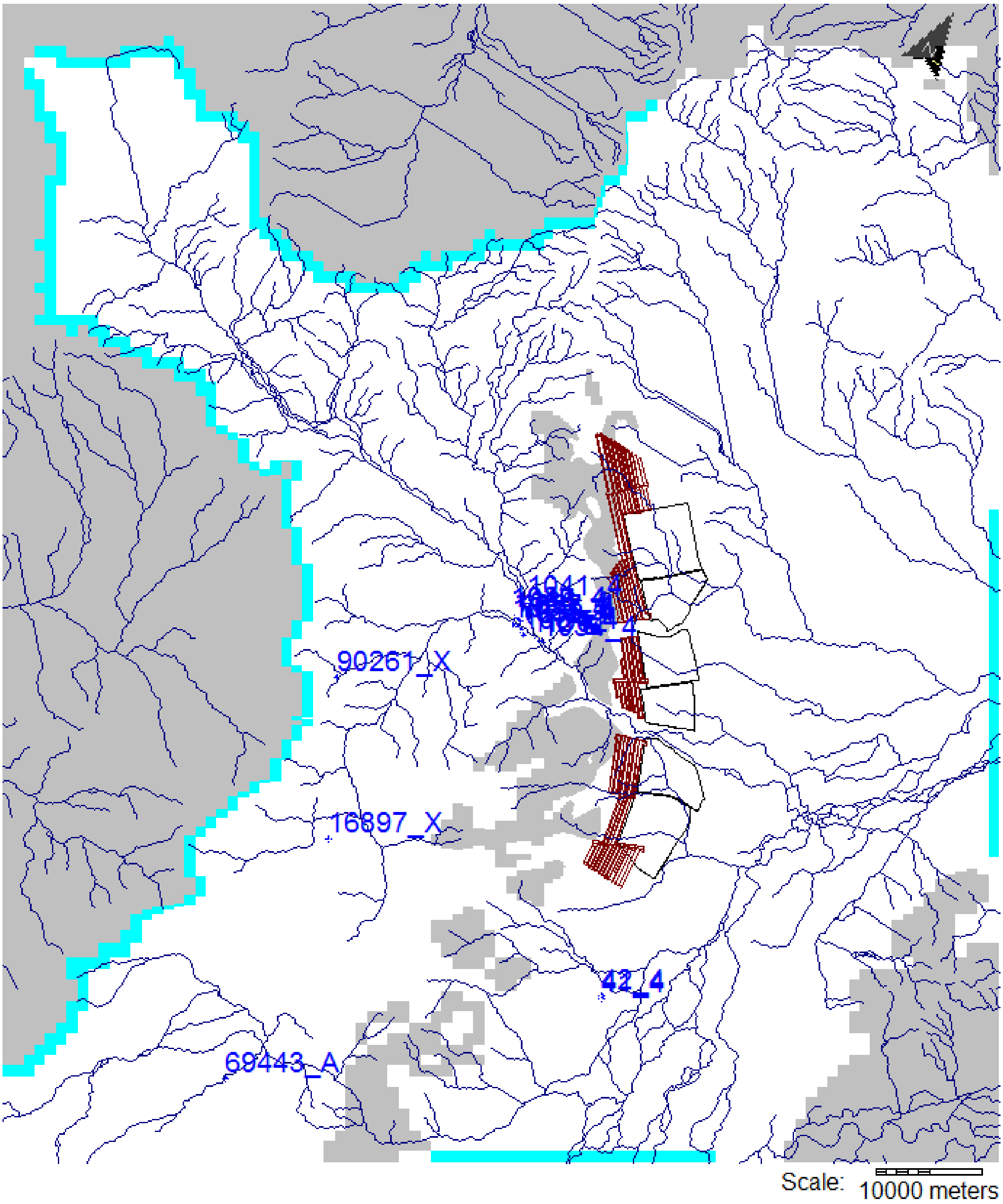
Attachment 4

Figure 3 General Head Boundaries – Model Layer 3 (Moolayember Formation / Tertiary Units)



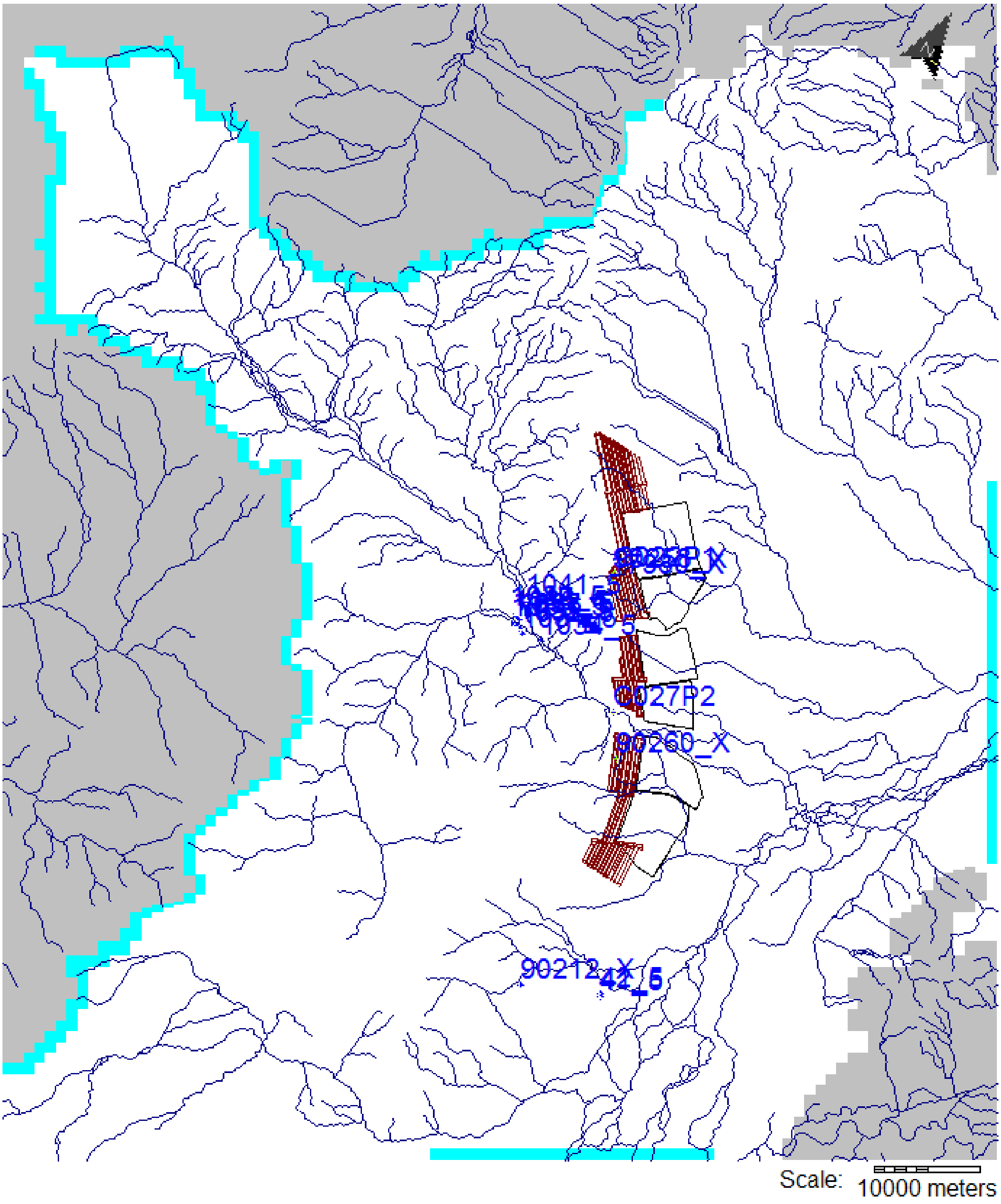
Attachment 4

Figure 4 General Head Boundaries – Model Layer 4 (Clematis Sandstone / Tertiary Units)



Attachment 4

Figure 5 General Head Boundaries – Model Layer 5 (Dunda Beds / Tertiary Units)



Attachment 4

Figure 6 General Head Boundaries – Model Layer 6 (Rewan Formation / Tertiary Units)

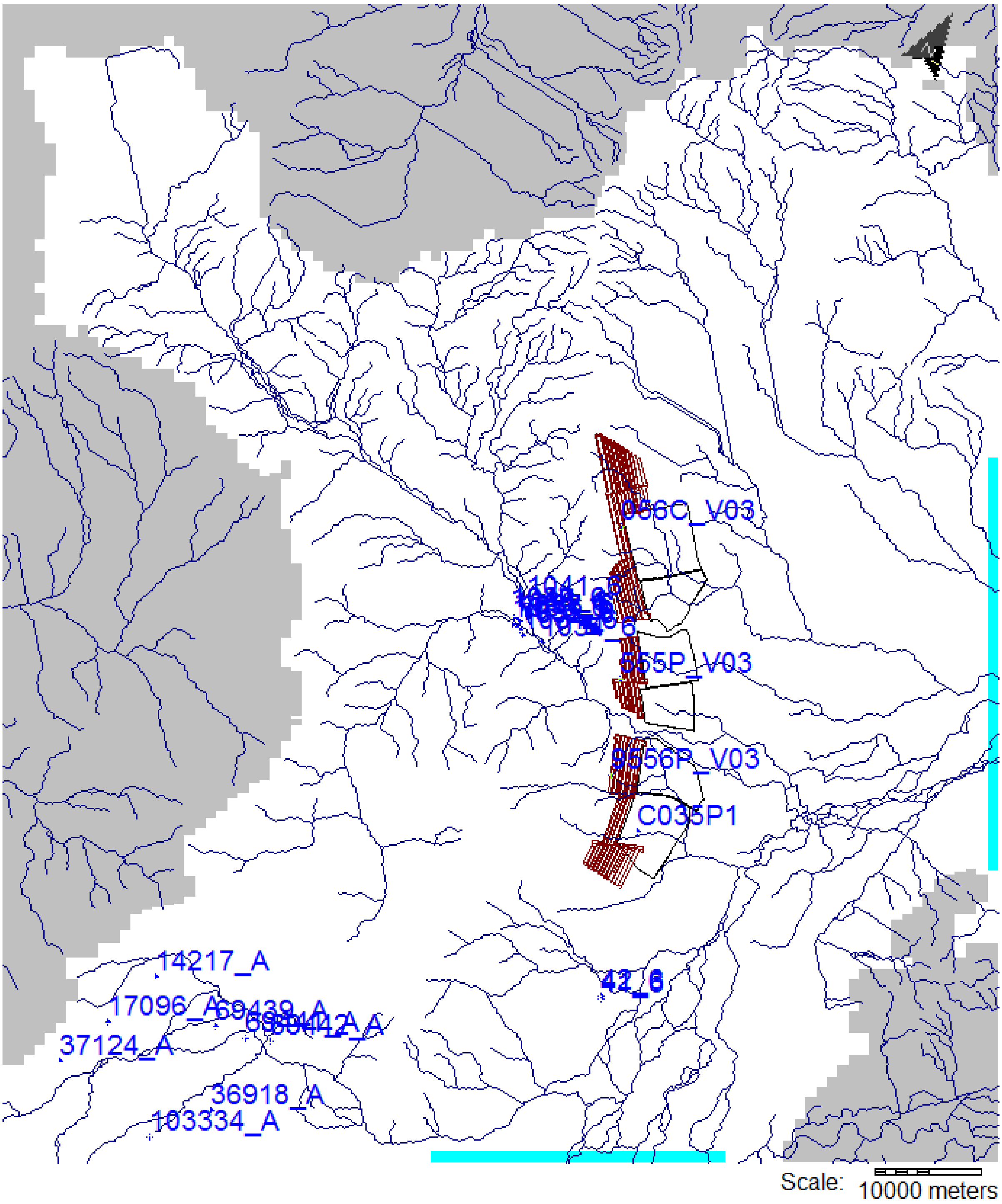
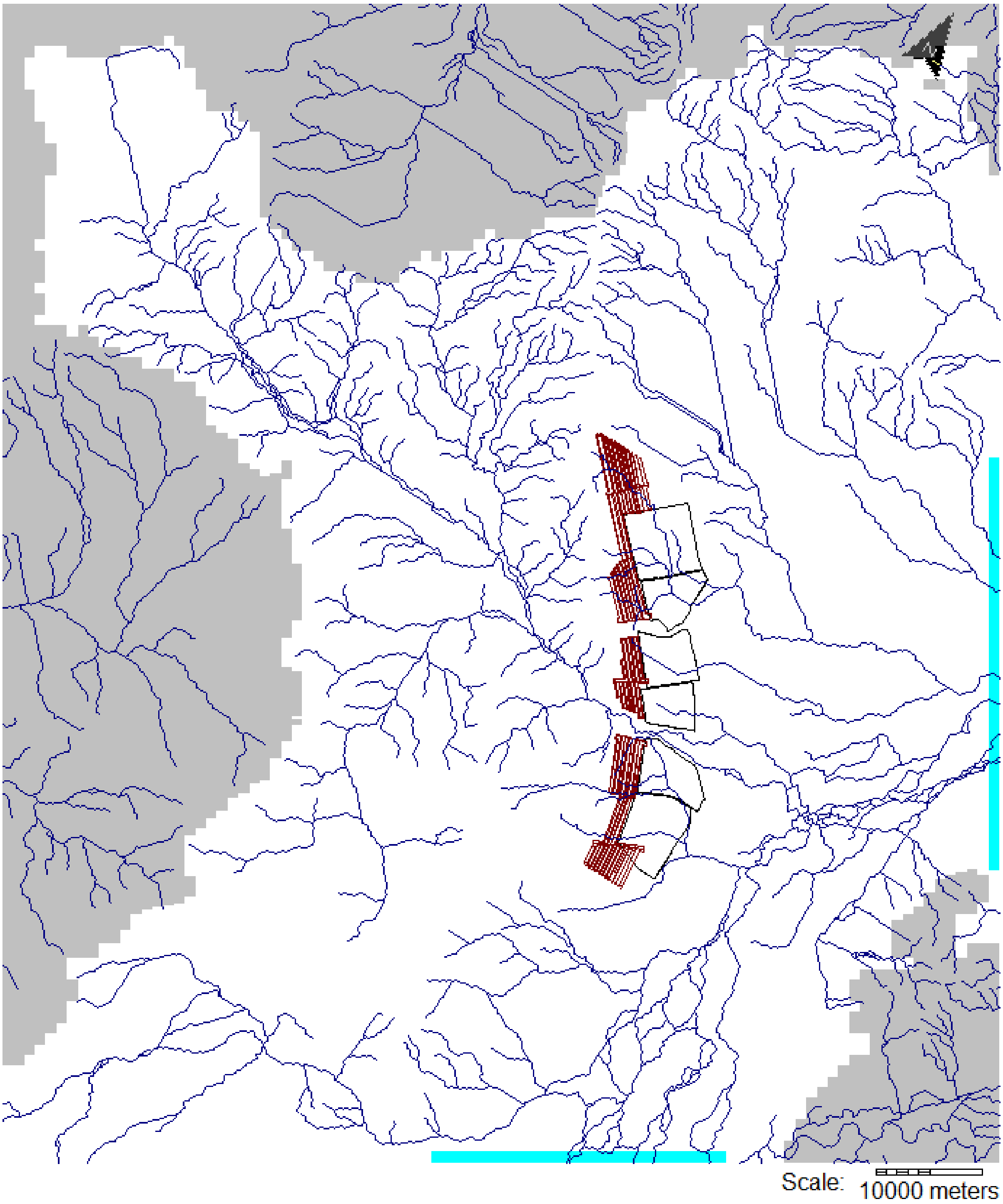
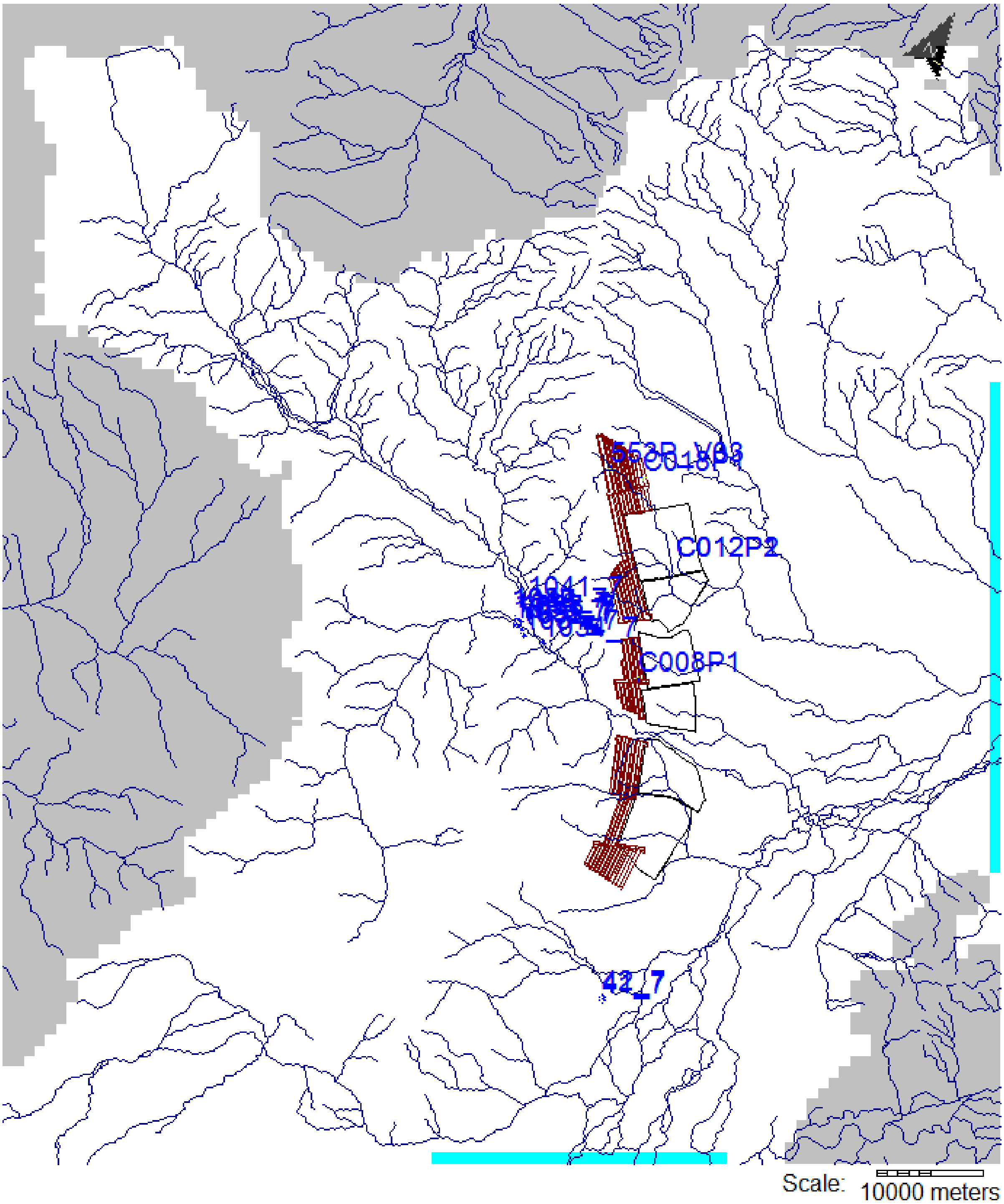


Figure 7 General Head Boundaries – Model Layer 7 (Rewan Formation / Tertiary Units)



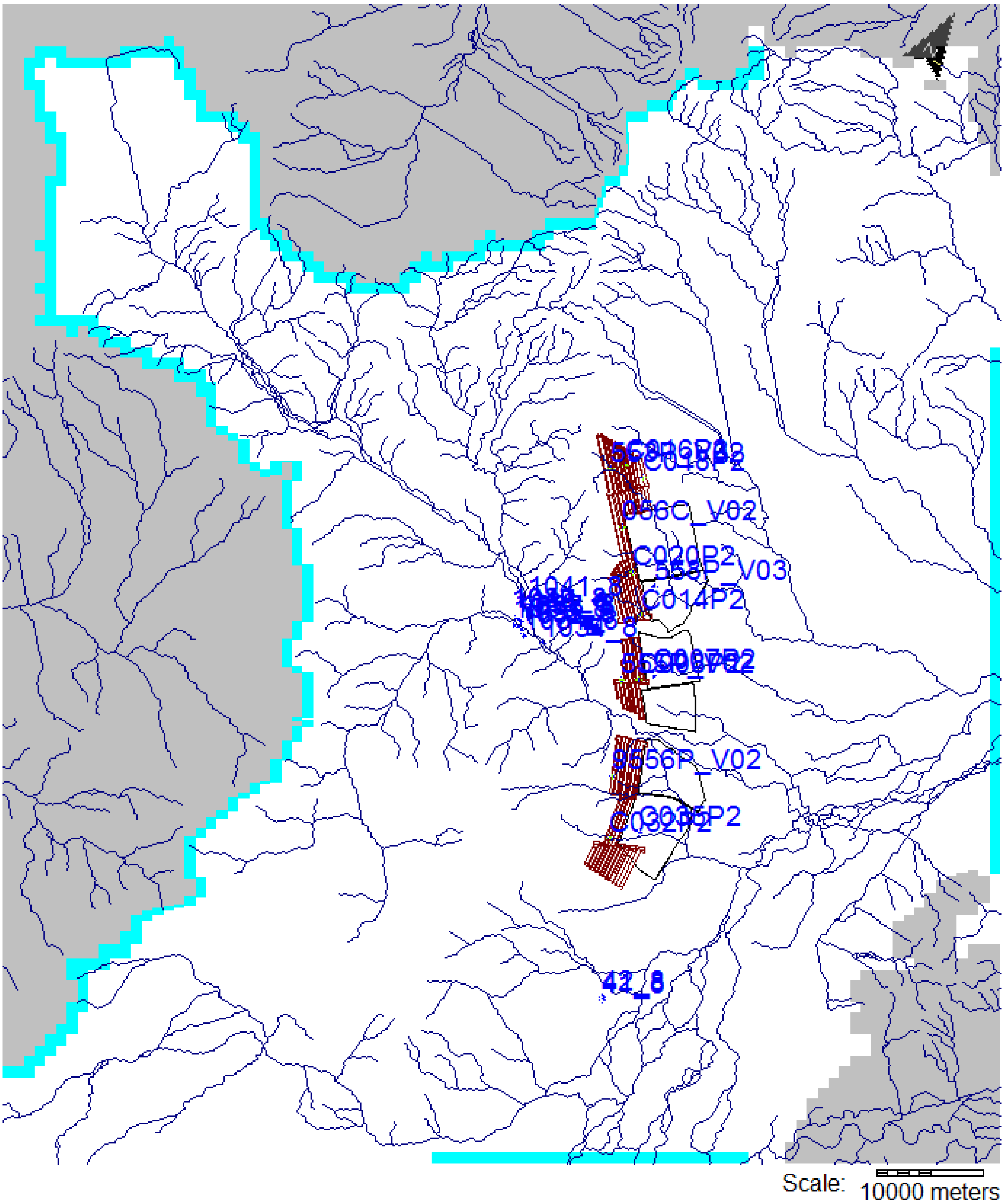
Attachment 4

Figure 8 General Head Boundaries – Model Layer 8 (Permian Overburden / Tertiary Units)



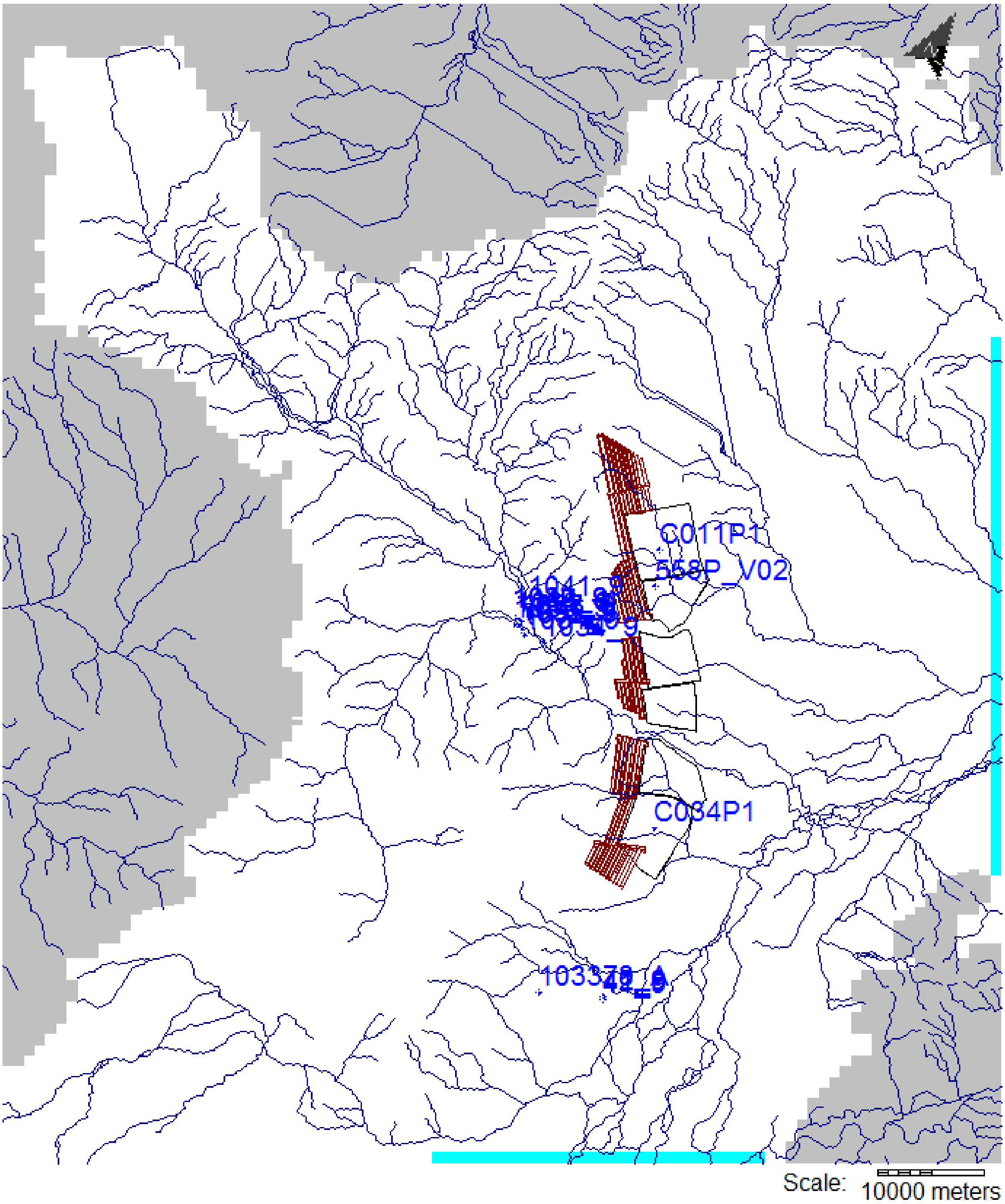
Attachment 4

Figure 9 General Head Boundaries – Model Layer 9 (Coal Seam AB / Tertiary Units)



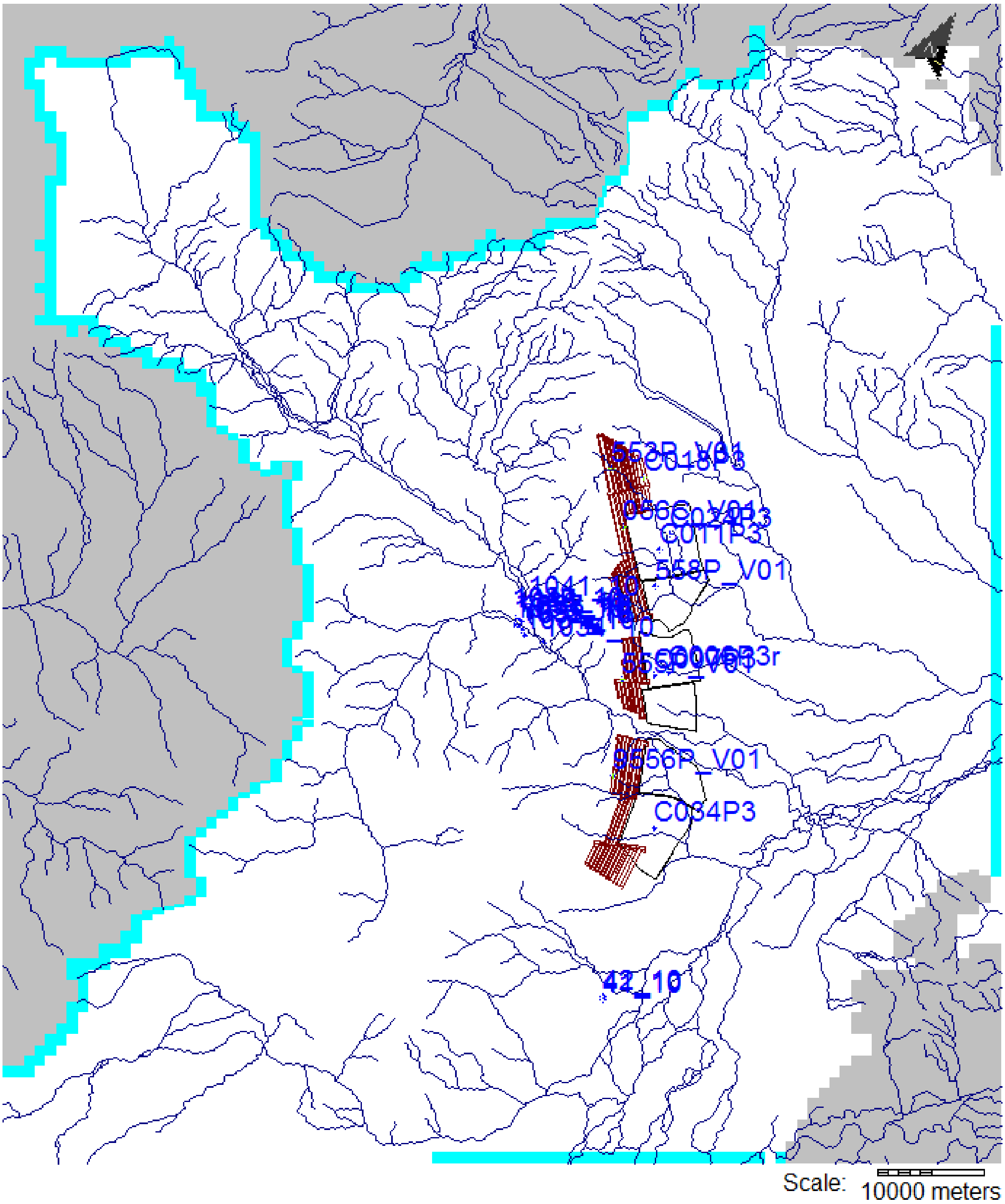
Attachment 4

Figure 10 General Head Boundaries – Model Layer 10 (Permian Interburden / Tertiary Units)



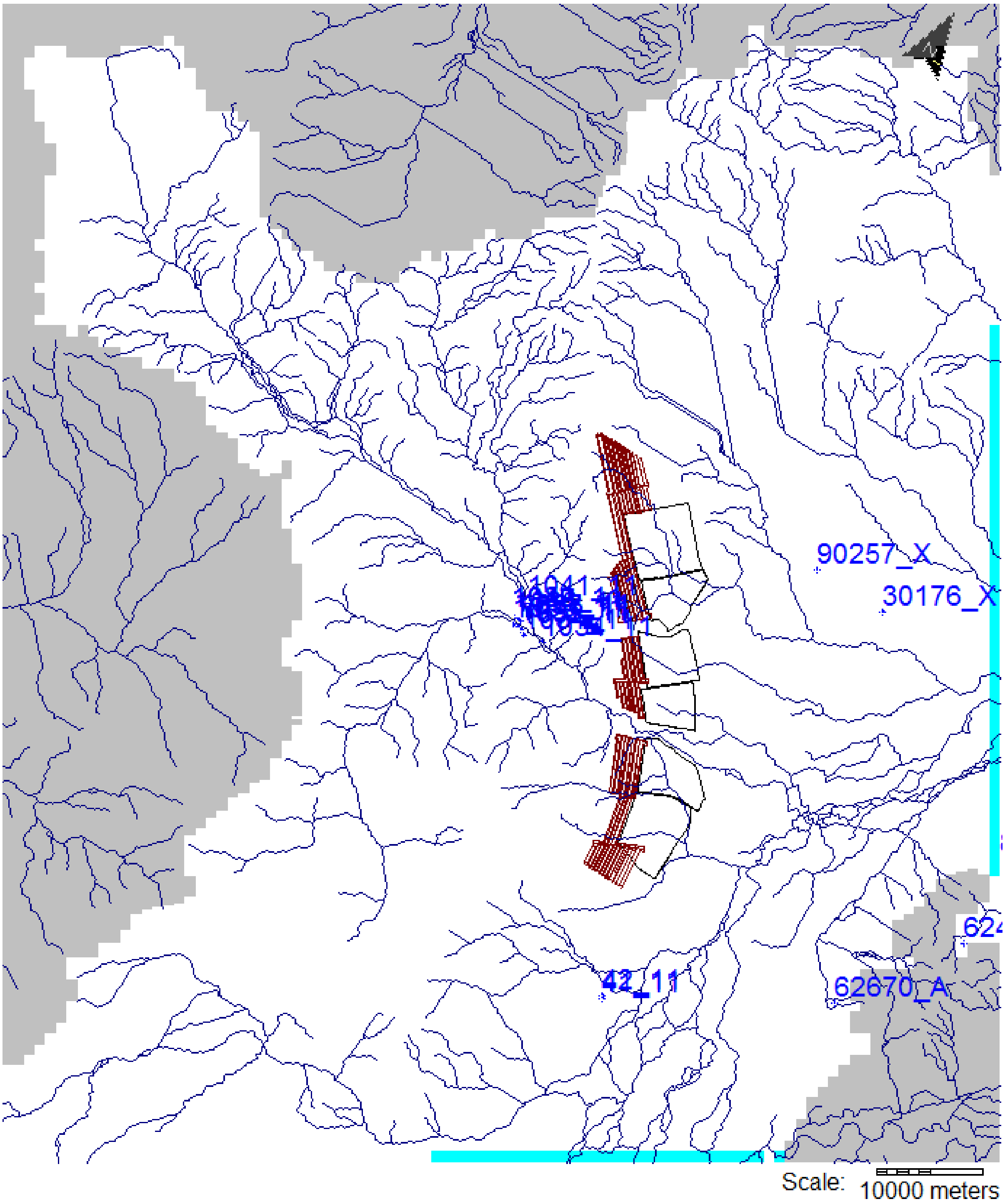
Attachment 4

Figure 11 General Head Boundaries – Model Layer 11 (Coal Seam D / Tertiary Units)



Attachment 4

Figure 12 General Head Boundaries – Model Layer 12 (Early Permian Units)



Attachment 5. Memo from Mark Biggs

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admin@romresources.com.au

SHORT TECHNICAL SERIES

FOR ADANI MINING PTY LTD

A SHORT REVIEW OF REGIONAL STRUCTURE IN THE REGION OF THE CARMICHAEL COAL DEPOSIT

CENTRAL QUEENSLAND

Mark Biggs
Principal Geologist
February 2014

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List of Figures and Tables

Executive Summary

ROM Resources has, at the request of Adani Mining Pty Ltd investigated the interaction of mine-scale faulting at the Carmichael Coal Project (as identified from field mapping, exploration drilling and a high resolution 2D seismic survey and interpretation undertaken in 2011 (McClintock 2012)) with regional trends identified from the eastern margin of the Galilee Basin.

In particular this study takes into consideration the influence of faulting within the overlying Rewan Formation and the relationship with the underlying Permian coal-bearing strata of the Betts Creek Beds and Colinlea Sandstone. Although large normal faults have been identified on the eastern boundary of the Galilee Basin within the Rewan Formation by Van Heeswijck (2006), at this location fault styles and throws are less significant with four (4) currently modelled faults with throws varying between 4-38m identified over a 40km strike-length. Several widely-spaced faults with throws <5m have been identified from the 2D seismic survey but have not yet been included in mine planning models due their minimal impact on resources and reserves at the deposit-wide scale. By contrast major fault structures to the north and west are characterised by a more vertical dip, larger throws 50-250m and a north-east trend rather than the east-west trending structures seen in the proposed mine area.

From the current fault regime documented it is highly unlikely that aquifers within the coal measures (mostly coal seams) would impact upon on groundwater flow processes in aquifers identified in the overlying Triassic Dunda Beds (a lateral equivalent of the Triassic Clematis Sandstone which is a known strong aquifer and bore water source). This is mainly due to the local fault throws not being significant enough to move formation boundaries the required distances that would allow aquifers to contact and mix. Local field mapping, exploration drilling and 2D seismic surveying has, to date, only revealed normal faulting with throws to a maximum of forty (40) metres in the planned mine area.

Regardless of these findings, ongoing exploration drilling, geotechnical coring and especially acoustic scanner downhole logging continues to provide data that will enable the structural model for the Carmichael Coal Project to be regularly revised.

Introduction and Scope

Adani Mining Pty Ltd is developing the Carmichael Coal Deposit, located in the Central-north Galilee Basin (refer to *Figure 1*). All along the eastern margin of the basin, the sedimentary strata comes to outcrop on the eastern and north-eastern margins but is covered by more recent Eromanga Basin sedimentary rocks in most of the remainder. Structurally, the coal deposit occurs adjacent to a feature of thickened sedimentation called the Koburra Trough, where the main structural fabric appears to trend north-east. The western area of the Koburra Trough was modified by a number of smaller fold structures such as the Rodney Creek Anticline. The eastern margins of the basin are reported to dip 0.5 to 3 degrees to the west (Carr 1975) and at Moray Downs (now Adani Mining's Carmichael Deposit), again on the eastern margin, 4.5 degrees to the west (Wells 1989). Regional reflection seismic indicates the central region of the Basin is relatively flat and the depth to the main coal-bearing unit (the Betts Creek beds) is 900 to 1,100m as shown on *Figure 2*. The seismic data supports the concept of continuous coals.

The basin has relatively thick Permian-age coal-bearing formations but these have not been mined in the past because of the lack of coking properties, lack of infrastructure, the distance to the principal markets, and to a lesser degree depth to the fresh coal. However, Coal exploration and development continues at several potential open cut areas on the eastern margin of the basin.

This report briefly examines the relationship between regional structure of the eastern Galilee Basin and the local structure identified at the potential mine site, with particular reference to the effect of faulting on any aquifers present in the target sequence and the overlying strata.

Figure 1: Location of the Carmichael Deposit

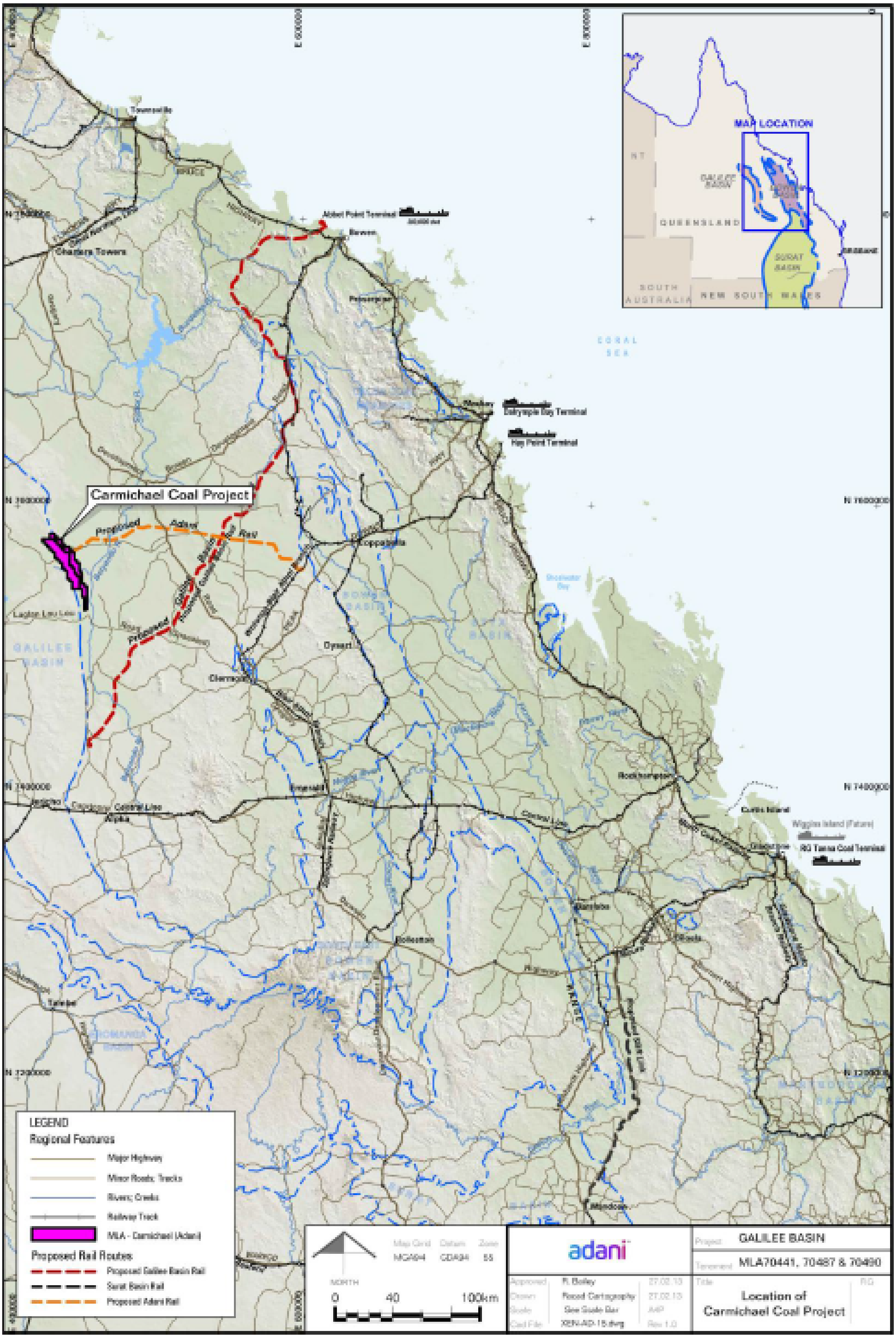


Figure 2: Galilee Basin - Depth to Basement

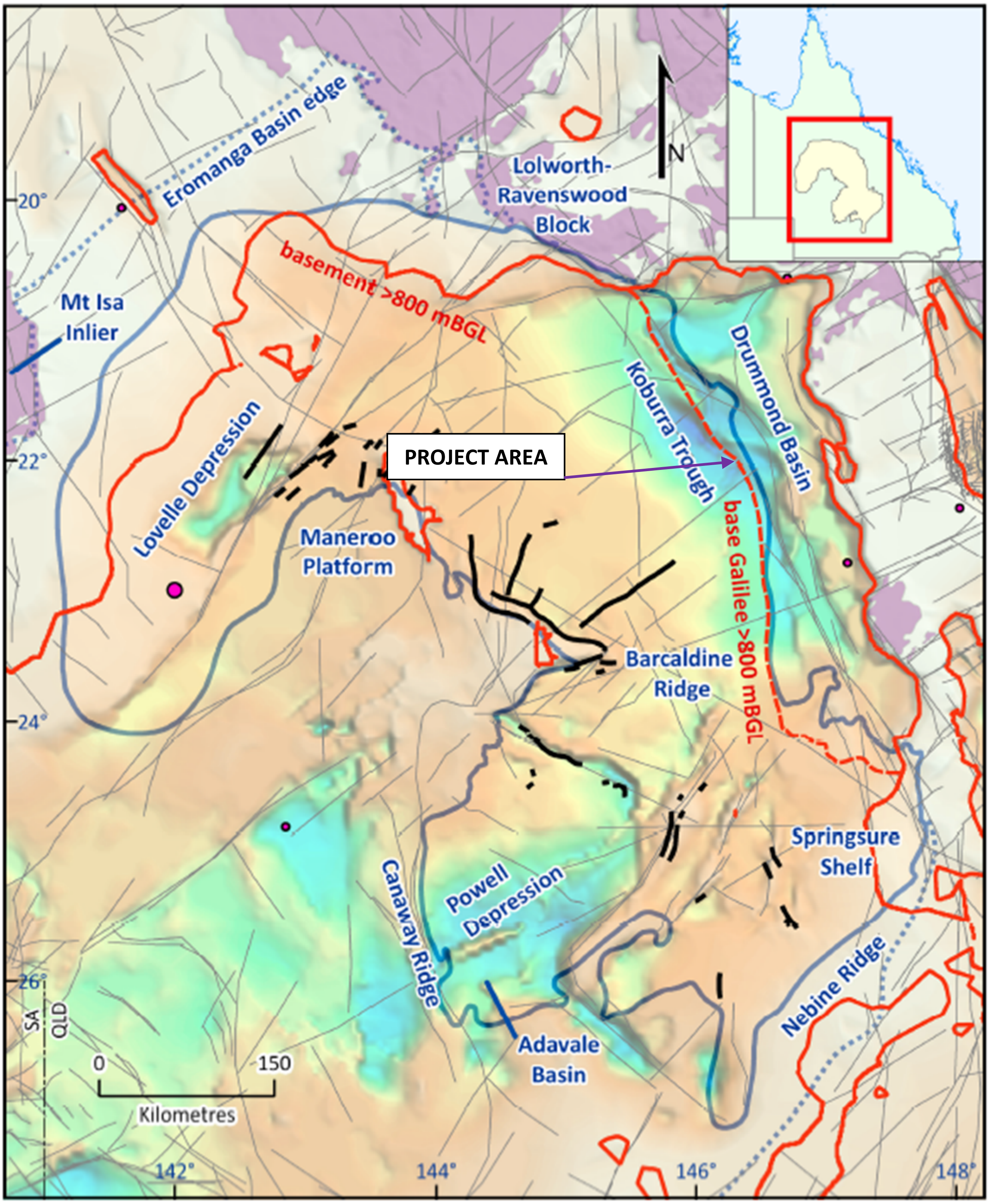


Figure GLL3: Basin elements, faulting and seismicity superimposed on OZ SEEBASE™ (2005) image. Most of the Galilee Basin (outlined in the solid blue line) is >800 m deep. The Eromanga Basin (outlined in the broken blue line) overlies most of the Galilee Basin.

Modified after Bradshaw and others (2009)

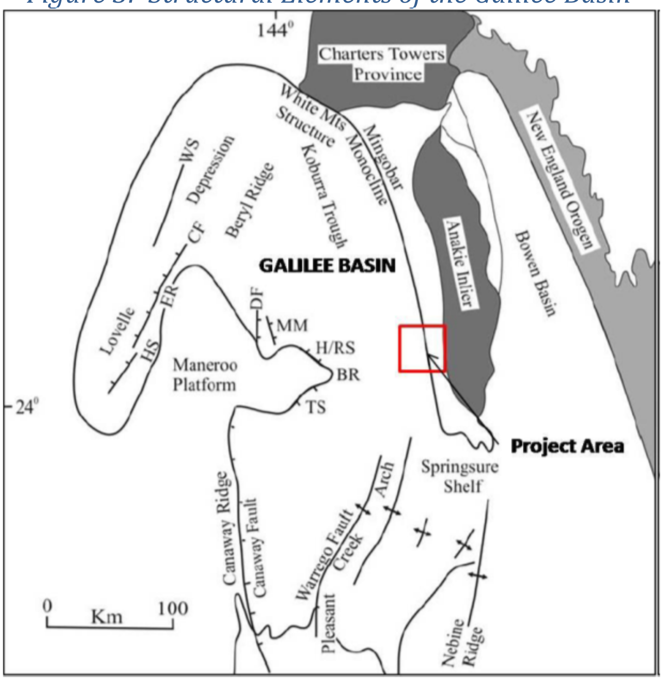
Regional Geology

The Galilee Basin is a Late Carboniferous to Mid-Triassic extensional intra-cratonic basin of predominantly fluvial sediment infill located in central Queensland. The basin covers an area of some 247,000 km^2 extending northwest from the contiguous central Bowen Basin. Tectonically, the basin is comprised of two main lobes which are joined in the north but are separated in the south by the Maneroo Platform (refer to *Figure 3*).

The Basin is divided in two parts:

1. the E-W trending Barcaldine Ridge; north of the Ridge, the basin is further subdivided by the Maneroo Platform and the Beryl Ridge which resulted in the development of a western depression, the Lovelle Depression, and an eastern depression, the Koburra Trough and;
2. South of the Ridge, the Basin is subdivided by the Pleasant Creek Arch into the western Powell Depression and the Springsure Shelf (SRK, 2008).

Figure 3: Structural Elements of the Galilee Basin



Modified after Hawkins and Green (1993a)

Most structures are subsurface and only the White Mountains Structure, Mingobar Monocline, and some structures on the southern margin occur in outcrop. Modified from Evans 1980. WS = Weatherby Structure, CF = Cork Fault, ER = Elderslie Ridge, HS = Holberton Structure, DF = Dariveen Fault, MM = Maranthona Monocline, H/RS = Hulton-Rand Structure, BR = Barcaldine Ridge, TS = Tara Structure.

The dominant structural feature is the Koburra Trough, which on seismic evidence, is about 300km long and reaches a depth in excess of 3000m. The Koburra Trough contains the thickest sedimentary sequence and is the deepest part of the basin. It is flanked on the north and east by the Mingobar Monocline/Belyando feature. The Galilee Basin strata are exposed on the eastern and north-eastern margins but elsewhere are covered by more recent Eromanga Basin sedimentary rocks. The eastern rim onlaps the older Devonian-Carboniferous Drummond Basin and lies in contact with the Bowen Basin to the southeast, along the north-south trending Nebine Ridge.

The basement geology is rather speculative in certain areas beneath the Galilee Basin but broad consensus indicates a combination of slightly-folded Devonian and Carboniferous rocks of the Drummond and Adavale Basins, which overlie Lower Palaeozoic to Neoproterozoic metamorphic rocks, (i.e., the exposed Anakie Inlier) (Hawkins and Green, 1993b). Uplift of the Anakie Inlier and the overlying Drummond Basin occurred in the latest Lower Carboniferous to Mid-Late Carboniferous and subsequently resulted in onlap of the Permian-Triassic sediments in the east and formed an eastward barrier of deposition for the Galilee Basin (Hawkins and Green, 1993b).

The Drummond and Galilee Basins are a broader basinal system that overlies Cambrian-Ordovician crystalline basement of the Thompson Fold Belt to the west of penecontemporaneous magmatic arc systems of the New England Orogen. The development of the Galilee Basin is partly synchronous with the formation and infill of the Bowen Basin (Hawkins and Green, 1993b).

The project area occupies a position on the eastern margin of the Koburra Trough which also corresponds with the basin margin.

Local Geology

The oldest rocks of the Galilee Basin succession are represented by the Late Carboniferous to Early Permian Joe Joe Group that comprises four (4) formations which from oldest to youngest are the Lake Galilee Sandstone, the Jericho Formation, the Jochmus Formation, and the Aramac Coal Measures (see regional stratigraphic column *Figure 4)*:

- The Joe Joe Group is entirely non-marine and the Jericho and Jochmus Formations show a strong glacial influence, as well as indications of proximal volcanism. The Late Carboniferous Lake Galilee Sandstone is restricted to the Trough axis; and
- The Late Carboniferous-Early Permian Jericho and Early Permian Jochmus Formations are represented throughout the Koburra Trough, whereas the Early Permian Aramac Coal Measures have to date only been identified on the south-western flank of the Trough near the Maneroo Platform (Van Heeswijck, 2006).

During the Early Permian, after the deposition of the Jericho Formation, explosive volcanic activity to the east gave rise to the volcanic-lithic labile sandstones of the Jochmus Formation. This volcanism produced numerous tuff horizons, and at its peak resulted in the Edie Tuff Member which separates the Upper and Lower members of the Jochmus Formation.

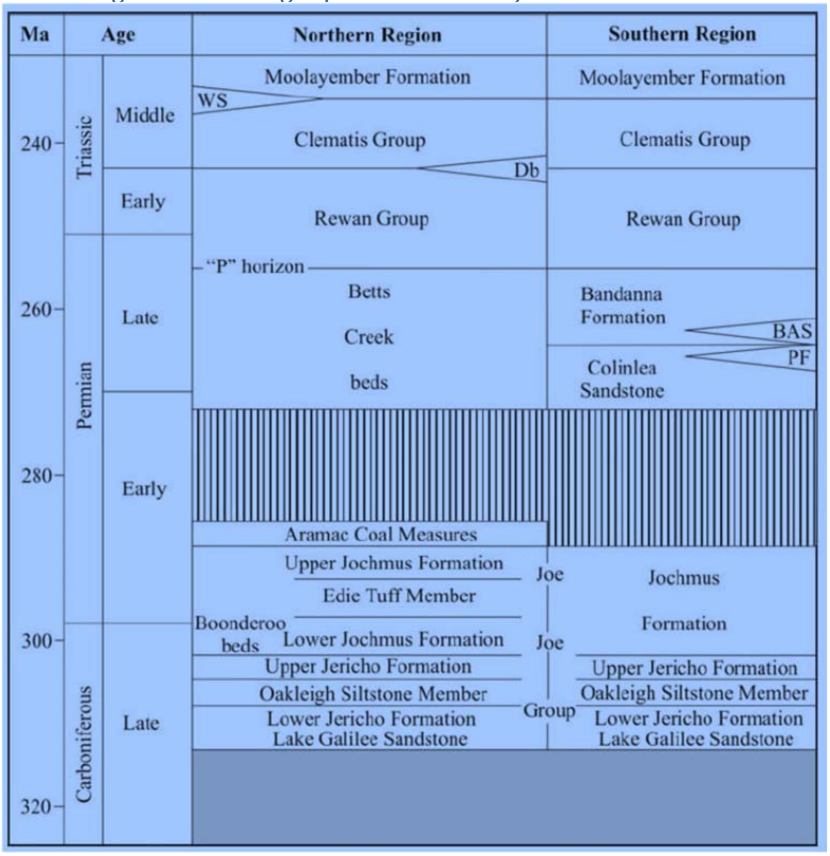
Following the cold-climate fluvio-lacustrine deposition of the underlying formations of the Joe Joe Group and coinciding with a certain degree of extensional tectonism towards the end of the Early Permian, coal swamps started to form, particularly on the downthrown side of reactivated faults and newly-formed grabens and half-grabens such as the Aramac Depression (Hawkins and Green, 1993a). The event gave rise to deposition of the Aramac Coal Measures throughout most of the Koburra Trough and Lovelle Depression.

The onset of an interpreted east-west compressional event during the closing stages of the Early Permian produced uplift and erosion which completely removed the Aramac Coal Measures from the eastern and southern areas of the Koburra Trough (Van Heeswijk, 2006).

A period of tectonic stability commenced in the Late Permian and was accompanied by a further stage of continental deposition fed by an uplifted landmass to the north that sourced quartz and rock detritus. Widespread coal swamps developed on the resulting fluvial/alluvial plains particularly over the central and northern parts of the Koburra Trough whilst to the south, coal accumulation seems to have been significantly reduced or non-existent.

At the onset of the Late Permian, sedimentation was restricted to the Koburra Trough axis and comprised the Colinlea Sandstone, a medium to coarse sandstone, with minor coal seams. The subsequent Bandanna Formation, deposited throughout the Koburra Trough is composed of a series of interbedded sandstones, mudstones and coals. It is reported that the climatic conditions during this phase were temperate (Hawkins and Green, 1993b).

Figure 4: Stratigraphic Elements of the Galilee Basin



Modified from Hawkins and Green (1993a)

A large shallow, intracratonic basin formed during the Late Carboniferous Deposition was initially confined to the Koburra Trough. The location of the trough is believed to be influenced by folding and inversion in the underlying Drummond Basin

By the early Permian, sedimentation was continuous across the northern end of the Maneroo Platform into the Lovelle Depression From Late Carboniferous to Early Triassic the Galilee Basin received dominantly fluviatile sedimentary rocks.

During the late Early Permian, widespread development of peat swamps resulted in deposition of the Aramac Coal Measures.

Substantial thickness of Aramac Coal Measures were deposited on the western side of reactivated basement faults in the Lovelle Depression. The end of the Early Permian saw east-west compression, resulting in reversal on normal faults, uplift and erosion. The Aramac Coal Measures were completely removed in eastern and southern parts of the Koburra Trough.

A period of non-deposition during the Early Permian separates the sedimentary rocks of the Joe Joe Group, which includes the Aramac Coal Measures, from the Middle-Permian sequence that includes the Betts Creek beds.

Widespread coal swamps occurred throughout the basin during the Late Permian, and the resulting coal measures are commonly referred to as the Betts Creek beds. The basin is largely concealed by the Jurassic to Cretaceous sedimentary rocks of the Eromanga Basin except at the north-eastern margin.

Location of Aquifers

Figure 5, below, shows the location of the cross-section illustrated by *Figure 6*. The major aquifers have been identified by recent studies (i.e. RLPS 2011) and are summarised in the section shown in *Figure 7*.

Figure 5 Location of Regional Cross-section showing major sedimentary formations

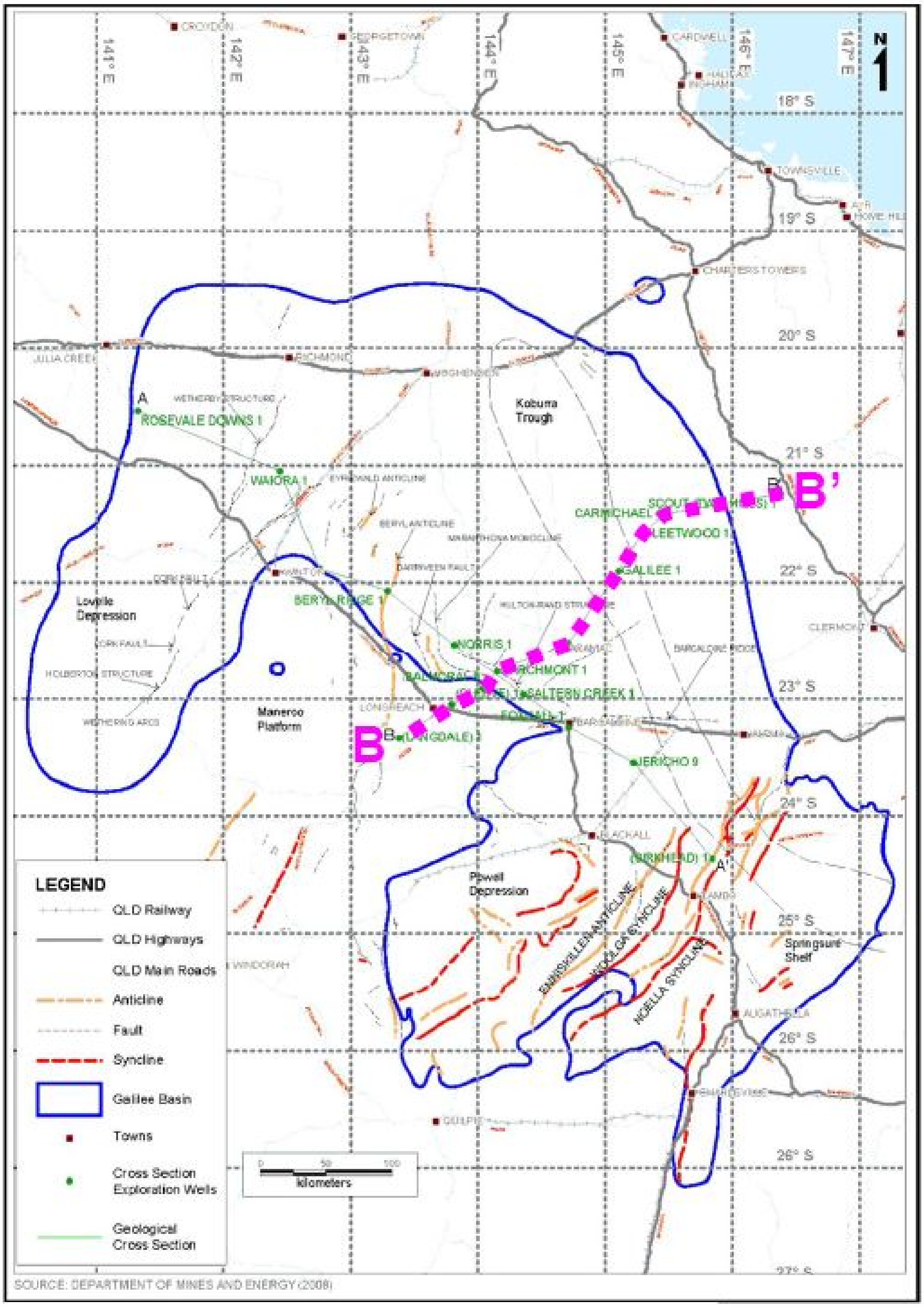


Figure 6 Regional West-East Cross-section at the Northing of the Carmichael Coal Project

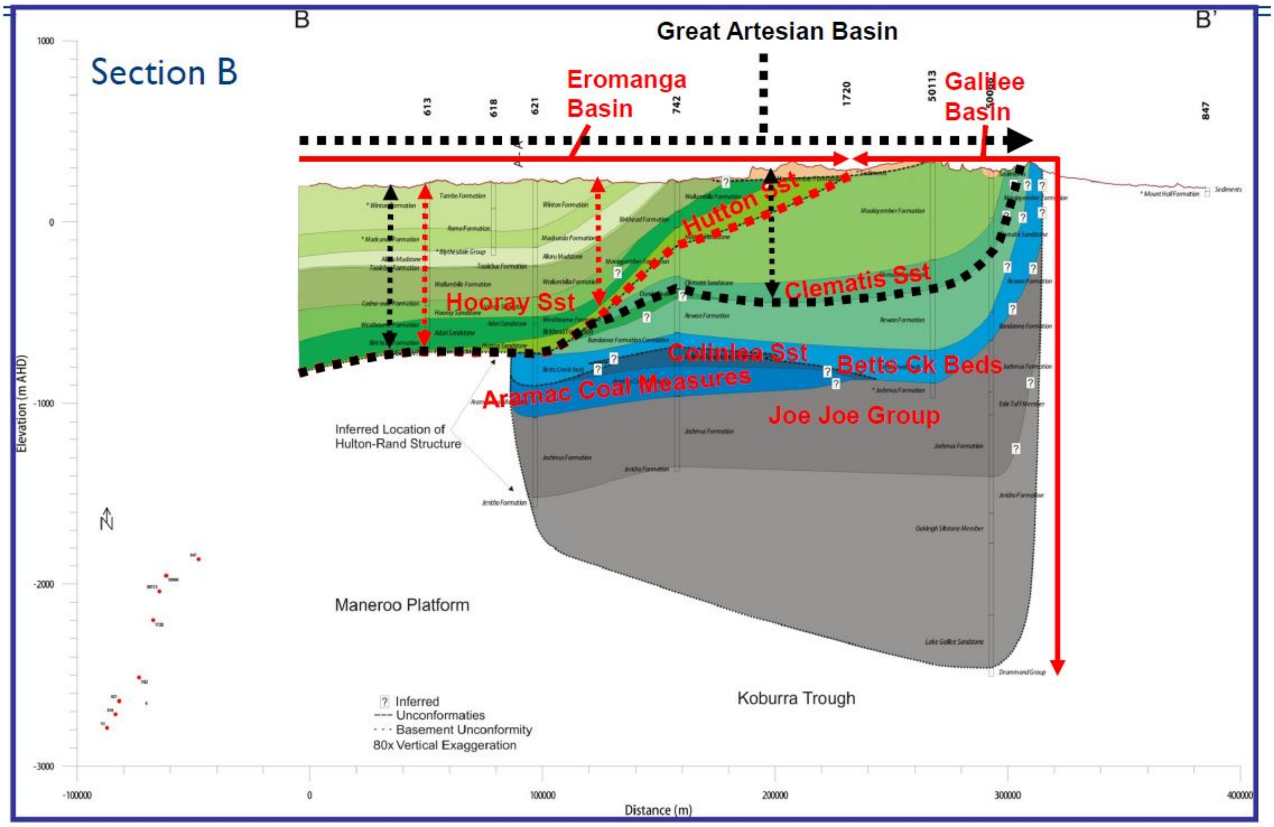
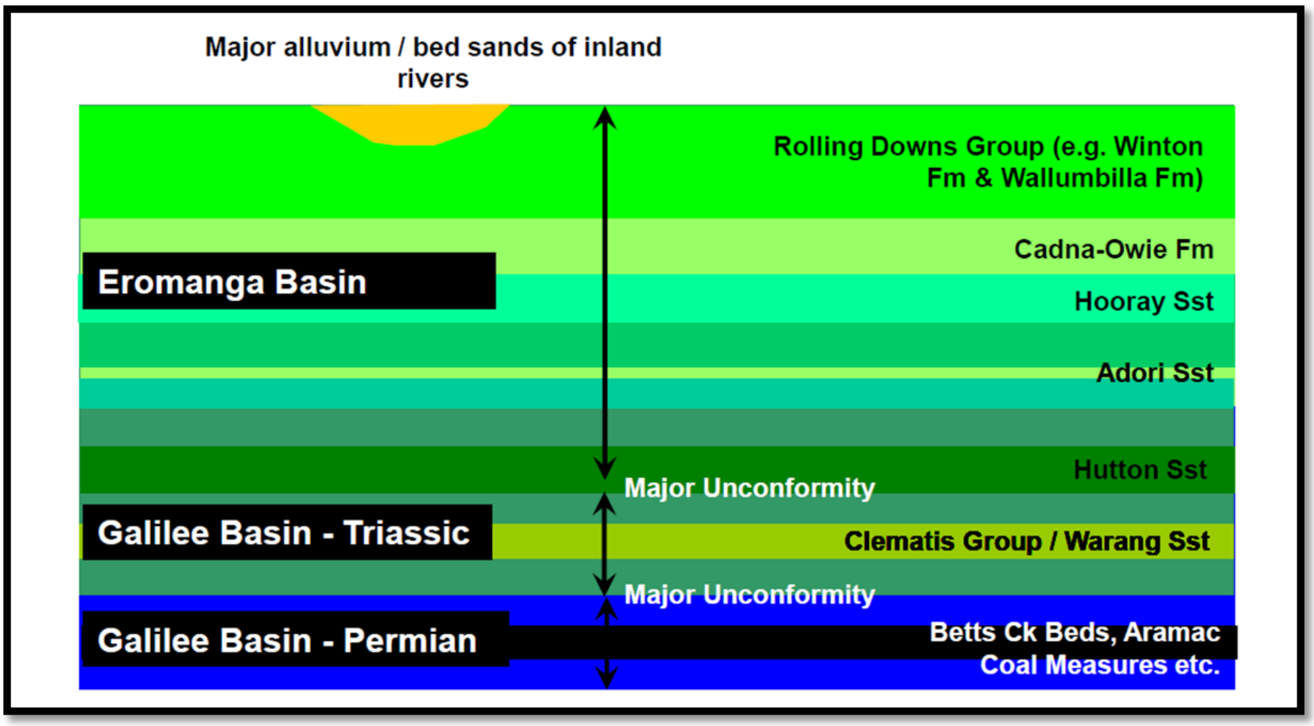


Figure 7: Local Formations that are Aquifers



A regional BMR 2D seismic survey near Carmichael shows the general structural of the Galilee and underlying Drummond Basins. The coal-bearing strata of interest (Betts Creek Beds) are shown as the "P" horizon on this figure (*Figure 8*).

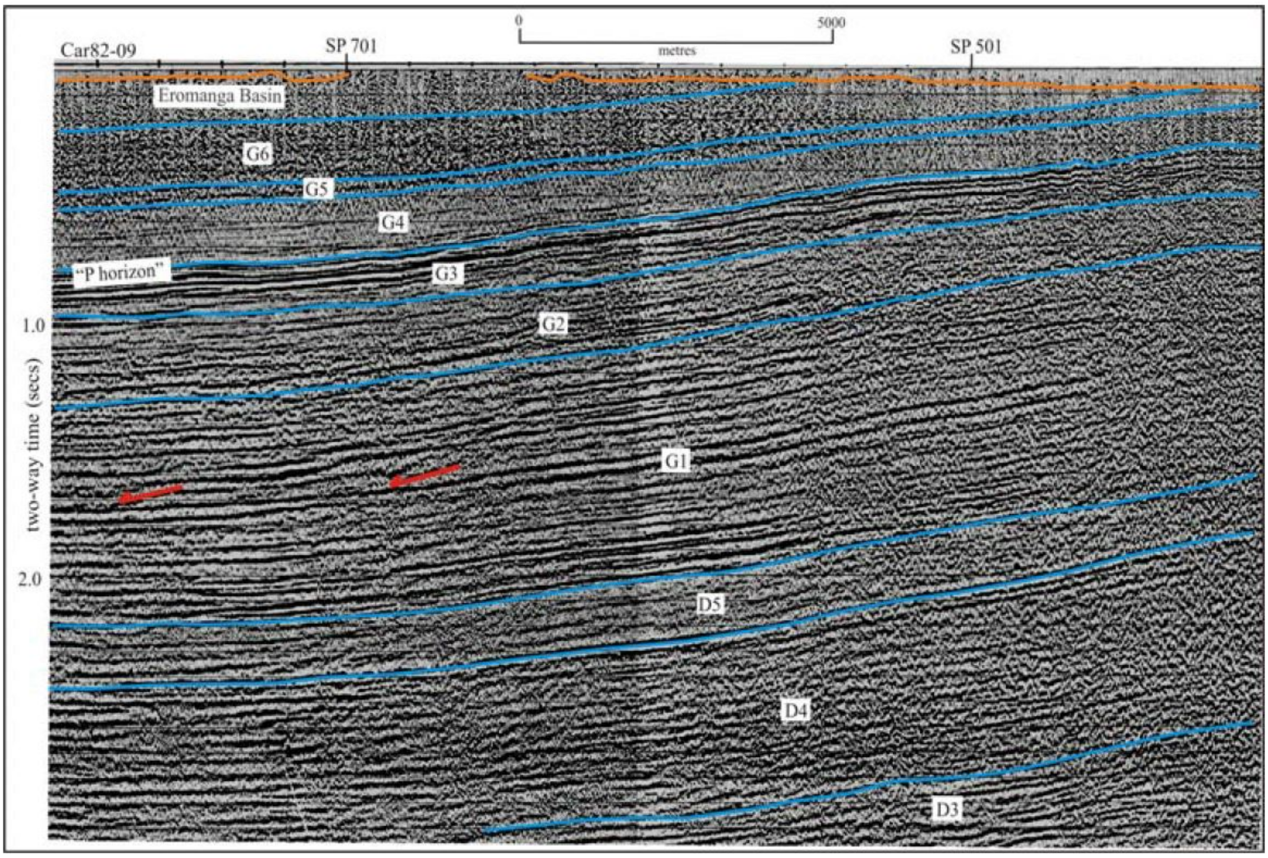


Figure 8 Regional West-East 2D seismic Reflection Survey across the Galilee Basin (Carmichael 82_09)

Current Investigations

Some studies (including the Queensland Carbon Geostorage Initiative Atlas, Bradshaw and others 2009) suggest the presence of a number of faults close to the boundary between the Galilee Basin and the Drummond Basin to the east (i.e. to the north and east of the proposed mining area). Regional scale mapping of the area has also been considered in overall geological assessments for the Carmichael Coal Project by Adani geological personnel, and by independent geologists acting as Competent Persons under JORC 2012, who have undertaken JORC Resource modelling assessments. This includes Xenith Consulting (Bailey and Turner,2013), and more recently ROM Resources, (this study, Biggs *in prep*), with the former currently preparing an updated resource assessment.

Following overall assessments of publically-available regional geology reports and maps, together with JORC resource modelling by these recognised independent expert geologists, it is concluded that there is a general absence of any significant faults in the area. This conclusion is based on structural geological interpretation to a standard suitable for JORC 2012 reporting, which is underpinned by a significant density of drilling and seam interpretation throughout the area as shown in *Figure 9*.

High-quality 2D seismic which has been interpreted along the lines shown in *Figure 10*, demonstrates no significant regional fault structures intersecting these lines. The level of geological interpretation based on successive comprehensive exploration campaigns and geological modelling since Adani purchased the EPC from Linc Energy in 2010 is considered to provide for a substantially higher level of structural geological understanding, and fault interpretation and relative displacements, when compared with existing regional interpretations.

An April 2013 JORC Coal Resource Estimate (Xenith Consulting, Bailey and Turner 2013) suggested the presence of only four minor faults in the coal strata with vertical throws between 10 m and 40 m, trending in a general east-northeast to west-southwest direction. This interpretation has recently been substantiated by Mark Biggs, ROM resources (Biggs 2013; Biggs *in prep*) based on additional drilling data provided by Adani from the 2013 drilling program.

A cross section of the stratigraphic sequence through the Carmichael Coal Project area is shown in *Figure 11*. As is shown, the Tertiary sediments are composed of unconsolidated to semi-consolidated clays, gravels and sands approximately 50 m in thickness in the east of the CCP, thinning to zero in the west. The Dunda beds and Rewan formation overlay the Permian coal sequence in the west, with overburden thicknesses of approximately 300 m to 400 m.

Figure 9 Carmichael Deposit: D3_1 Structure roof from drilling and mapping data

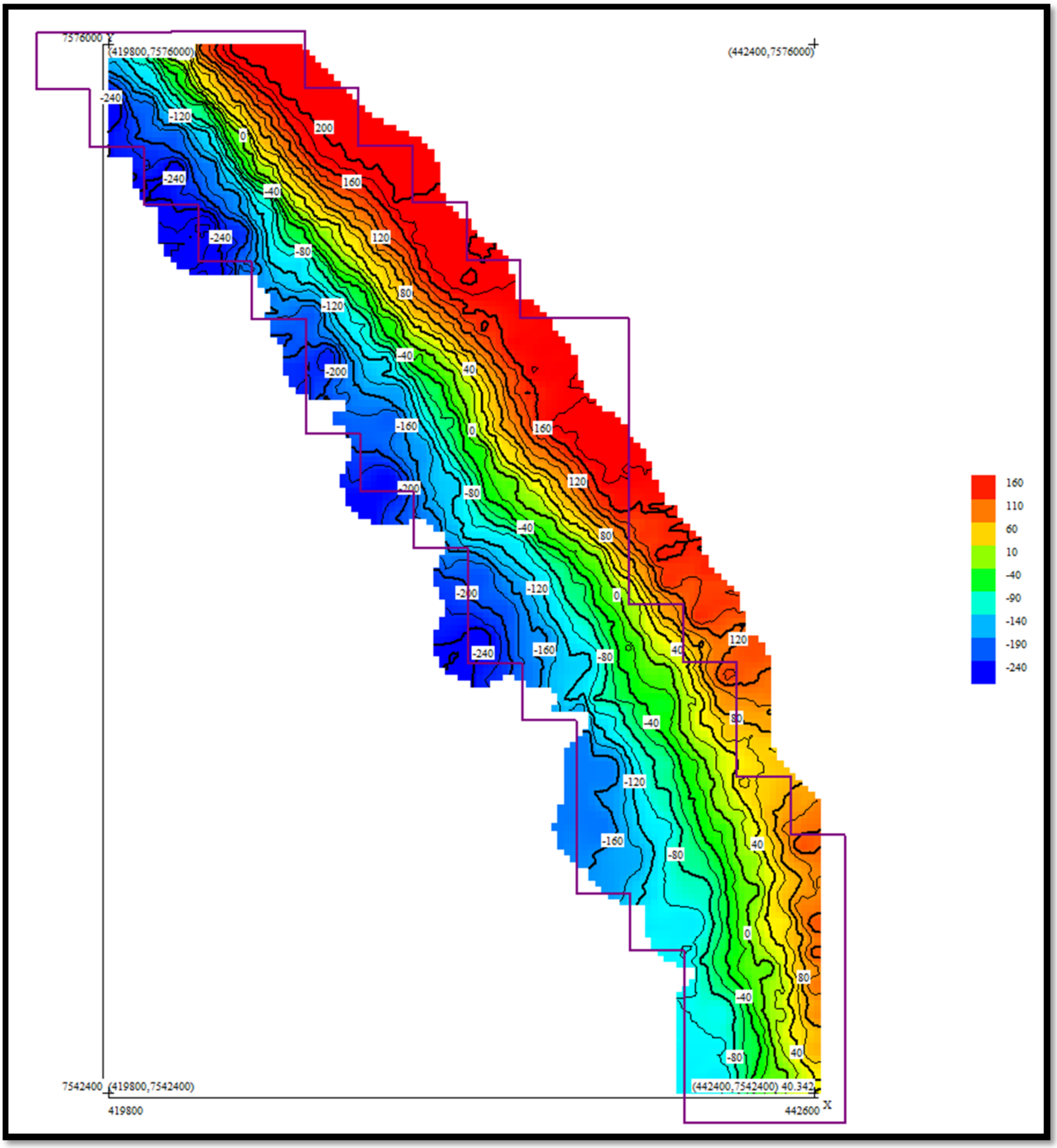
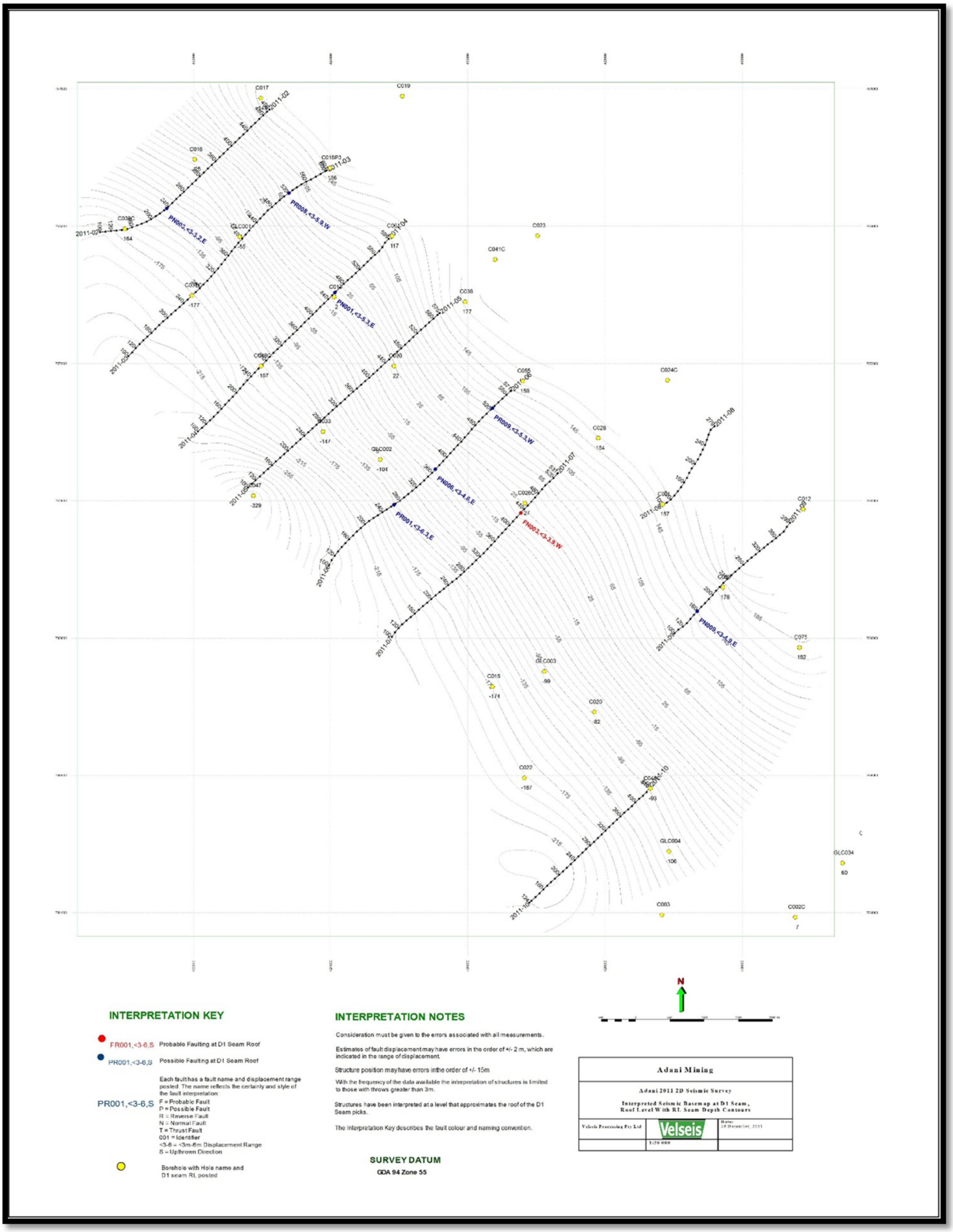
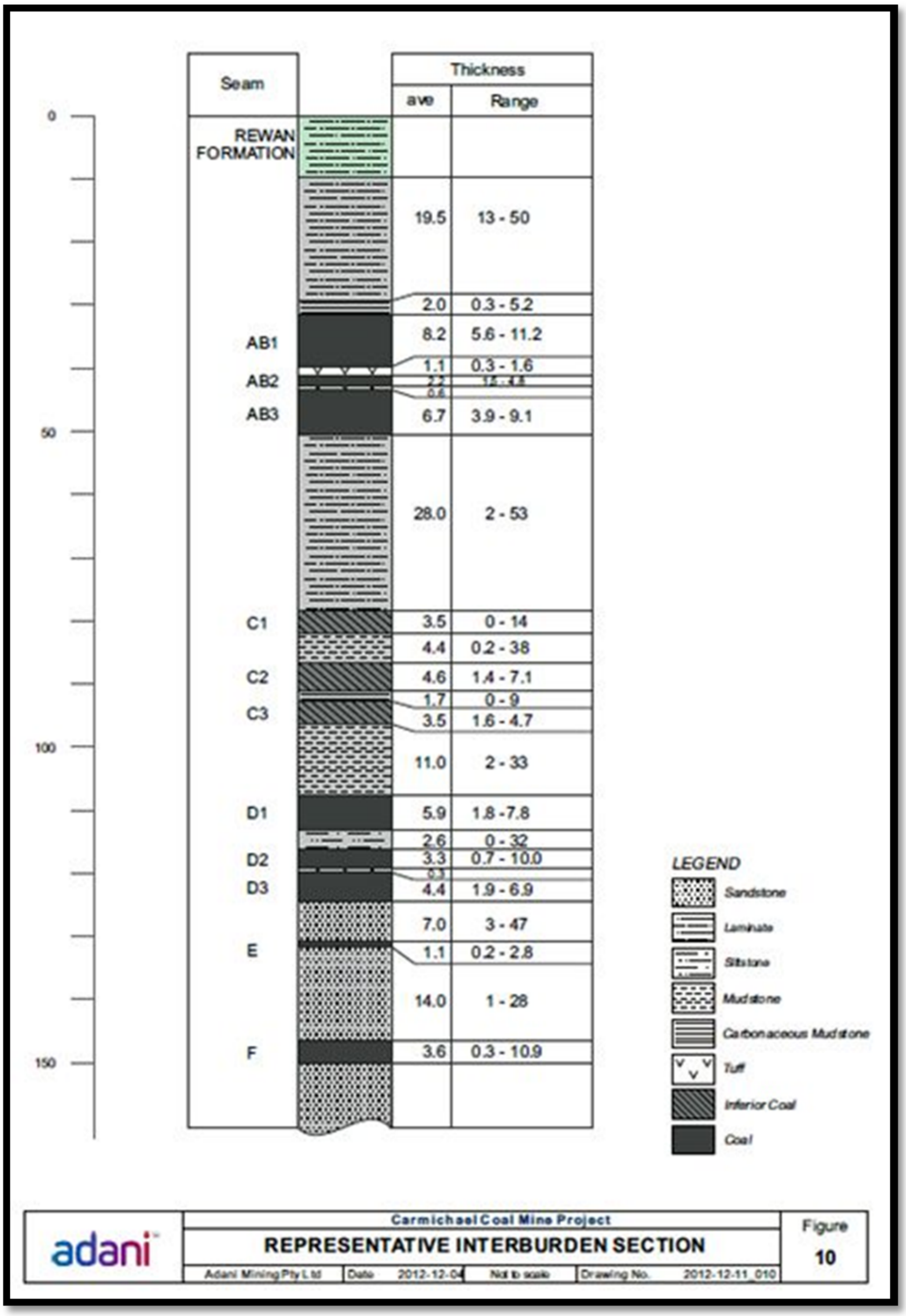


Figure 10: Carmichael Coal Deposit – 2D Seismic Interpretation of the D1 seam roof



Given that the Rewan Group is around 250 m thick at the western boundary of the proposed Mine Area a throw of 40 m would still result in an effective aquitard thickness of 210 m. There is no evidence in the geological data set of any faults of with sufficient throw to bring the Clematis sandstone into contact with the underlying Permian-age units on the other side of a faulted contact.

Figure 11 – Geological Cross Section of the Carmichael Coal Project Area



All available geological interpretation based on the existing geological structural interpretation demonstrates, therefore, any potential connection between the Dunda beds and fresh Permian formations is not considered feasible.

2D Seismic Interpretation

Similar findings were concluded from an analysis of the 2D seismic lines surveyed in 2011 (McClintock 2012). As shown in *Figure 12*, below, the seismic reconfirms coal seam development and continuity and illustrates the development of small-scale structures. Analyses of the mid-points of the fault throws interpreted from all seismic lines are shown in *Figure 13*. The average is about 3m, with the maximum interpreted throw at 8.6m

Figure 12: 2D Seismic line 2011-06

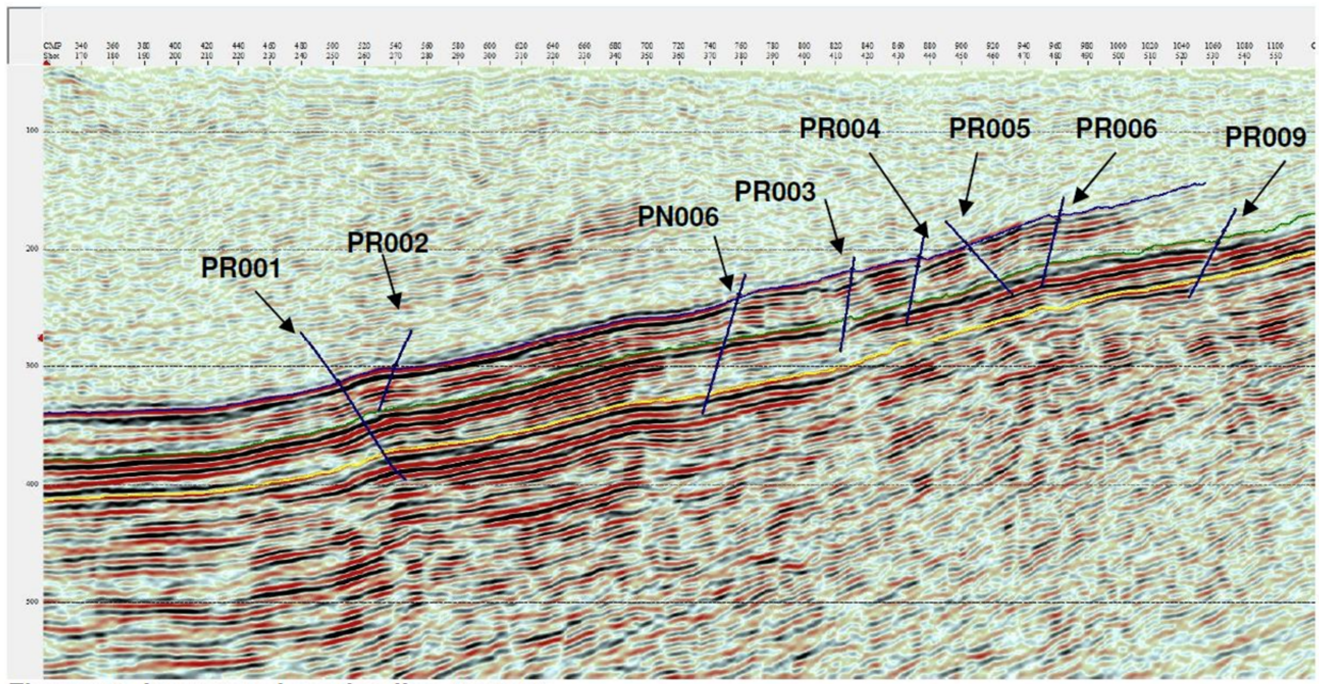
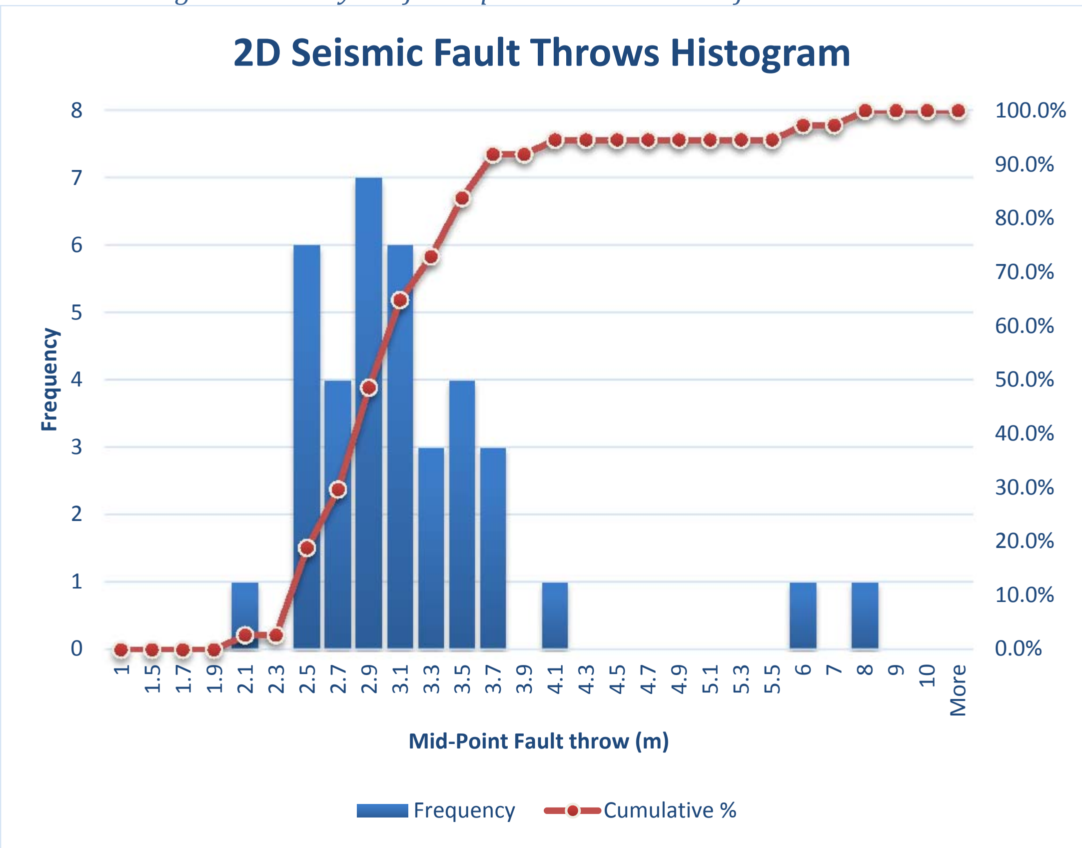


Figure 12. Interpreted section line 2011-06
Seams shown are AB1 (blue), AB3 (green), and D1 (yellow) seams. Various styles of faulting are illustrated and are coloured with respect to the interpretation confidence, probable=red and possible=blue. Orientation looking north-west.

Figure 13: Analysis of Interpreted Fault Throws from 2D seismic



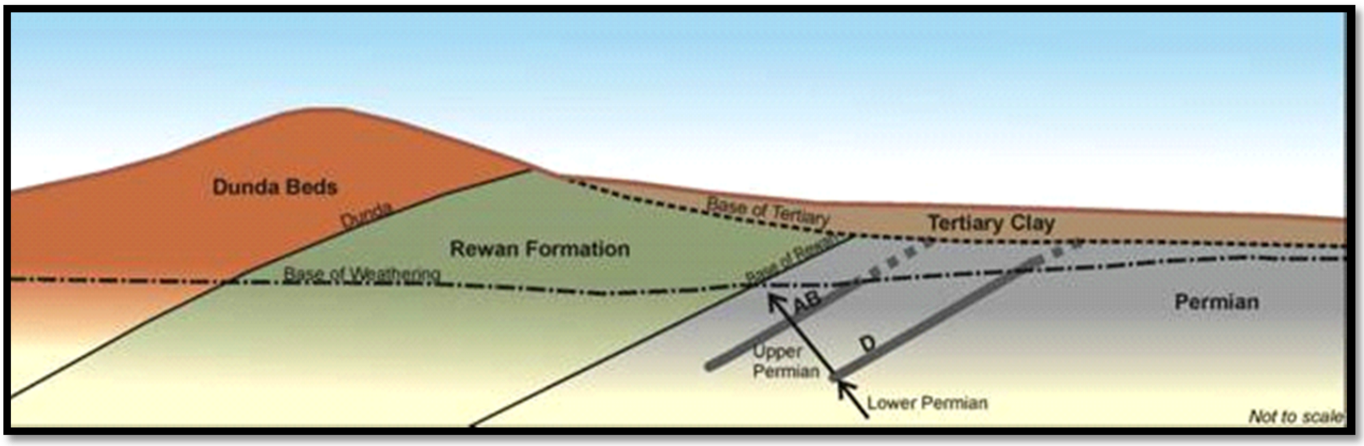
Groundwater Flow

No direct simulations of hypothetical faulting of the Rewan Group or other strata have been undertaken. However, as discussed in the mine's EIS document detailed sensitivity analysis has been undertaken to quantify groundwater impacts based on a wide range of possible hydraulic conductivity values for the Rewan Group.

The results of this sensitivity analysis were listed in of the Mine Hydrogeology Report Addendum. Hydraulic conductivity values for the Rewan Group of as high as $1x10^{-2}$ m/d horizontally and $1x10^{-3}$ m/d vertically were considered for the Rewan Group, increasing post mining to $1x10^{-2}$ m/d horizontally and vertically in the area immediately overlying the underground mine workings. Hence under the 'worst case' Rewan Group hydraulic conductivity scenario considered for the sensitivity analysis the groundwater modelling assumes that the Rewan Group will respond uniformly as a fractured sandstone aquifer (*Figure 14*).

This is akin to assuming that the Rewan Group is heavily faulted and fractured throughout the area such that it ceases to function as an aquitard. Impact predictions based on this 'worst case' scenario suggest that maximum impacts at the Doongmabulla Springs could be up to around 1 m compared to up to around 0.2 m drawdown based on the calibrated or 'best estimate' parameter set.

Figure 14: Carmichael Deposit, Proposed Mining Area, Simplified Section, West to East.



Modified: supplied by Adani Mining PtyLtd

Conclusions

From the current fault regime documented it is highly unlikely that aquifers within the coal measures (mostly coal seams) would impact upon on groundwater flow processes in aquifers identified in the overlying Triassic Dunda Beds (a lateral equivalent of the Triassic Clematis Sandstone which is a known strong aquifer and bore water source). This is mainly due to the local fault throws not being significant enough to move formation boundaries the required distances that would allow aquifers to contact and mix. Local field mapping, exploration drilling and 2D seismic surveying has, to date, only revealed normal faulting with throws to a maximum of forty (40) metres in the planned mine area.

Regardless of these findings, ongoing exploration drilling, geotechnical coring and especially acoustic scanner downhole logging continues to provide data that will enable the structural model for the Carmichael Coal Project to be regularly revised.

References

Bailey R., 2013 Adani Mining Pty Ltd, JORC Coal Resource Estimate, Carmichael Coal Deposit, April 2013, Xenith Consulting Pty Ltd, unpublished report, April 2013, 65pp

Biggs M.S. 2013 Carmichael Deposit, EPC 1690, JORC Resource Re-Estimate, ROM Resources unpublished confidential report to Adani Mining Pty Ltd, Sep 2013, 18pp

Bradshaw, B.E., Spencer, L.K., Lahtinen, A.C., Khider, K., Ryan, D.J., Colwell, J.B., Chirinos, A. and Bradshaw, J. 2009, Queensland carbon dioxide geological storage atlas.

Carr, A.F., 1975, Galilee Basin *in* Travers, D.M., & King, D., Economic Geology of Australia and Papua New Guinea 2.Coal, *AusIMM Monograph Series No.6*

Day, R. W. 1969. *The Lower Cretaceous of the Great Artesian Basin.* Canberra: ANU Press.Exon, N. F. (1976). Geology of the Surat Basin in Queensland. *Bureau of Mineral Resources, Australia, Bulletin.* , 166.

Gray, A. R. 1977, Stratigraphic Drilling in the Hughenden 1:250,000 Sheet Area. *Queensland Government Mining Journal, 78.* , 382-392.Geological Survey Queensland IRTM Viewed online September 2011. https://webgis.dme.qld.gov.au/webgis/webqmin/viewer.htm

Harrington,M.R., and Zebrowitz, M.,1995, Coalbed Methane Development in the Galilee Basin of Central Queensland, Australia. *Proceedings of Intergas '95, University of Alabama, Tuscaloosa, Ala. USA.*

Holland, J.R., and Bocking, M.A., 2008, Galilee Energy Rodney Creek 8 Well Completion Report, *Galilee Energy unpublished report.*

Hawkins, P. J. 1978a. Galilee Basin - review of petroleum prospects. *Queensland Government Mining Journal, 79.* , 96-112.

Hawkins, P. J. 1978b. Stratigraphic and Seismic investigation in the Lovell Depression, western Galilee Basin. *Queensland Government Mining Journal, 79.* , 623-650.

Heikkila, H. H. 1965. Palaeozoic of the Avadale Basin. *Australian Institute of Mining and Metallurgy.* , 157-165.

Hawkins, P.J., Gray, A.R.G., Brain T.J. and Scott S.G., (in Prep), Geology and resource potential of the northern Galilee Basin, *DME Queensland Geological Record (in prep).*

Leslie, R. B. 1976, Galilee Basin Economic Geology of Australia and Papua New Guinea. . *Australasian Institute of Mining ang Metallurgy.* , 309-315.

McClintock K., 2012, 2011 Adani 2D Seismic Survey, Galilee Basin QLD, Final Interpretation and Data Processing Report, Velseis Processing Pty Ltd,

RPS Group., 2011, Galilee Basin Hydrological Investigations: briefing to RAPAD Group Longreach, 16th May 2011, unpublished presentation.

Scott, S.G., Beeston, J.W., and Carr, A.F., 1995, Galilee Basin *in* Ward et al 1995 "Geology of Australian Coal Basins" *Geol. Soc. Aust. Coal Geol. Spec. Group Spec Pubn No.1*

Scott, S.G., and Hawkins, P.J., 1992, Coal geology of the northern Galilee Basin and its implications for coal seam methane investigations. *Proc.of the Symposium on coalbed methane research and development in Australia, 5, 85-102*. James Cook University.

Senior, B. R. 1978, Geology of the Eromanga Basin. *Bureau of Mineral Resources, Australia, Bulletin.* , 167.

Slater S., 2009, Galilee Basin – Historical perspective and future challenges, RLMS QLD/NT PESA Lunchtime Presentation Feb 2009

Tanner, J. J. 1967, Devonian of the Avadale Basin, Queensland, Australia. *International Symposium on the Devonian System, II. Alberta Society of Petroleum Geologists, Calgary.* , 111-116.

Wells, A.T., 1989 Stratigraphy and Permian Coal Measures of the Galilee Basin, Queensland *in* Harington, H.J. et al Permian Coals of Eastern Australia, *BMR Bulletin 231, AGPS Canberra.*

Attachment 6. Response to specific IESC comments

Attachment 6 – Response to Specific IESC Comments

<table>
<tr><th>ISSUE</th><th>RESPONSE</th></tr>
<tr><td><u>Advice</u></td><td></td></tr>
<tr><td>This advice has been based on the draft Supplementary Environmental Impact Statement (draft SEIS) provided by the regulators. However, the Committee is aware that in the process of finalising its advice, a final version of the SEIS was publically released on 25th November 2013. The respective joint referral regulators both confirmed that the Committee should base its advice on the draft SEIS.</td><td>Adani notes that the material supplied to the OCG on the 31/10/13 for the purposes of the IESC review included the following documents:

A response report addressing comments made by the IIESC and addressing the assessment items under the IESC review charter
A number of attachments:

<table>
<tr><th>Carmichael Coal SEIS Section</th><th>Title</th></tr>
<tr><td>Volume 2 Section 6</td><td>Water resources</td></tr>
<tr><td>Volume 2 Section 6</td><td>Briese Groundwater Consulting Pty Ltd Peer Review</td></tr>
<tr><td>Volume 4 Appendix B</td><td>Updated Mine Project Description</td></tr>
<tr><td>Volume 4 Appendix I1</td><td>Subsidence Assessment Report</td></tr>
<tr><td>Volume 4 Appendix I2</td><td>Subsidence Management Plan</td></tr>
<tr><td>Volume 4 Appendix J3</td><td>Doongmabulla and Mellaluka Springs Report</td></tr>
<tr><td>Volume 4 Appendix K1</td><td>Revised Mine Hydrogeology Report</td></tr>
<tr><td>Volume 4 Appendix K2</td><td>Water Balance Report</td></tr>
<tr><td>Volume 4 Appendix K3</td><td>Water Quality Report</td></tr>
<tr><td>Volume 4 Appendix K4</td><td>Flood Mitigation and Creek Diversion Design</td></tr>
<tr><td>Volume 4 Appendix K5</td><td>Revised Mine Hydrology Impact Assessment Report</td></tr>
<tr><td>Volume 4 Appendix K6</td><td>Revised Mine Hydrogeology Report Addendum</td></tr>
<tr><td>Volume 4 Appendix O1</td><td>Mine Waste Characterisation Report</td></tr>
<tr><td>Volume 4 Appendix R1</td><td>Closure and Rehabilitation Management Strategy - Mine</td></tr>
<tr><td>Volume 4 Appendix K7</td><td>URS Pty Ltd Groundwater Model Peer Review</td></tr>
<tr><td>Volume 4 Appendix K8</td><td>Response to URS Groundwater Model Peer Review</td></tr>
</table>
Subsequent to this submission, the OCG requested Adani finalise a number of minor edits</td></tr>
</table>

ISSUE	RESPONSE
	and administrative updates to SEIS documents. None of these updates altered or affected the material provided to the IESC relevant to the requirements of their assessment.
Relevant data and information: key conclusions	
Groundwater flow conceptualisation: There are important data gaps, especially in the deeper groundwater systems, most notably hydraulic head information, which bring into question the conclusions being drawn about groundwater flow directions. The groundwater flow interpretation contained within the draft SEIS appears to be based primarily on shallow groundwater monitoring. This interpretation is not considered to be consistent with expected groundwater flow for deeper formations, given regional geology and accepted regional groundwater flow directions within the Great Artesian Basin (GAB).There is insufficient data provided in the draft SEIS to substantiate the proponent's groundwater flow conceptualisation.	See GHD Response Letter, Section 1.1
Rewan Formation: The current groundwater model assumes the Rewan Formation will respond uniformly as an aquitard. However, the Committee questions this assumption based on variability in the hydraulic conductivity field data. Further data collection and assessment of the Rewan Formation is necessary. In addition, more data is needed to predict the effect of potential subsidence induced fracturing in the Rewan Formation on leakage rates from the GAB to the coal seam. Information on the degree of groundwater connectivity between the coal seams and the GAB is essential to understand the potential impacts of this project.	See GHD Response Letter, Section 1.2

ISSUE	RESPONSE
Springs: The source aquifer for the Mellaluka Springs Complex has not been determined, and as such it is not possible to accurately predict impacts from mining on these Springs. For both the Mellaluka and Doongmabulla Springs Complexes there is insufficient information on ecology and water chemistry, particularly in relation to potential seasonal variability, to design scientifically appropriate management and mitigation strategies. The Committee has little confidence in the capacity of the groundwater flow conceptualisation and groundwater flow model to predict the impact on these Spring Complexes.	See GHD Response Letter, Section 1.3
Ecological Impacts: Additional information to quantify the likelihood and extent of ecological impacts e.g. to riparian vegetation, as a result of changes to surface and groundwater systems would be beneficial to inform the development of mitigation and management measures.	See GHD Response Letter, Section 1.4
Cumulative Impacts: The proponent undertook a limited cumulative impact assessment including four other proposed projects in the region. There are, however, additional relevant proposed projects which should be included in the cumulative impacts assessment, including the China Stone Coal Project. These proposed developments extend over 300 km in length within the Galilee Basin and comprise some of the largest coal mines in Australia. On this basis, the Committee considers that information on cumulative impacts should be commensurate with the scale of all proposed developments.	See GHD Response Letter, Section 1.5
Application of appropriate methodologies: key conclusions	

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ISSUE	RESPONSE
Numerical Groundwater Model: The Committee is not confident that the proponent's groundwater model will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine. The Committee does not have confidence in the model's predictions for the potential groundwater impacts to the Doongmabulla and Mellaluka Spring Complexes and the Carmichael River. The Committee has significant concerns in relation to the use of no flow boundaries at most of the edges of the model domain and the truncation of the Clematis Sandstone (and other geological formations) on the western side in the numerical model. It appears that surface water catchment boundaries have been used to define the overall model domain, for both shallow and deeper groundwater systems. It is not good practice to employ model boundary conditions such as no flow boundaries without justification and validation. The use of no flow boundary conditions in a groundwater flow model can have profound effects on its predictions. Due to these unjustified and unvalidated assumptions, the Committee does not consider that the numerical model provides a reasonable prediction of the impacts of the development.	See GHD Response Letter, Section 2.1
Regional Faults: The conceptual model would benefit from an assessment of regional faults. The proponent's groundwater model does not take into consideration the influence of faulting within the Rewan Formation. The Committee notes that faults have been identified on the eastern boundary of the Galilee Basin within the Rewan Formation in other project proposals, but their potential role on groundwater flow processes has not been considered in this project.	See GHD Response Letter, Section 2.2

ISSUE	RESPONSE
Subsidence Fracturing: The assessment of the height of the subsidence fracture zone above longwall mining was not based on local site data nor with due consideration of multi-seam mining. The draft SEIS notes that these factors are significant and may result in underestimation of the fracture zone height above longwall mining. Likewise the connectivity of the fracture network and the relative increase in hydraulic conductivity of strata within this zone needs verification. Subsidence fracture zone height and hydraulic connectivity could have implications for the GAB and surface water resources.	See GHD Response Letter, Section 2.3
Reasonable values and parameters in calculation: key conclusions	
The Committee supports URS's peer review recommendation on the need to *"validate the location and type of boundaries in the model, emphasising suitability, impact on model results/predictions, and assumptions used when selecting the model boundaries.*"	See GHD Response Letter, Section 3.1
The proponent's field data needs to be further integrated into the groundwater model to establish an appropriate set of values and ranges for model layers, in particular, hydraulic conductivity parameters for the Rewan Formation. Sensitivity analysis of the groundwater model confirms that the integrity of the Rewan Formation plays a critical role in controlling impacts to the GAB and the Doongmabulla Springs Complex. This role may also extend to include ecological communities supported by discharge from the GAB, the groundwater dependent Waxy Cabbage Palm and other threatened species in the region.	See GHD Response Letter, Section 3.2

ISSUE	RESPONSE
Rewan Formation: On-site measurements of hydraulic conductivity values for the Rewan Formation ranged across several orders of magnitude, consistent with the variable lithology presented from drilling logs. These variations in local geology, including the potential for faulting, deep weathering or lateral gradation into the Warang Sandstone, may increase the permeability of the Rewan Formation. The implications of this contrasting behaviour for regional groundwater processes need to be further explored.	See GHD Response Letter, Section 3.2
Question 1: To what extent has the revised information provided by the proponent addressed the Interim Committee's advice?	
1. The revised information has filled a number of data gaps identified by the Interim Committee. Notwithstanding, there remain important data gaps and modelling inaccuracies which bring into question the hydraulic conductivity values employed by the model, the results of the groundwater model and conclusions being drawn about groundwater flow which directly affect the predicted impacts and proposed mitigation strategies.	The main perceived data gaps and modelling inaccuracies described by the IESC relate to i) the groundwater flow direction conceptualisation ii) model boundary conditions and iii) the modelled hydraulic conductivity of the Rewan Group. Detailed responses to each of these perceived issues are provided in Sections 1.1, 1.2 and 2.1 respectively of the GHD Response Letter.
2. The Committee acknowledges the Queensland Department of Natural Resources and Mines' preliminary work on a regional scale water balance assessment for the eastern edge of the Galilee Basin. The water balance work is to now include a regional groundwater and surface water quality monitoring program. This information is not yet available to the Committee.	Adani would welcome the opportunity to review any such material.
3. Changes in the draft SEIS addressing some of the Interim Committee's comments include:	

ISSUE	RESPONSE
a. An updated groundwater model which was independently reviewed, however, the peer review highlights inconsistencies with the modelling with which the Committee agrees. The review recommendations do not appear to have been addressed or rectified in the draft SEIS.	A peer review of the groundwater model which underpins the SEIS Mine Hydrogeology Report (SEIS Appendix K1) was completed in October 2013, the findings of which are included as SEIS Appendix K7. Based on the findings of this review and other comments received from a number of agency consultees including the DNRM, DEHP, DotE further modelling and reporting work was completed as summarised in the SEIS Mine Hydrogeology Report Addendum (SEIS Appendix K6). A specific response to each of the peer review recommendations was provided in SEIS Appendix K8. Additionally, the peer reviewer has provided a statement in response to the IESC comments, which generally supports the model and DNRM findings.
b. Additional subsidence modelling and sensitivity analysis of groundwater modelling parameters, with the notable exception of flow boundaries. However due to uncertainty around model parameters for hydraulic conductivity and the characterisation of the Rewan Formation, conclusions on impacts to the GAB and springs need to be reconsidered.	See GHD Response Letter, Section 1.2 and 3.2. Adani considers the justification given for the model extent, the truncation of the Clematis Sandstone to the west and the groundwater flow conceptualisation should give the IESC confidence in the integrity of the groundwater model and the impact assessment based on this modelling, particularly in relation to impacts to the Springs.
c. Assessment of the overburden materials for the potential to produce acidity and salinity in the final void has only partially been addressed.	See GHD Response Letter Attachment 7.
d. Additional studies on GAB impacts and on the Doongmabulla Springs and, to a lesser extent, Mellaluka Spring complex sites have been undertaken.	
4. Areas not fully addressed in the draft SEIS in response to the Interim Committee comments include:	

ISSUE	RESPONSE
a. Revision of the groundwater model and more in-depth spring surveys to enable a more rigorous assessment of potential impacts on the Doongmabulla and Mellaluka Springs Complexes, along with the development of appropriate and better aligned mitigation measures	The AEIS included a revision to the groundwater model presented in the EIS (Appendices K1 and K6), a report on targeted surveys of the Doongmabulla and Mellaluka Springs (Appendix J3), updated impact assessment in regards to potential impacts to these spring complexes (Appendices H (MNES Report), J1 (Revised Mine Ecology Report), K1 and K6). Mitigation measures in regards to the potential impacts to the springs are included in Appendices H, J1, K1 and K6. Additionally, Adani had committed in the AEIS to the preparation of a Groundwater Dependant Ecosystem Management Plan (Appendix G Commitment M4.27) which addressed both Spring Complexes. The draft of this plan has since been provided to State and Commonwealth agencies.
b. The development of an appropriately scaled regional groundwater model and water balance, commensurate to the size of the development, to reduce uncertainty in regard to cumulative impacts.	The scale of the regional model developed for the project is sufficient to assess the impacts of the proposed development. The cumulative impact assessment included within the SEIS has been subject to review by the DNRM and other consulted State agencies. Adani has committed to contribute to development of a basin scale groundwater flow model to assess the cumulative impacts of all proposed coal mining activities in the area. DNRM will have jurisdiction to impose conditions on Adani's approval to this effect, similar to that imposed on other Galilee basin Coal Projects. Refer to Section 1.5 of the GHD response letter also.
c. Ecological issues associated with a range of threatened species including the Waxy Cabbage Palm, Black Throated Finch and groundwater dependent vegetation.	The AEIS included additional ecological studies and impact assessment in regards to the matters including the following: • A report on targeted surveys for the Doongmabulla and Mellaluka Springs (Appendix J3), • A report providing results of additional black-throated Finch surveys (Appendix J2) • A report providing results of targeted waxy cabbage palm surveys (Appendix J4) • An updated impact assessment in regards to potential impacts to these matters (Appendix J1) An updated matters of National Environmental Significance Report (Appendix H)
Question 2: Is the conceptual groundwater model adequate, or what changes should [be made] to the conceptual groundwater model?	
Question 3: Are the revised groundwater models and the relevant data and analyses adequate to assess the potential impacts to groundwater?	

ISSUE	RESPONSE
6. The conceptual groundwater model is not adequate nor underpinned by sufficient representative data. There is insufficient hydraulic head information, particularly in the deeper geological units, to justify the groundwater flow predictions made by the groundwater flow model. Further hydraulic head information, especially in the deeper geologic units, and at a regional scale both within and beyond the mine site is required in order to better constrain the groundwater model.	See GHD Response Letter, Section 1.1. The basis of the IESCs statement that there is a lack of hydraulic head information in deeper units is not clear. As discussed in Section 1.1 of the GHD Response Letter, bores have been installed in each unit present within the site, including 13 monitoring locations in the Permian strata underlying the coal seams at the site, which is present at depths of over 500 m below ground close to the western boundary of the site. If anything, the number of monitoring bores generally increases with depth. Further information on regional groundwater levels has only recently become available via an independent study undertaken by the DNRM which suggests topographically driven flow in the Colinlea Sandstone as well as the Clematis Sandstone. Based on this information the DNRM conclude that the available data support the GHD conceptualisation of topographically driver groundwater flow in this area. Further monitoring to track the development of any impacts and confirm groundwater level flow directions in the GAB area to the west of the Mine Area is also proposed as outlined in the Groundwater Monitoring Plan. The additional issues relating to the model identified by the IESC appear to be predominantly related to a misinterpretation of the model boundary conditions and a lack of recognition of the scope of the sensitivity analysis work undertaken. See section 2.1 of GHD response letter.
7. The Committee considers that the revised groundwater model is not adequate to assess the potential impacts on groundwater, including springs, groundwater dependent ecosystems and the Carmichael River. Due to inappropriate boundary conditions the Committee has no confidence in the results of the groundwater model.	See GHD Response Letter, Section 1.1 and 2.1.2 . The IESC's lack of confidence in the groundwater modelling appears to be based on a mistaken interpretation of the model lateral model boundary conditions. As reported in Section 5.4.2 of the SEIS Mine Hydrogeology Report, MODFLOW General Head Boundary (GHB) conditions (rather than the no-flow boundary conditions) have been applied around the outer edge of the active model area, in all areas where significant lateral flow into and out of the model area is considered likely. Consequently, the groundwater model outputs and subsequent impact assessments are considered appropriate and adequate.

ISSUE	RESPONSE
8. ***Groundwater Flow***: The contour maps (based on limited regional bore data in some formations) depict (pre mining) groundwater flow towards the Carmichael River in each of the formations. For the shallow tertiary and alluvial aquifers the flow direction is conceivable and may be consistent with topographically driven flow. However the Committee questions the application of this flow direction to deeper formations in the absence of substantiating information, noting theoretical research in this regard. Geological cross sections of Permian and GAB Formations indicate, as expected, a general dip to the west. As such groundwater flow in deeper aquifers would be anticipated to conform to the generally recognised regional westerly flow within the GAB from the eastern recharge zone towards the centre of the basin. Furthermore, the groundwater contours are based on point measurements from bores that are in a relatively straight line (trending north south), which leads to multiple interpretations and may introduce bias when determining groundwater flow direction. The independent peer review of the groundwater model undertaken by URS also notes that the model flow direction is at odds, and is not consistent, with the regional flow direction and geology.	See GHD Response Letter, Section 1.1. Further information on regional groundwater levels has only recently become available via an independent study undertaken by the DNRM and also suggests topographically driven flow in the Colinlea Sandstone as well as the Clematis Sandstone. Based on this information the DNRM conclude that the available data support the GHD conceptualisation of topographically driven groundwater flow in this area. Further monitoring to track the development of any impacts and confirm groundwater level flow directions in the GAB area to the west of the Mine Area is proposed as outlined in the Groundwater Monitoring Plan. It should be stressed that whilst the available groundwater level data (including information for the Colinlea Sandstone recently identified by the DNRM) and the associated conceptual model suggest topographically driven flow, the numerical groundwater flow model has been set up such that flow can occur in a south westerly direction. All the modelled strata dip in this direction and the south western boundary of the model has been simulated using a MODFLOW General Head Boundary condition (not a No Flow boundary as suggested by the IESC) such that flow within the more permeable aquifer units can exit the model towards the south west. In no way have modelled groundwater flow directions been 'forced' to comply with the conceptual model of topographically controlled flow. The available groundwater level data, which generally indicate flow towards the Carmichael and/or the Belyando Rivers, have quite properly been used as calibration targets and to set boundary elevations in some cases. The fact that the numerical model has been able to replicate the observed flow directions, without recourse to unrealistic flow parameters, is considered to provide further supporting evidence that the conceptual model of topographically controlled flow is accurate. It should also be stressed that whilst the URS peer review does observe that modelled groundwater flows are "contrary to the dip of the strata" the comments do not discount topographically driven flow as a possibility. Instead the peer reviewer asked for further information and discussion of this feature of the modelling work. This was provided in Section 2.4.2 of the Mine Hydrogeology Report Addendum. In a further memo produced by URS following receipt of the IESC comments the peer reviewer concludes in favour of the groundwater flow conceptualisation presented in the SEIS.

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9. ***Model extent and boundary conditions:*** The URS review of a draft version of the groundwater model recommends that the proponents *"validate the location and type of boundaries in the model emphasising suitability, impact on model results / predictions, and assumptions used when selecting the model boundaries."* This recommendation has not been adequately addressed in the draft SEIS.	Further detail on model boundaries in the critical south western part of the model is provided in Section 2.1.2 of the GHD response letter. The sensitivity of model predictions to General Head Boundary (GHB) conductance is reported in Section 3.6.3 of the Mine Hydrogeology Report Addendum K6. As expected given the separation of the model boundaries from the proposed Mine Area sensitivity analysis results suggest that the predicted impacts are not sensitive to the conductance or elevation of the defined GHB cells. The IESC's concerns with regard to modelled boundaries appear to be related to a misinterpretation of the boundaries applied. This was also clarified previously in Section 2.1.2 of the GHD response letter. Peer review comments on additional boundary conditions are specifically addressed in Appendix K8 of AEIS.
10. The Committee can find no evidence in the documentation provided to substantiate the truncation of the Clematis Sandstone (and other geological units) on the western side in the numerical model. This truncation and the no flow boundary condition employed forces the numerical model to indicate groundwater flow towards the Carmichael River based on limited available bore data (noting that the proponent raises doubts as to whether some of these bores are in fact completed in the Clematis Sandstone). As all the information presented indicates that the Clematis Sandstone extends to the west of this truncation in the numerical model, the Committee cannot accept that such a truncation is valid. As a result, impacts on the Clematis Sandstone, or its dependent ecosystems including the Doongmabulla Springs Complex, cannot be inferred from the numerical model predictions.	Refer to comments above in relation to the 'boundary conditions'. Refer to section 2.1.2 of the GHD Response for the justification for truncating the Clematis Sandstone to the west. The active model area extends to the hydrological divide between the catchments of the Belyando River and Lake Galilee catchments. As previously discussed in Sections 1.1 and 2.1 of the GHD Response Letter it should be stressed that MODFLOW General Head Boundary Conditions (rather than No Flow boundary conditions) have been applied to selected model layers in this area such that flow within the more permeable aquifer units can exit the model towards the south west. In no way have modelled groundwater flow directions been 'forced' to comply with the conceptual model of topographically controlled flow.

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11. Further, the Committee can find no justification in the documentation provided, for the apparent delineation of 'no flow' boundaries in the numerical model based on surface water catchments particularly for the Triassic and Permian hydrogeological units. As depicted in the geological cross-section, both the GAB and Permian Formations extend well to the west of the proposed mine area and beyond the numerical model boundary. As a consequence the Committee has no confidence in the predicted groundwater flows in the Permian and Triassic Formations.	Unfortunately given that the Clematis Sandstone and other GAB units to the south of the project area potentially extend to the Queensland State border and around 200km to the west it is not practicable to produce a groundwater model which includes the full extent of the Clematis Sandstone whilst retaining sufficient detail in and around the Mine Area to quantify impacts on local surface water courses. Truncation of the GAB units to the south and west of the Mine Area is therefore necessary. In this case the active model area extends to the hydrological divide between the catchments of the Belyando River and Lake Galilee catchments. As previously discussed in Sections 1.1 and 2.1 of the GHD Response Letter it should be stressed that MODFLOW General Head Boundary Conditions (rather than No Flow boundary conditions) have been applied to selected model layers in this area such that flow within the more permeable aquifer units can exit the model towards the south west. In no way have modelled groundwater flow directions been 'forced' to comply with the conceptual model of topographically controlled flow.
12. The Committee recommends that the western truncation of the Clematis Sandstone and the 'no flow' boundaries be removed, unless adequate justification is provided, so that the numerical model better reflects the known geology and groundwater flow of the region to allow a better assessment of the potential impacts of the proposed development. Further the model domain should be extended, especially to the west, and additional groundwater levels for the Clematis Sandstone and Permian Formations be added to both better constrain the model as well as to validate groundwater flow conceptualisation and groundwater model results. Once these adjustments have been made the model should be re-run with methods and results provided to the regulators.	Adani considers that adequate justification for the model extent and boundary conditions have been provided above. Adani has committed to further monitoring to track the development of any impacts and confirm groundwater level flow directions in the GAB area to the west of the Mine Area in the Groundwater Monitoring Plan. This information will be used to inform future numerical modelling work which will include regular updates and potential re-calibration of the model developed to date. The sensitivity of model predictions to General Head Boundary (GHB) conductance is reported in Section 3.6.3 of the Mine Hydrogeology Report Addendum. As expected given the separation of the model boundaries from the proposed Mine Area, sensitivity analysis results suggest that the predicted impacts are not sensitive to the conductance or elevation of the defined GHB cells in this area. Hence whilst additional groundwater level data in the area to the west of the proposed Mine Area would be useful there is no evidence that extending the active area would have an effect on the model results.

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13. ***Rewan Formation:*** There is uncertainty around the capacity of the Rewan Formation to act as an aquitard to limit vertical leakage between adjacent formations, with consequent uncertainty on potential impacts to the GAB and Doongmabulla Springs Complex. There is a wide range of horizontal hydraulic conductivity (ranging from 1.0x10-1 m/d and 9.5x10-5 m/d) and limited vertical conductivity data. The Committee notes other evidence that suggests that north of this proposal the Rewan Formation appears to grade laterally into the Warang Sandstone, which is described as an aquifer; implying that in this region literature values for the Rewan Formation conductivity may not be appropriate. The numerical model used a 'blanket' figure for hydraulic connectivity which was lower than the mean of the field values. Given that the sensitivity analysis indicated the significance of the Rewan Formation in mitigating impacts on the Doongmabulla Springs and the GAB, the Committee recommends that as part of the revised model the mean of the measured hydraulic conductivity values be used.	See GHD Response Letter, Sections 1.2, 2.2 and 3.2. The IESCs comments do not properly take into account the sensitivity analysis undertaken on the groundwater model. The sensitivity of a range of model predictions to different modelled values of the Rewan Group are also presented in Section 3.6.1 of the Mine Hydrogeology Report Addendum (SEIS Appendix K6). As discussed in Section 3.3.2 of the GHD Letter Response it is recognised that higher values of hydraulic conductivity than those considered in the modelling can be returned by tests undertaken in horizons where the Rewan Group has been weathered to its constituent components which include fine sand. However, detailed information derived from the extensive exploration drilling undertaken in the Mine Area also suggests: — Only partial weathering of the Rewan Group over 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. In fact, given the dip of the strata, little or no weathering of the Rewan Group is anticipated throughout the area to the west of the Mine Area. It was therefore not considered appropriate or realistic to apply field test values for weathered strata to the full thickness of the modelled Rewan Group.
14. The proponent's groundwater model does not take into consideration the potential of faulting within the Rewan Formation. The extent of faulting in the Rewan Formation should be determined in order to inform the connectivity assessment. The conceptual model would benefit from an assessment of regional faults to enable greater certainty on the scale of impacts possible from this proposal.	See GHD response letter Section 2.2. There is no evidence in the geological data set of any faults with sufficient throw to, for example, bring the Dunda Beds or Clematis Sandstone into contact with the underlying Permian-age units on the other side of a faulted contact. Therefore, no direct simulations of hypothetical faulting of the Rewan Group or other strata have been undertaken. However, as noted above and at 1.2.2 of GHD's Response detailed sensitivity analysis has been undertaken to quantify groundwater impacts based on a wide range of possible hydraulic conductivity values for the Rewan Group.
15. The Committee highlights the importance of ongoing monitoring and assessment of hydrogeological field data (using appropriate sampling methods) to update and improve the conceptualisation of the system and its parameters	Adani recognise the importance of ongoing monitoring and have already installed a substantial monitoring network comprising some 84 groundwater monitoring points. With assistance from the URS peer reviewer Adani have also developed a comprehensive draft Groundwater Monitoring Plan to include further monitoring bore installations in the GAB area to the west and to the south towards Mellaluka springs. This monitoring plan has been

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prior to and during the operation of the mine, particularly in light of the 60 year life of the mine.	submitted to State and Commonwealth agencies.
Question 4: What are the key uncertainties and risks of the project and/or potential impacts on groundwater and surface water resources, and other water dependent matters of national environmental significance?	
16. Key risks and uncertainties in relation to understanding potential impacts are:	
a. The characterisation and role of the Rewan Formation, given its importance as a barrier to groundwater flow and minimising drawdown impacts on the overlying GAB Formations;	See GHD Response Letter Section 1.2 and item 13 above. Addressed via the Sensitivity Analysis reported in Section 3.6.1 of the Mine Hydrogeology Report Addendum.
b. Very limited understanding of regional faults in the area;	See GHD Response Letter Section 2.2 and item 14 above. Minor faulting only observed within the proposed Mine Area.
c. The lack of confidence in the interpretation of groundwater flow direction;	See GHD Response Letter Section 1.1 and item 8 above. As noted above, this lack of confidence has arisen in part out of a misinterpretation of the groundwater modelling and the justification provided by GHD should be sufficient to address any remaining concerns. Further, as noted in GHD's response – further opinion provided by URS and further work done by DNRM in the region has independently validated the groundwater flow conceptualisation. Further monitoring to confirm groundwater level flow directions in the GAB area to the west of the Mine Area is proposed as outlined in the Groundwater Monitoring Plan.
d. The limited extent of the model domain and the use of no flow boundaries in the groundwater model; and	See GHD Response Letter Section 2.1 and items 10 and 12 above. Given the scale of the GAB truncation of the GAB units to the south west of the Mine Area is therefore required. However, MODFLOW General Head Boundary Conditions (rather than No Flow boundary conditions) have actually been applied to selected model layers at the south-western limit of the active model area such that flow within the more permeable aquifer units can exit the model towards the south west. In no way have modelled groundwater flow directions been 'forced' to comply with the conceptual model of topographically controlled flow.
e. The adequacy of hydrogeological values used in the groundwater model	See GHD Response Letter Section 3.2 and item 13 above. A wide range of values for the Rewan Group and other modelled strata have been assessed via the detailed sensitivity analysis reported in Section 3.5.1 and 3.6.1 of the Mine Hydrogeology Report Addendum.

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17. The potential impacts to groundwater and surface water resources as drawn from the proponent's draft SEIS documentation include;	
a. The Doongmabulla Spring Complex1 is an EPBC Act listed endangered ecological community which will be impacted by groundwater drawdown and is assigned to the highest conservation ranking under the recovery plan for the springs community;	
b. Significant impacts to Mellaluka Springs, (located four to ten kilometres south of the project site) have been predicted;	
c. Potential impacts to terrestrial vegetation communities that may rely on shallow groundwater (<20 meters below ground level), for example along watercourses;	
d. Reduced baseflows and groundwater drawdown are predicted to result in up to 100% canopy dieback of riparian tree cover in the worst affected area involving the River Red Gum, Paper Bark and the EPBC Act listed Waxy Cabbage Palm;	The impact of reduced base flow within the Carmichael River on riparian vegetation (river red gum and paperbark) and waxy cabbage palms is discussed in Section 4.12 of Volume 4, Appendix J1, Updated Mine Ecology Report and the Carmichael River sub-plan of the Groundwater Dependent Ecosystem management plan. The dominant riparian vegetation in the Carmichael River is tolerant of extended zero/low flow events, although the predicted reduction in base flow volume and subsequent increase in zero flow periods is likely to stress plants in locations where groundwater is predicted to be drawn down by up to around 4 m in the near vicinity of the river. In the 800 m stretch where drawdown of between 1 and 4 m are predicted, these changes are likely to result in the death of some or all of the canopy trees (probably after a period of some years of slow decline). It is also possible that some individual trees may be adversely affected in the eastern half of the Project (Mine) Area. River red gums are less affected by changes in base flow than by changes in depth to water table (Rogers and Ralph, 2011), and are not expected to be affected significantly by the base flow changes due to the relatively low change predicted in the depth to the water table. Some paperbark species are also known to be more sensitive to changes in groundwater depth than base flow (Eamus et al., 2006). As the eastern section of the Carmichael River within the Project (Mine) Area is mostly predicted to experience reductions in base flow rather than increases in depth to the water table, it is likely that only the waxy cabbage palm will be impacted significantly in this

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	section. Adani have committed to carrying out an extensive program of ecological and hydrogeological monitoring along the Carmichael River as detailed in the Groundwater Dependent Ecosystem management plan to provide additional information on riparian vegetation health.
e. Permanent changes to the flow regimes, stream morphology and water quality;	
f. Permanent reduction in the Carmichael River base flows after mine closure of 31% of the long term average pre-development baseflow due to reduced groundwater baseflow and discharge from the Doongmabulla Springs Complex, and a local reduction of surface water flows of 21.5% flows; and	
g. The proposed extraction of up to 12,500 ML per annum from the Belyando sub-catchment, together with the predicted reduction of flow from the upstream Carmichael River sub catchment, and a range of changes to surface water flow (i.e. flood patterns, stream morphology), has the potential to contribute to downstream impacts.	See GHD response letter Section 1.4. Downstream impacts are assessed in a number of places including Section 4 of Volume 4, Appendix J1, Updated Mine Ecology Report and the Carmichael River sub-plan of the Groundwater Dependent Ecosystem management plan. The proposed extraction from the Belyando under a strategic allocation was included in the EIS and AEIS. This includes detailed hydrological assessment of the proposed external water sources.
18. The Committee considered the following risks and uncertainties from the proposal:	
a. The Committee is not confident that the proponent's groundwater model, based on the current conceptualisation will be able to accurately predict responses to perturbation of the groundwater system arising from the proposed mine;	IESC concerns seem to be predominantly related to i) the groundwater flow direction conceptualisation ii) model boundary conditions and iii) the modelled hydraulic conductivity of the Rewan Group. Detailed responses to each of these perceived issues are provided in Sections 1.1, 1.2 and 2.1 respectively of the GHD Response Letter.
b. There is unresolved uncertainty about the potential impacts on GAB groundwater resources, given that the groundwater model does not consider flow to the GAB outside the model domain.	Groundwater model results suggest topographically driven flow both with the GAB units and other strata. The available groundwater flow data including data for deep Permian units within the GAB area are consistent with this flow direction. However, MODFLOW General Head Boundary Conditions (rather than No Flow boundary conditions) have been applied to selected model layers at the south-western limit of the active model area such that flow within the more permeable aquifer units can exit the model towards the south west. It is therefore not true to say that the groundwater model does not consider flow to the GAB outside of the model domain. All of the strata dip towards the south west and the model boundary conditions would allow flow to occur in this direction.

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c. There is unresolved uncertainty around the impacts that reduced flow will have on riparian ecosystems and individual species, with the proposal information providing a generalised discussion on the impacts to terrestrial and aquatic ecosystems and does not identify or consider species' tolerances to predicted changes in flow regimes;	The impact of reduced base flow within the Carmichael River on riparian vegetation (river red gum and paperbark) and waxy cabbage palms is discussed in Section 4.12 of Volume 4, Appendix J1, Updated Mine Ecology Report and the Carmichael River subplan of the Groundwater Dependent Ecosystem management plan. The dominant riparian vegetation in the Carmichael River is tolerant of extended zero/low flow events, although the predicted reduction in base flow volume and subsequent increase in zero flow periods is likely to stress plants in locations where groundwater is predicted to be drawn down by up to around 4 m in the near vicinity of the river. In the 800 m stretch where drawdown of between 1 and 4 m are predicted, these changes are likely to result in the death of some or all of the canopy trees (probably after a period of some years of slow decline). It is also possible that some individual trees may be adversely affected in the eastern half of the Project (Mine) Area. River red gums are less affected by changes in base flow than by changes in depth to watertable (Rogers and Ralph, 2011), and are not expected to be affected significantly by the base flow changes due to the relatively low change predicted in the depth to the watertable. Some paperbark species are also known to be more sensitive to changes in groundwater depth than base flow (Eamus et al., 2006). As the eastern section of the Carmichael River within the Project (Mine) Area is mostly predicted to experience reductions in base flow rather than increases in depth to the water table, it is likely that only the waxy cabbage palm will be impacted significantly in this section. Adani have committed to carrying out an extensive program of ecological and hydrogeological monitoring along the Carmichael River as detailed in the Groundwater Dependent Ecosystem management plan to provide additional information on riparian vegetation health.
d. There is a degree of uncertainty in the flood model predictions due to the paucity of temporal and spatial gauging data;	The Tuflow hydraulic model of the Carmichael River will be validated against the two new monitoring stations on the Carmichael River prior to final design.

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e. The source aquifer for the Mellaluka Springs Complex has not been identified and as such it is not possible to accurately predict impacts from mining on these springs	See GHD Response Letter Section 1.3. Adani has made a commitment to determine the Mellaluka springs source aquifer. Full details of further ecological and hydrogeological monitoring and further drilling to be undertaken by Adani at the Mellaluka and Doongmabulla spring complexes springs is provided in the Groundwater Monitoring Plan and Groundwater Dependent Ecosystem Management Plan. Data collected during these investigations will be used to confirm: — The most likely source of each spring; — Baseline ecological and hydrogeological conditions; — The sensitivity of each individual spring vent to groundwater level drawdown impacts; and — Appropriate mitigation and management measures.
f. The proposal assumes that that the six post mining voids are expected to remain dry (assuming that evaporation will exceed groundwater inflow) but the Committee considers that there is still potential for the voids to gradually fill with water, particularly after prolonged heavy rainfall events, and as such there could be potential risks to nearby surface water and groundwater resources as a result of degraded water quality; and	Further detailed water balance calculations for the post closure voids (see Attachment 8) have been undertaken based on the complete historic climate record which includes a rainfall event of between 1:100 and 1:200 event over a 3 month period. Based on this historical data set, it is extremely unlikely that a discharge to surface water courses is anticipated post closure. Furthermore given that ongoing evaporation from the pits will maintain groundwater flow towards each void no impacts on groundwater quality outside of the proposed voids are anticipated irrespective of the quality of water stored within each pit.
g. A discharge strategy containing sufficient information to understand the risks to aquatic ecology and water quality has been not provided in the draft SEIS	Mine water discharge requirements will be imposed by the QLD Department of Environment and Heritage Protection under an Environmental Authority (EA) for the operation of the mine. The EA will include an appropriate discharge strategy in relation to the receiving environment including constraints on the quality of discharge, the timing of discharge, the volume of discharge and the rate of discharge. These conditions are established in order to permit only acceptable harm to downstream environmental values which includes ecological values and water quality values.
Question 5: Are there additional measures and commitments required to monitor, mitigate and manage impacts resulting from changes to surface or groundwater resources?	
19. Although a number of management strategies are proposed to minimise the impacts of the proposal, due to the scale of this project, there will be both unavoidable and permanent impacts that are unlikely	Adani has adopted a hierarchy throughout the project, in line with EIS guidelines to: 1. Avoid wherever possible impacts to environmental and other values, 2. Where impacts are unavoidable, seek to mitigate actions in order to reduce the severity of those impacts, and

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to be adequately mitigated.	3. Where there are unavoidable residual impacts, seek to provide Offsets or other arrangements under relevant State and Federal policies. Where there is an unavoidable impact requiring an offset, this has already considered the potential application of mitigation measures. Therefore, the IESC comment that unavoidable or permanent impacts are unlikely to be adequately mitigated, is inconsistent with the EIS guidelines under which Adani has prepare the EIS and AEIS.
20. Groundwater Modelling: Due to the lack of confidence in the current groundwater model predictions, the model needs to be revised, as discussed in paragraph 12, to adequately understanding of the proposal's impacts to groundwater and inform appropriate mitigation and management measures	See response to item 12. Further revisions to the groundwater model will be considered during the operational stage when additional drilling and monitoring data is available.
21. ***Water Balance***: To assess the impacts of the proposed water management strategy on receiving environments, future iterations of the site water balance model should assess all changes to stores and flows of water in the system, with consideration to seasonal variation, longer-term climatic scenarios and the staged project plan. The Committee recommends the following refinements to the model input parameters:	
a. Parameters assigned for the runoff model should be calibrated using regional stream gauging data if there is limited stream flow data available for the site;	Calibrating to regional gauging data will provide no benefit as no natural catchments are included in the water balance model. The catchments modelled are disturbed areas which contribute either mine affected or sediment affected water to the system. The parameters for these are consistent with those used at coal mines across eastern Australia and have been confirmed as being appropriate by Engeny's peer review. Calibration of the adopted parameters will occur when the mine is operational and Adani are able to measure runoff generated from these areas.
b. The total for runoff, seepage losses, and water demand for dust suppression should be presented with consideration of seasonal and long-term climate variations;	Water volumes for runoff, seepage losses, and dust suppression are presented in Sections 3.3.3, 3.4.4 and 3.4.2 respectively of the SEIS Appendix K2. Seasonal climate variation has been incorporated into the model using the method described in Section 3.2 Appendix K2. Sensitivity testing of long-term climate variations will be incorporated during refinement of the water balance model once the water management system for the mine site is confirmed.

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c. The volume of evaporation losses from the mine should be presented with consideration of storage characteristics (storage size and water depth), and seasonal and long-term climate variations;	Evaporation losses incorporating storage characteristics are presented in Section 3.4.1 of the SEIS Appendix K2. Seasonal climate variation has been incorporated into the model using the method described in Section 3.2 Appendix K2. Sensitivity testing of long-term climate variations will be incorporated during refinement of the water balance model once the water management system for the mine site is confirmed.
d. The total water demand for the mine water operation rather than the net demand should be estimated;	Adani has confidence in the water assessments provided in the SEIS. However, in response to submissions made, the details and assumptions in the identified reports are being reviewed. This review is expected to result in lessened overflows, discharges and impacts when compared with those stated in the AEIS. The timing of these releases will be correlated to the timing of flows in the Carmichael River (e.g. high rainfall events), to meet the water quality objectives of an environmental authority (as referenced in Appendix C6).
e. Other internal water movements, such as return water from the tailing facilities, need to be taken into account;	Return water from the tailing facility is included in the model as per the two scenarios listed in Section 3.4.6 of the SEIS Appendix K2.
f. External water demands and discharge requirements should be presented with consideration of seasonal variations and long-term climatic scenarios to provide an understanding of the potential magnitude of water demand in dry seasons, and release and overflow scenario during high rainfall wet seasons; and	External water demands and discharge requirements with consideration of both seasonal climate variation and long-term climate variations will be incorporated during refinement of the water balance model once the water management system for the mine site is confirmed.
g. For significant mining horizons, information should be presented to provide an understanding of the relative magnitude of water demands and discharge requirements during various mining stages.	The water balance model was run using the mine stages shown in Appendix A of the SEIS Appendix K2 document. The results for external raw water demand and discharge from the central MAW dams are presented in Section 5.2 and Section 5.7 of the SEIS Appendix K2.

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22. ***Springs***: The proposal indicates that any impacts to the Doongmabulla Springs Complex are likely to fall within the range of seasonal fluctuations to which the springs are already adapted. Based on the previously covered lack of confidence in the groundwater model to predict impacts, and the ecological significance of the Doongmabulla Spring Complex there is the need to put in place more than just monitoring, but also mitigation strategies to manage potential impacts to the springs should these be greater than currently predicted. Once the groundwater model has been revised (as recommended in point 12) the proponent should revise the impacts analysis and proposed mitigation.	See response to item 12. Further revisions to the groundwater model will be undertaken during the operational stage when additional data is available during construction and operations. Furthermore as outlined in Sections 3.5 and 3.6 of the Mine Hydrogeology Report Addendum impacts have been calculated based on a wide range of possible alternative parameter sets. It should also be stressed that all model predictions including the worst case scenarios 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. 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. A validation monitoring program will be implemented for the life of the mine. This will consider the mine plan and predicted drawdown impacts so as to allow for the monitoring bore network to be augmented or replaced over time as mining progresses to the west. During the operational period, predicted drawdown contours will be used at regular intervals (for example 10 years) to show the proposed monitoring locations and units over time. These data will be used to validate and update the predictive groundwater model. During operations the groundwater monitoring network will provide for VWPs to be constructed along the CCP boundary to enable the assessment of groundwater level decline over time, as envisaged in the predictive modelling. Threshold levels, set based on predictive modelling, will provide early warning before groundwater levels decline within the unconfined aquifers, such that potential impact on the vegetation (sensitive and groundwater dependent ecosystems) could occur.

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23. The proposal has predicted adverse impacts at the Mellaluka Spring Complex, including loss of all ecological function due to a maximum predicted drawdown of up to 8.22m during the mine's operational phase and up to 25.6m post-closure. Proposed mitigation measures include the manual pumping of groundwater to the surface to offset the loss of flows to spring-fed wetlands. The proponent also proposes to prepare a wetland remediation and management plan when drawdown commences. The Committee considers that detailed consideration of mitigation and management measures at the Mellaluka Springs Complex should be carried out prior to the commencement of mine operations and include comprehensive ecological and water quality studies. It would be important to determine and characterise the source aquifer for the Mellaluka Springs Complex to determine the effectiveness of mitigation measures.	See GHD Letter Response Section 1.3 and response to Item 18e. Adani is committed to collecting further time series groundwater level and groundwater quality data to confirm the source aquifer for the Mellaluka springs. Full details of further ecological and hydrogeological monitoring and further drilling to be undertaken by Adani at the Mellaluka and Doongmabulla spring complexes springs is provided in the Groundwater Monitoring Plan and Groundwater Dependent Ecosystem Management Plan. Data collected during these investigations will be used to confirm: — The most likely source of each spring; — Baseline ecological and hydrogeological conditions; — The sensitivity of each individual spring vent to groundwater level drawdown impacts; and — Appropriate mitigation and management measures.
24. Further mitigation actions for both springs complexes could include:	
a. Identifying suitable trigger levels, the rationale for deriving the trigger levels and a response strategy for managing the resultant impacts; and	Suitable trigger levels have been identified as part of the Groundwater Monitoring and Groundwater Dependent Ecosystem Management Plans. Groundwater level decline thresholds will also be developed for early warning bores between the mine workings and the springs, as detailed in the Groundwater Monitoring Plan.
b. Reference and adopt the monitoring and mitigation measures applied in conditions for the three previously Commonwealth approved coal seam gas to liquefied natural gas projects in the Surat Basin.	Appropriate monitoring and mitigation measures relevant to the specific impacts for this Project have been included in the Groundwater Monitoring and Groundwater Dependent Ecosystem Management Plans. Requirements imposed on another industry in a different region are not considered relevant to this Project.

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25. ***Groundwater***: The development of a Groundwater Monitoring Plan to build and update information on the current monitoring network would be beneficial. This Plan would need to address the significant uncertainties that exist within the groundwater model (discussed in responses to Question 2 and 3). The Plan should consider the inclusion of additional groundwater monitoring locations to the west of the mine site to specifically monitor the drawdown in the GAB units (including the Rewan Formation) and the Doongmabulla Springs Complex. Should drawdown levels alter from the predicted levels the potential impacts and required mitigation measures should be reassessed.	Proposed additional monitoring points to the west of the Mine Area are included in the Groundwater Monitoring Plan (Table 5-10). Further ecological and hydrogeological monitoring of the Doongmabulla and Mellaluka springs complexes forms part of the Groundwater Dependent Ecosystem Management Plan.
26. Groundwater Dependent Ecosystems (GDE): The proponent intends to provide a GDE Management Plan prior to commencement of mine operations. The Plan should determine the efficacy of mitigation and management options proposed to reduce impacts on the 831 EPBC listed Waxy Cabbage Palms.	Groundwater Dependent Ecosystem Management Plan provided
27. The proponent intends to monitor the health of the riparian vegetation, including groundwater dependent ecosystems such as the River Red Gums and Paper Bark. The proponent has provided limited management measures in the event that the health of these species declines as a result of the permanent reduction in groundwater discharge to the Carmichael River. The proposed management measures should address the impacts arising from predicted dieback of riparian vegetation.	Mitigation and management measures to address riparian vegetation are provided in the Carmichael River subplan within the GDE management plan. Management, mitigation and corrective measures address impacts from habitat fragmentation and changes to hydrology on riparian vegetation. Proposed monitoring is also included in the GDE Management Plan.
28. ***Water Quality***: The following management plans would further improve the development of appropriate mitigation and management measures:	

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a. To ensure effective and environmentally sustainable outcomes from controlled and uncontrolled mine releases, it would be expected that the proponent would develop a mine water Discharge Strategy, which would take account of the volume and timing of controlled and uncontrolled discharges, specific discharge scenarios and seasonal variations. Management measures within site specific Management Plans will need to reflect the risks identified within the Discharge Strategy and the site water balance should also be updated to account for both controlled and uncontrolled releases;	The Surface Water Management Plan to be developed during the detailed design stage will outline the volume and timing of controlled and uncontrolled discharges of mine affected water, specific discharge scenarios and seasonal variations to prevent potential impacts on surface and groundwater quality. This will be developed prior to the consideration of the application for the environmental authority.
b. The proponent commits to providing a Site Water Management Plan and Receiving Environment Management Plan. The project would benefit from a surface water monitoring program to assess background hydrological and water quality conditions, inter-annual and seasonal variation, and the effectiveness of mitigation and management measures. The monitoring program should be robust to enable early detection of impacts arising from mine operations and identification of the cause of any change from baseline conditions or water quality / hydrological objectives and be consistent with the National Water Quality Management Strategy;	A surface and groundwater monitoring program has been developed which will provide baseline conditions, water quality objectives and be consistent with State and national water quality guidelines and strategies
c. Revise the site specific Water Quality Objectives (WQOs) for the sub-catchment with additional seasonal data to meet a minimum of two years' contiguous monthly data and give consideration to developing trigger values that represent the strong dry and wet seasonal periods. The four sampling locations used to derive the WQOs are largely within (or very close to) the project boundaries. The Committee considers that additional upstream and downstream sampling along the Carmichael River would strengthen the effectiveness of the monitoring	The SEIS Mine Water Quality Report (Volume 4, Appendix K3) provides an update of surface water quality assessment of the Project (Mine). A combination of desktop and field assessments were undertaken to describe the existing surface water resources that may be affected by the Carmichael Coal Mine and Rail Project in the context of environmental values. Information from that report was used to develop the surface and groundwater monitoring programme.

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network.	
29. ***Void Management***: The management of the voids could be further strengthened by providing a Mine Void Management Plan, which would be expected to be developed prior to completion of mining in the first pit. This Plan should consider aspects such as groundwater hydrology and properties, surface water hydrology and include measures to minimise potential impacts associated with the final void. In the Final Void Management Plan, the proponent should demonstrate that impacts to water resources are mitigated and managed in perpetuity where backfilled voids are not part of the final landform and consider options for the post-mine use.	In accordance with the IESC's advice, Adani has proposed to prepare a Final Void Management Plan before closure of the pits as one of the draft EA conditions.
30. Further assessment, taking into account seasonal and climatic variations (i.e. high rainfall and flooding) would be beneficial to assess final void water levels and the likelihood of the final voids to discharge water into surface water and groundwater system. Given the scale of the project, the accumulation of salt and other potentially harmful constituents identified in the final voids should be modelled to inform adequate mitigation and management measures.	Further detailed water balance calculations for the post closure voids (see Attachment 8) have been undertaken based on the complete historic climate record which includes a rainfall event of between 1:100 and 1:200 event over a 3 month period. Based on this historical data set, it is extremely unlikely that a discharge to surface water courses is anticipated post closure. Furthermore given that ongoing evaporation from the pits will maintain groundwater flow towards each void no impacts on groundwater quality outside of the proposed voids are anticipated irrespective of the quality of water stored within each pit.
31. ***Mine waste management plan***: Future revisions to the mine waste management plan should be undertaken to take into consideration the management and handling of overburden material, soil testing to characterise overburden and a robust monitoring network for migration of acid, saline or metaliferous drainage.	Noted.

ISSUE	RESPONSE
32. ***Flood modelling data***: Utilise additional data from the two new monitoring stations installed within the Carmichael River as it becomes available, to update/validate the flood model predictions. The flood model should be updated prior to the final design of the flood levees to ensure that the planned height remains sufficient to protect mining areas from a 1:1000 ARI event. This is particularly important given the significant seasonal and climatic variability in the region.	The Tuflow hydraulic model of the Carmichael River will be validated against the two new monitoring stations on the Carmichael River prior to final design of the flood levees.
33. ***Water Supply***: In future planning and design the proponent could investigate the feasibility of onsite treatment and reuse of 'mine affected water' to reduce the volumes required to be harvested from the downstream Belyando River and to reduce the need to discharge 'mine affected water' during high flows.	The feasibility of onsite treatment to allow for reuse of the mine affected water will be assessed as part of the future planning and design with the aim of minimising water demand from the Belyando River and minimising discharge from the central MAW dams.
Question 6: Given the impacts to the Carmichael River identified by the Interim Committee, are the proposed mitigation and management measures adequate?	
34. The Carmichael River will be adversely affected by a reduction in catchment size and reduced groundwater discharge to the river due to drawdown, and this is predicted to increase no-flow periods and compromise the ecosystem health in the riparian zone. Reduced groundwater discharge and water table drawdown will also adversely affect groundwater dependent ecosystems and species, and is predicted to lead to mortality and decreased spatial extent of the vulnerable Waxy Cabbage Palm.	No response required

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ISSUE	RESPONSE
35. Management measures that address the risks (i.e. changes to spawning, feeding, and breeding) to individual species as a result of predicted reduction of flows to the Carmichael River, and the predicted increase in flood levels, would better mitigate impacts. These management measures should take into consideration any uncertainties within the hydrological and flood modelling.	The flow regime of the Carmichael River is subject to seasonal variability. Late in the dry season the Carmichael River is reduced to a low flow environment, interspersed with deeper pools. Monitoring of fish and macroinvertebrates distribution and abundance within the Carmichael River is proposed within the GDE Management Plan. This information will confirm the individual species present, their hydrological requirements and whether changes in the flow regime will impact these species. A flood inundation assessment has been conducted post SEIS with the majority of the predicted changes in inundation duration are of less than 12 hours. These changes were not assessed as significant.
36. The Carmichael River is the southern limit of the Waxy Cabbage Palm. All populations of this species occur in areas of remnant vegetation (Vegetation Management Act 1999 Qld) and are therefore currently protected from broad scale clearing. The proponent intends to monitor the health of riparian vegetation, and limited management measures have been provided in the event of decline in vegetation health. Translocation of the Waxy Cabbage Palms is mentioned but this may not be feasible and is an unproven technique. The Committee investigation of the water requirements of this species, and monitoring of changes to groundwater and baseflow in the Carmichael River, with consideration of management options.	Mitigation and management measures to address riparian vegetation and waxy cabbage palms are provided in the Carmichael River and Waxy Cabbage Palm sub-plans within the GDE Management Plan. Management, mitigation and corrective measures address potential impacts from habitat fragmentation and changes to hydrology on riparian vegetation. Proposed monitoring is also included in the GDE Management Plan.
37. The draft SEIS states that water may be pumped to the Carmichael River channel near the upstream mine area boundary during dry periods to mitigate the impact of drawdown on the Carmichael River. Proposed mitigation measures could be further improved by better understanding aspects of natural flow regimes and ecological water requirements. Specific water quality standards and potential water treatment of discharge should also be considered when baseflows are likely to be low or nil, as this can lead to reduced dilution factors. Given that groundwater drawdown impacts are generally predicted to increase post closure, options for post-	Monitoring of flow and aquatic ecosystems in the Carmichael River during the pre-construction, construction, operation and post operation periods is proposed in the GDE Management Plan and Groundwater and Surface Water Monitoring Programs. The quality, quantity and conditions under which water to the Carmichael River is discharged will be specified in the environmental authority. Measures outlined in the Surface Water Management Plan to prevent potential impacts on surface and groundwater quality will be implemented. The closure and rehabilitation strategy includes post closure groundwater modelling to be conducted at least 2 years prior to closure to confirm and/or validate predicted impacts and inform ongoing mitigation measures and the need to have agreements in place with affected parties prior to the post operational phase in regards to groundwater flow impacts.

ISSUE	RESPONSE
closure flow supplementation should also be taken into consideration.	
Question 7: The proponent has concluded that there is a low risk of direct hydraulic connection between the surface and the coal seam as a result of subsidence, and has therefore concluded that the GAB will not be impacted. Does the Committee agree with this conclusion?	
38. Subsidence induced fracturing has the potential to impair the capacity of the Rewan Formation to present a barrier to groundwater flow from the GAB units to the underground workings.	See GHD Letter Response Section 2.3. No direct simulations of the sensitivity of model prediction to potential variations in the height of the free draining fracture zone have been undertaken to date. However, given that other models identified by MSEC resulted in free draining fracture zones of as low as 58 m above the extracted seam. The 160 m value recommended by MSEC is considered to be conservative. Furthermore, 'worst case' predictions of impacts on the Doongmabulla spring complex and GAB are based on vertical hydraulic conductivity values for the Rewan Group of $1x10^{-2}$ m/d inside of the predicted free draining fracture zone and $1x10^{-3}$ m/d outside. Given the large number of low-permeability clay, claystone or siltstone horizons logged within the Rewan Group, the chances of the bulk vertical hydraulic conductivity of this formation approaching $1x10^{-3}$ even in a scenario where the full thickness of the Rewan Group is fractured by longwall mining operations is considered remote. For instance Domenico & Schwartz (1990) quote maximum upper bound values for fractured siltstone of $1x10^{-3}$ m/d and $4x10^{-4}$ m/d for clay (i.e. values which are the same or lower than the 'worst case' values for the Rewan Group which have already been considered).
39. The groundwater model predicts an increase in net leakage through the Rewan Formation post mining. Even a minor increase to vertical conductivity has the potential to affect post closure leakage rates and result in permanent impacts on groundwater resources and GDEs.	Predicted impacts on leakage from the GAB through the Rewan Group based on a wide range of possible values for the vertical hydraulic conductivity of the Rewan are reported in Section 3.6.1 of the SEIS Mine Hydrogeology Report Addendum. However, Adani has also developed a GDE Monitoring Program, to monitor the health of ecosystem and apply necessary mitigation measures.

ISSUE	RESPONSE
40. The Committee supports the recommendation outlined in the draft SEIS that a detailed assessment by an appropriate specialist groundwater consultant be undertaken on the potential hydraulic connectivity of the subsidence fracture networks. A monitoring program should consider sensitive ecological receptors and be established prior to mining in higher risk areas close to the GAB boundary or the Carmichael River riparian corridor. Additional monitoring bores should also be installed in the Clematis Sandstone.	Refer to SEIS EMP for the Mine Adani has conducted additional drilling and aquifer testing within the underground mine footprint. This data plus additional geotechnical assessments, using SCT a specialist geotechnical firm, will be used to construct and calibrate a numerical groundwater model to assess the impacts on aquifer parameters due to longwall mining. This modelling will allow for the assessment of groundwater ingress and provide input into the existing regional EIS model. The draft Groundwater Management Plan includes for the construction of additional monitoring points to the west of the mine footprint, within the Dunda Beds and Clematis Sandstone, as well as along the Carmichael River.
Question 8: Are the proposed management responses to subsidence adequate? If not, are there additional measures and commitments required to mitigate and manage impacts to listed threatened species and communities as a result of subsidence?	
41. The proponent acknowledges uncertainty in the predictions of the hydraulic conductivity of the subsidence induced fracture network, and the height above mining within which direct hydraulic connection with mine workings may occur, and this creates uncertainty in relation to the likelihood of direct hydraulic connectivity between the coal seam, GAB Formations, and the ground surface.	See GHD Letter Response Section 2.3 and response to item 38 above.
42. The project would benefit from additional consideration of ponding impacts to watercourses and proposed management responses. Significant areas of subsidence ponding are predicted and further consideration of the effects of ponding on post-mining stream catchment extent, on surface water flow, or on natural flooding regimes would be beneficial in identifying and managing potential impacts. The effectiveness of mitigation measures already proposed, including draining subsidence ponds, and in some cases, diversion of watercourses, should also be evaluated and demonstrated through	A draft Subsidence Management Plan (SMP) has been developed to address potential environmental impacts from the underground operations of the mine. The SMP was prepared as part of the Supplementary EIS to provide control, mitigation and management measures for subsidence impacts on State Significant Biodiversity Values (SSBV) and Matters of National Environmental Significance (MNES). This is a working draft document that will be updated as the Project progresses to detailed design. A finalised SMP will be developed for approval prior to the commencement of underground mining activities. In addition, an evaluation of ponding and inundation duration within the Carmichael River floodplain as a result of the Project (Mine) has been presented in the Carmichael River Flood Inundation Report, provided to the Office of the Coordinator General on the 28th January 2014.

ISSUE	RESPONSE
surface water modelling.	
43. A large portion of the area predicted to be subject to subsidence represents potentially suitable habitat for four threatened species confirmed present or likely to be present. These include the Black-Throated Finch, the Squatter Pigeon, the Yakka Skink and Little Pied Bat. Ecological impacts should be accurately assessed in important habitat areas where impacts to surface water resources may affect habitat stability and utilisation by these species.	The draft Subsidence Management Plan (SMP) details the subsidence impact areas for each environmental value, including potential habitat for individual species. Total impacts have been tabulated and graphically represented in the assessment of impacts. Control, mitigation and management measures for the described subsidence impacts have been included within the SMP.
44. The proposed application in the Galilee Basin of NSW and Bowen Basin parameters for subsidence in a different geological setting increases the level of uncertainty in relation to subsidence predictions.	In the absence of any operational mines in the Galilee Basin, information on subsidence due to current longwall operations in the Bowen Basin represents the best available source of information on likely subsidence. In any case the authors of the subsidence assessment (MSEC, 2013, see SEIS Appendix I1) identify the height of the free draining fracture zone appears to be dependent on a range of site specific factors, including: • the longwall panel width • the seam thickness extracted • the thickness and geomechanical properties of the overlying strata units • the presence of faults and natural jointing • the presence of low permeability layers that can restrict the vertical flow of groundwater; and • in some cases the bulking and compaction factors of the goafed material (MSEC, 2013) MSEC used a number of different models to predict the height of the free draining fracture zone above the uppermost extracted seam at the Carmichael Coal project. Estimates ranged from 58 to 160 m above the extracted seam. Recognising that these estimates are based on single seam extraction MSEC recommended adoption of the upper bound estimate of 160 metres based on the model developed by Klenowski (ACARP C5016, 2000). In terms of the enhanced permeability factors which apply within this free draining fracture zone MSEC recommended adoption of the factors calculated by Guo et el (ACARP C14033, 2007). Given the range of factors which govern development of the fracture zone and the highly variable nature of the overlying strata the authors indicate that verification of the predicted height of fracturing and the enhanced permeability factors can only be provided by monitoring of subsidence groundwater levels and permeability at selected horizons both before and after mining.

ISSUE	RESPONSE
45. Given the predicted impacts of the proposal on baseflows in the Carmichael River, and the uncertainty regarding the degree of hydraulic connectivity within the subsidence fracture zone, the Committee considers that an assessment of potential impacts of subsidence fracturing on groundwater-surface water interactions in the vicinity of Carmichael River is needed. The assessment should target potential impacts in the western portion of the mining lease where base flow contribution from groundwater is expected to be retained post mining.	Subsidence modelling results suggest that the proposed stand off distances from the Carmichael River will be sufficient to prevent any subsidence along the river corridor (Revised Subsidence Assessment Report MSEC, 2013, SEIS Appendix I2). Given the distance of the proposed panels from the river then the uncertainty regarding the vertical extent of the zone of induced fracturing has little or no bearing on the probability of subsidence zones extending to the Carmichael River. As shown in the MSEC report (SES Appendix I2) predicted subsidence zones extend only a few metres outside of the proposed longwall panels and hence there is considered to be limited prospect of subsidence zones extending laterally as far as the Carmichael River.
46. Where impacts to threatened species and ecological communities are predicted, including communities supported by the natural discharge from springs, further mitigation options (including alternative mining methods) may need to be considered, such as narrower longwalls, or mining methods with lower subsidence impacts. Various studies and guidelines exist for mining under water resources.	Subsidence modelling results confirm proposed stand off distances from the Carmichael River will be sufficient to prevent any subsidence along the river corridor (Revised Subsidence Assessment Report MSEC, 2013, SEIS Appendix I2). Given the distance of the proposed panels from the river then the uncertainty regarding the vertical extent of the zone of induced fracturing has little or no bearing on the probability of subsidence zones extending to the Carmichael River. As shown in the MSEC report (SES Appendix I2) predicted subsidence zones extend only a matter of a few metres outside of the proposed longwall panels and hence there is considered to be little or no prospect of subsidence zones extending laterally as far as the Carmichael River. In relation to potential impacts associated with groundwater drawdown, a groundwater dependant ecosystem management plan has been prepared and submitted which identifies further mitigation measures.

Attachment 7. GHD Memo responding to IESC Comment 3c

Memorandum

31 January 2014

To	Keith Phillipson		
Copy to	Philip Bradley		
From	Stuart Winchester	Tel	02 9239 7337
Subject	IESC questions on Carmichael SEIS	Job no.	41 26422

Keith,

As discussed on the phone yesterday, 30 January 2014, please find below a brief response to the IESC's question 1 (3) (c) being:
Assessment of the overburden materials for the potential to produce acidity and salinity in the final void has only partially been addressed.
The ability of overburden material at the proposed Carmichael Mine to produce acidity and salinity in the final void is to a large extent, a combination of the final landform design, the hydrology, the post-mining hydrogeological rebound, and the geochemistry of the overburden material. The final landform design, the hydrology, and the post-mining hydrogeological rebound have been addressed in the Carmichael Supplementary Environmental Impact Statement (SEIS). In order to assess the potential for the overburden materials to produce acidity and salinity, which may ultimately report to the final voids as a function of the other factors noted above, Adani commissioned a study of the overburden geochemistry.
The stages of reporting with respect to the overburden geochemistry study were / are progressive; largely a function of scheduling interactions between the on-site exploration drilling program, and the subsequent availability of overburden geochemical samples, and the various milestones within the overall planning and approvals process.
The reports were / are:

1. Carmichael Project: Mine Waste Acid and Metalliferous Drainage and Dispersive Materials Assessment. (SRK Consulting, November 2012). This document was included as an appendix to the Carmichael Environmental Impact Statement (EIS) and reported on the environmental geochemistry of 100 primary mineral waste samples from the over and interburden.
   This report is publically available at: http://adanimining.com/EIS_PDFDocs_Listing.aspx.
2. Carmichael Coal Mine and Rail Project: Mine Waste Characterisation (SRK Consulting, August 2013). This document was included as an appendix to the Carmichael SEIS and update the EIS report by reporting on the environmental geochemistry of an additional 370 primary mineral waste samples from the over and interburden.
   This report is publically available at: http://adanimining.com/SEIS_PDFDocs_Listing.aspx.
   The SEIS report included initial commentary on a kinetic geochemical column leach program that had been commissioned to compliment the completed and reported static geochemical test program. The kinetic leaching program would assist with better predicting the risk of mine inter and overburden generating acidity and/or salinity once stored long term in waste rock dumps. SRK's August 2013 report noted that:
   Kinetic testing commenced in May 2013 and should be continued to determine the rates of oxidation, acid generation, acid neutralisation and metal leaching rates. The measured rates can then be used to complete water quality predictions and infer potential impacts on receiving water quality. These estimates would also be used to identify suitable mitigation and environmental management measures that would address any issues that may be of significance.
3. Report for Mine Waste Management Strategy (GHD, 18 October 2013). This document was included as an appendix to the Carmichael SEIS, and discussed the environmental

geochemistry of the proposed Carmichael tailings management strategy as it interfaced with the over and interburden management. Specifically, Adani propose to store dried tailings in cells within waste rock dumps D and E; this report discussed the potential for the tailings surrogates to produce acidity. This report is publically available at: http://adanimining.com/SEIS_PDFDocs_Listing.aspx.

4. Project Memo from SRK Consulting, November 2013. Memo provided additional information on the environmental geochemistry of the first six months of kinetic testing, which helps inform drainage water quality. The memo summarises results of the first 6 months of kinetic testing, with recommendations to continue 6 of the 10 columns. This memorandum is attached for your information as Attachment 1.
5. Carmichael Dam Water Quality (GHD, January 2014). This memorandum was prepared to assist with categorising the environmental dams at Carmichael with reference to drainage water quality; in particular, the mine water impacted dams drainage the waste rock dumps. This memorandum is attached for your information as Attachment 2.

The next commissioned report will be an update of the Carmichael Coal Mine and Rail Project: Mine Waste Characterisation 1 (SRK Consulting, October 2013) that will be updated to include all kinetic leach column results.
All reports would inform the risk of overburden material at the proposed Carmichael Mine producing acidity and salinity in the final voids.

Please advise if you require additional information.

Regards,

Dr Stuart Winchester
Principal GeoEnvironmental Scientist

Attachments:
1. SRK Consulting (November 2013) – Carmichael Geochemical Characterisation: Recommendations for continuation of 10 kinetic columns.
2. Carmichael Dam Water Quality (GHD, January 2014).

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Project Memo

Client:	GHD Australia	**Date:**	15 November 2013
Attention:	Stuart Winchester	**From:**	Andrew Garvie
Project No:	GHD002	**Revision No:**	0
Project Name:	Carmichael geochemical characterisation		
Subject:	Recommendations for continuation of 10 kinetic columns		

1 Purpose

This memorandum makes recommendations on whether to stop or continue the operation of kinetic columns after 20 weeks of operation.

2 Background

Ten kinetic columns are being operated as part of the geochemical characterisation of materials that will be mined at the Carmichael Project. The objective is to estimate acid production and neutralisation rates, and metal release rates from waste and coal samples. In general, it may be necessary to operate a column for many months, or sometimes years, to obtain data necessary to assess the potential future water quality at a mine site. The duration of operation of an individual column is dependent on the time taken for leachate characteristics to stabilise and indicate the long-term rates of reaction and metal release.

As at 8 October 2013, columns had operated for 20 weeks. Leachate and sample characteristics have been reviewed to determine whether any columns can be stopped.

3 Summary of Test Outcomes

In addition to the kinetic tests, supplementary static tests were conducted. These tests included measurement of the net acid generation (NAG) potential, chromium reducible sulfur (CRS) content and neutralisation potential by determination of the acid buffering characteristic curve (ABCC). The CRS was used to estimate the acid potential.

The CRS acid potential, NAG test results and the ABCC-derived neutralising potential (to pH 6) were used to classify the samples according to methods described in Price, 2009 (based on the net potential ratio) and AMIRA, 2002 (based on the NAG pH combined with net acid producing potential, NAPP).

For each column, the sulfate release rate determined for the column leachate and the acid potential from the CRS were used to estimate the time to deplete the acid potential. Similarly, the time to deplete the neutralisation potential was estimated from the neutralising potential to pH 6 and the rate of leaching of calcium and magnesium. Here it was assumed that the neutralising minerals were calcium and magnesium carbonates.

Table 3-1 presents a summary of sample characteristics and test outcomes for each column. At the end of 20 weeks of column operation, leachates for C1 and KT3 had dropped below 6 and were trending towards becoming acidic. This is consistent with the PAF classification of these samples and suggests that the neutralising potential is being depleted. The other leachates were circum-neutral to alkaline. Figure 3-1 compares the sulfate release rates and pH values of column leachates.

The concentrations of major ions and trace elements in the leachates were monitored and used to calculate release rates. In some columns, release rates show an increasing trend, e.g. Al in column C4 and Ca, Sr, Mn, Ni and Co (column KT3).

Typically, element release rates would be expected to increase as pH of the pore water of the column decreased (due to the higher solubility of many elements under acidic conditions). Therefore, if the pH of some leachates continues to decrease, the release rates may continue to increase. Perhaps this is most likely in the near term for columns C1, C2 and KT3. Monitoring these changes would improve the estimates of release rates used in future water quality assessments for the site by extending the range of geochemical conditions represented.

An assessment of the benefits of continuing to operate the columns was undertaken. For each column the factors used in the assessment included:

- Trends in the leachate pH
- Acid potential
- Sample classification
- Depletion times of the acid and neutralisation potentials.

It is recommended that the four columns are stopped and the operation of six columns is continued for another 20 weeks. After 20 weeks, the leachate characteristics should be reviewed again. Recommendations for the operation of each column, along with justifications, are summarised in Table 3-2.

Table 3-1: Summary of Column Characteristics

Column ID	Lithology	Sample Characteristics									Column Outcomes		
		Calcite	S% from pyrite	CRS	ABCC to pH 6	NAPP (CRS & ABCC pH 6)	NPR (CRS & ABCC pH 6)	NPR Class	NAG pH	AMIRA Class	Leachate pH	CRS AP Depletion time,	ABCC Depletion time
		%	%	%	kg H2SO4/t				pH Unit			years	years
C1	Sandstone		0.37	0.33	0.015	10.08	0.001	PAF	3.1	PAF	7.7 to 4.91	12.8	0.0
C2	Carb Siltstone		0.33	0.199	0.11	5.98	0.02	PAF	3.8	PAF	8.0 to 6.5	2.0	1.7
C3	Carb Mudstone	0.6	0.09	0.043	1.9	-0.59	1.45	UC	4.9	NAF	7.9 to 8.3	23.9	13.4
C4	Siltstone			<0.005	0.7	-0.62	9.15	NAF	7.2	NAF	Stable at ~ 8	0.2	9.5
C5	Carb Mudstone			0.032	0.38	0.60	0.38	PAF	4.7	UC(NAF)	Stable at ~ 7	3.0	2.8
KT3	Carb Mudstone			0.048	0.12	1.35	0.08	PAF	6.6	UC(NAF)	Decreased 6.8 to 5.5	5.2	1.1
KT4	Coal			0.049	1.56	-0.06	1.04	UC	4.4	UC(PAF)	Decreased to 7.3	47.1	27.5
KT6	Siltstone	1.0	0.37	0.299	7	2.15	0.77	PAF	5.7	UC(NAF)	pH stable 7.3	8.0	6.8
KT7	Carb Siltstone		0.00	0.005	0.1	0.05	0.65	PAF	4.3	PAF	pH stable 7.1	4.7	1.3
KT8	Coal		0.00	0.01	3.95	-3.64	12.91	NAF			pH stable 7.5	13.5	46.6

PAF = potentially acid forming, UC – uncertain, NAF = non-acid forming

Table 3-2: Recommendation for continuation of columns

Column ID	Recommendation	Justification
C1	Continue	Leachate pH is trending downward; if this trend continues, the metal and sulfate release would likely increase and this should be measured.
C2	Continue	To determine whether the sulfate release rate and, by implication, the acid production rates are decreasing and/or possibly observe the column leachate become acidic.
C3	Continue	To obtain longer term data on metal release rate variability.
C4	Continue	To obtain longer term data on metal release rate variability.
C5	Stop	pH and metal release rates are relatively stable. The acid potential of this sample was very low.
KT3	Continue	To measure metal release rates in the event that leachate pH continues to trend downward.
KT4	Stop	pH and metal release rates show limited variability. Long times to depletion of acid production (47 years) and neutralisation potential (27 years) indicate that the pH may not become acidic on the timescale of lab measurements.
KT6	Continue	To obtain longer term data on metal release rate variability.
KT7	Stop	Although material may generate acid at later times, the acid potential is low.
KT8	Stop	Although material may generate acid at later times, the acid potential is low.

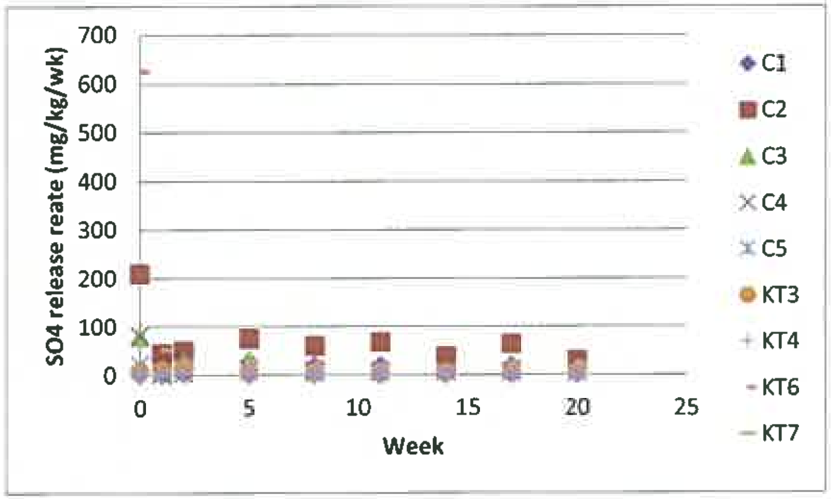

Figure 3-1 a: Sulfate release rates

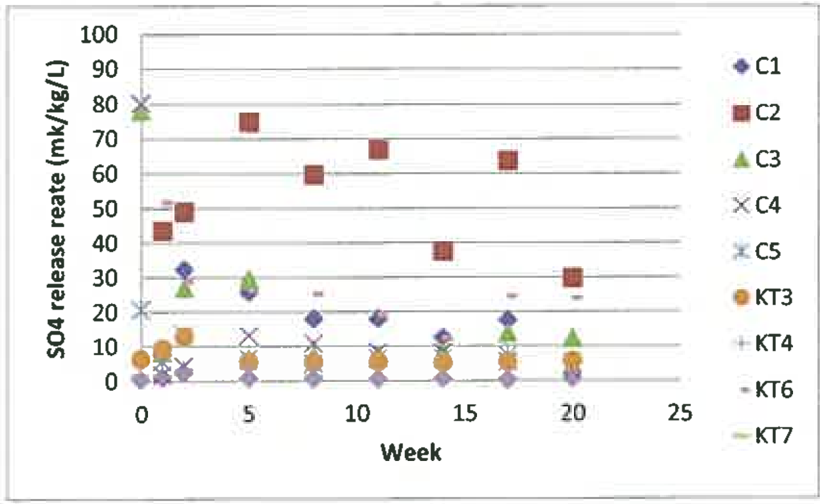

Figure 3-1 b: Sulfate release rates (expanded vertical axis)

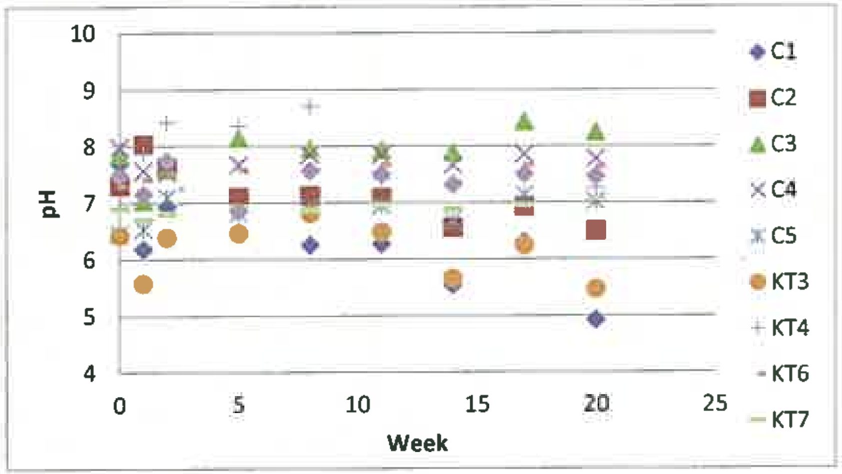

Figure 3-1 c: Leachate pH

4 References

AMIRA International Limited, 2002. ARD Test Handbook: Project P387A Prediction and Kinetic Control of Acid Mine Drainage.

Price, W A, 2009. Prediction Manual for Drainage Chemistry from Sulphidic Geologic Materials, MEND Report 1.20.1, CANMET Mining and Mineral Sciences Laboratories.

Yours faithfully

SRK Consulting (Australasia) Pty Ltd

Signed by:	**Signed by:**
Andrew Garvie	**Claire Linklater**
Principal	Principal

Memorandum

09 January 2014

To	Christopher Howell		
Copy to	Shaun Kelly		
From	Stuart Winchester	Tel	02 9230 7337
Subject	Carmichael dam water quality	Job no.	41 26630

Hi Chris,

As requested, please find following an indicative water quality assessment for the dams at Carmichael based on work completed to date.

Background

The *Manual for Assessing Consequence Categories and Hydraulic Performances of Structures* (the Manual) (Queensland Department of Environment and Heritage (DEHP) 2013 – EM635 Version 3) requires that all structures which are dams or levees associated with the operation of an environmentally relevant activity (ERA), must, unless otherwise stated in the Manual, have their consequence category assessed based on the potential environmental harm that would result from failure event scenarios as described in the Manual.

The consequence category would then determine whether the water storage structure being assessed is a regulated structure. A structure is only a regulated structure where the consequence category for the structure is 'significant' or 'high'.

The consequence category of the structure must consider the following three failure scenarios that would lead to water being released into the environment:

- 'Failure to contain - seepage' – spills or releases to ground and/or groundwater via seepage from the floor and/or sides of the structure;
- 'Failure to contain – overtopping' - spills or releases from the structure that result from loss of containment due to overtopping of the structure; and
- 'Dam break' – collapse of the structure due to any possible cause.

The potential consequences must be considered with respect to:

a) the failure of a structure placing lives at risk due to dwellings or workplaces being in the failure impact zone;

b) downstream consequences, including but not limited to failure of other structures that may be affected by any flooding;

c) the consequences of such cascade failure for other structures;

d) the impact to both on-site and off-site environmental values;

e) long term potential adverse effects due to release of contaminants to groundwater systems and

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soil profiles;

f) potential consequential effects on surface water systems; and

g) storage releases that may chemically interfere with waters used as sources of drinking water.

This memorandum, therefore, broadly correlates existing water quality and mineral waste information to inform the consequence assessment. Information was sourced from the following appendices from the Adani Carmichael Supplementary Environmental Impact Assessment (SEIA) (all GHD 2013 unless otherwise stated):

- Appendix K1 – Revised Mine Hydrogeology Report;
- Appendix K2 – Water Balance Report;
- Appendix K3 – Water Quality Report;
- Appendix K5 – Revised Mine Hydrology Impact Assessment Report;
- Appendix O1 – Mine Waste Characterisation Report (SRK 2013); and
- Appendix O2 – Mine Tailings Management Strategy.

Method

The Manual states that:

“Evaluation of the consequence potential on release requires information on the probable chemical nature of the stored material, including rates, volume and concentrations at the time of a possible release. Acidity and metal ions in solutions due to prolonged contact with ore bodies or stored material must be considered. Contaminant concentrations at discharge must be estimated based on the contaminant concentration in the dam, and design parameters such as available storage volume. Operational water balance models may also be used to estimate likely instances of volumes and concentrations at discharge”.

Potential water quality in the following dams was qualitatively / semi quantitatively assessed using information from the sources noted above:

- Overburden Sediment Dams at Pits B, C, F and G (contain runoff and seepage from waste rock dumps B, C, F and G respectively);
- MAW Transfer Dams at Pits D and E (contain runoff and seepage from waste rock dumps at Pits D and E, which also contain tailings);
- Phased Undisturbed Sediment Dams at Pits, B, C, D, E, F, and G. These dams progress with the high wall. The only inflows/ contaminants entering these dams are those inflows running over undisturbed land (not listed in Table 1); and
- MAW Transfer Dams at Pits B, C, D, E, F and G. These dams receive water from box cuts, underground seepage pump out and mine pits.

The information in this memorandum remains indicative only. Maximum design storage parameters for the dams listed above are provided in Table 1.

Table 1: Maximum design storage parameters

Dam	Required Volume (m^3)	Footprint Length (m)	Footprint Width (m)	Footprint Area (m^2)	Storage Depth (m)	Water Surface Area (m^2)
MAW Transfer Dam Pit B	200,000	191	191	36,481	13.4	25,728
MAW Transfer Dam Pit C	350,000	240	220	52,984	17.0	36,764
MAW Transfer Dam Pit D	600,000	335	235	78,953	18.4	55,292
MAW Transfer Dam Pit E	900,000	415	255	105,557	20.6	74,029
MAW Transfer Dam Pit F	650,000	356	236	84,016	18.4	59,100
MAW Transfer Dam Pit G	450,000	285	225	64,227	17.3	44,810
Overburden Sediment Dam Pit-B	744,505	656	200	131,121	10.0	131,121
Overburden Sediment Dam Pit-C	411,735	389	200	77,878	10.0	77,878
Overburden Sediment Dam Pit-F	565,468	348	400	139,276	5.0	139,276
Overburden Sediment Dam Pit-G	867,022	515	400	205,826	5.0	205,826
MAW Dam Pit D	13,660,000	1,197	600	718,414	20.0	718,414
MAW Dam Pit E	11,250,000	1,500	400	600,000	20.0	600,000

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Existing environment

In order to assess any potential environmental consequences of a dam failure from resident water quality, baseline water quality of the existing environmental must be known. A summary of existing hydrological and hydrogeological baseline data is provided below.

Surface water

Key environmental risks from mine waters released from water storage failure would likely include:

- Elevated dissolved metals impacting aquatic ecosystems;
- Acidity, characterised by low pH values, from oxidising sulphidic minerals and/or metals hydrolysis reactions for example. Acidity in water bodies also facilitates increased concentrations of certain dissolved metal species;
- Increased salinity due to increased concentrations of salts including sulphate for example; and
- Turbidity caused by elevated concentrations of suspended sediment.

The following summary of baseline surface water quality is reproduced from Appendix K2 of the 2013 SEIA. Refer to Appendix K2 of the 2013 SEIA for additional detail on baseline surface water quality.

The Carmichael River is the major surface water resource within the Study Area. The flow regime of the Carmichael River is subject to seasonal variability as wet season overland flow drains from the catchment. A baseline surface water quality data set was collected between April 2011 and April 2013.

The waters of the Carmichael River displayed an alkaline pH throughout the wet and dry season monitoring programs. The soils investigation report associated with this Project (Mine) indicates this is likely linked to the alkalinity of the adjacent soils (refer 2012 Environmental Impact Statement Soils Appendix L). Total suspended solids increased during the wet season sampling program confirming the elevated flows were due to surface runoff. Water quality showed elevated anions and cations during the dry season sampling program indicating that groundwater had a significant influence on water quality in the River. This was confirmed as the anions, cations and electrical conductivity (EC) decreased during the wet season sampling program as the river was influenced by surface runoff.

Metals detected in the waters of the Carmichael River include aluminium, antimony, arsenic, barium, boron, chromium, copper, iron, manganese, nickel, tin and zinc. The majority of these metals were also present in the in-stream sediments of the river. The 90th percentiles of aluminium, copper, chromium and iron in the Carmichael River are above the ANZECC and ARMCANZ (2000) 95 percent species protection trigger values without hardness modification. However, by applying the ANZECC and ARMCANZ (2000) hardness modifying factor, copper and chromium trigger values are not exceeded.

Similarly, a number of metals were present in the waters and sediments of the still water bodies. These include aluminium, arsenic, barium, boron, chromium, cobalt, copper, iron, lead, manganese, nickel, strontium, vanadium and zinc. The differences in metal concentrations between the Carmichael River and the still water bodies are likely attributable to local soil characteristics and previous farming activities. Total and dissolved aluminium, copper, iron and zinc 95th percentile concentrations exceeded the ANZECC and ARMCANZ (2000) 95 percent species protection trigger values.

Table 2 provides a selected subset of the water quality objectives (bolded) for the Carmichael River as

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reproduced from Appendix K2 of the 2013 SEIA.

Table 2 Carmichael River conditions and water quality objectives for ecosystem protection

Parameter	Unit	Carmichael River 80th percentile	ANZECC and ARMCANZ 2000 Default Trigger Values	QWQG (DERM, 2009) + Dight (2009)	Selected WQO
Physico chemical					
pH	pH Units	7.39-8.31	6.6-7.3[1]	6.5-8.5	**6.5-8.5**
EC	µS/cm	1,300	802	168	**1,300**
Turbidity	NTU	130	5	25	**130**
TSS	mg/L	106	112	nd	**106**
TDS	mg/L	711	-	-	**711**
Nutrients					
Sulfate	mg/L	13.4	1000[2]	-	**129[3]**
Dissolved metals					
Aluminium	mg/L	0.212	0.055[4]	-	**0.212**
Arsenic	mg/L	0.002	0.0135	-	**0.013**
Boron	mg/L	0.182	0.375	-	**0.37**
Cadmium	mg/L	<0.0001	0.00025	-	**0.0002**
Copper	mg/L	0.0026	0.00145	-	**0.0026**
Chromium (III+IV)	mg/L	0.002	0.0015	-	**0.002**
Iron	mg/L	0.58	0.3[5]	-	**0.58**
Lead	mg/L	BDL	0.00345	-	**0.0034**
Manganese	mg/L	0.35	1.95	-	**1.9**
Mercury	mg/L	BDL	0.00065	-	**0.0006**
Nickel	mg/L	0.002	0.0115	-	**0.011**
Zinc	mg/L	0.004	0.0085	-	**0.008**

[1] ANZECC and ARMCANZ 2000 section 8.2.2.1 default trigger value for QLD upland rivers

[2] ANZECC and ARMCANZ 2000 section 4.3.3.4 livestock drinking water guidelines

[3] Elphick et al. 2011

[4] ANZECC and ARMCANZ 2000 table 3.4.1 trigger value for 95 percent species protection. These values apply for dissolved metals.

[5] ANZECC and ARMCANZ 2000 low reliability trigger value for iron.

Groundwater

The following summary of baseline groundwater quality has been reproduced from Appendix K1 of the 2013 SEIA. Refer to Appendix K1 of the 2013 SEIA for additional detail on baseline groundwater quality.

Three rounds of groundwater monitoring were conducted (October and November 2011, and May 2013), to collect groundwater samples for water quality analysis.

The major ion chemistry for the sampled bores indicates that the groundwater is typically of sodium-chloride type in each of the strata monitored. For the most part there appears to be no clear difference between the major ion chemistry of the strata monitored, although the proportion of chloride and hence the final plotting position in most units is highly variable. A possible exception to this general rule is the D Coal seam where some samples contain proportionally less chloride and more bicarbonate when compared to the overlying monitored units, i.e. some of the samples suggest a sodium-bicarbonate-chloride type rather than sodium-chloride type water.

Comparison of ground and surface water data sets suggests that both the Carmichael River and groundwater samples can be classified as sodium-chloride type waters. In fact the Carmichael River samples appear to become progressively more similar to the groundwater samples as the dry season progresses. Hence, some difference can be observed between the major ion chemistry of the May 2012 surface water samples and the groundwater samples.

The main point of difference is the relatively low proportion of chloride present in the surface water samples, which suggests a higher rainfall/runoff component. However, by July 2012 the proportion of chloride in the surface water samples had increased to 70-80 per cent such that there is little apparent difference between the major ion chemistry of the groundwater and surface water samples. This suggests that groundwater discharge becomes an increasingly important component of flow in the river as the dry season progresses.

Concentrations of sodium in groundwater samples detected above the laboratory detection limit ranged from 47 to 6,710 mg/L and exceeded the long-term irrigation guidelines of 460 mg/L (ANZECC 2000) in 12 boreholes monitoring the alluvium, Tertiary-age strata, Rewan Group, overburden, interburden and the AB seam (i.e. all units monitored except the Dunda Beds and D Seam). Concentrations of chloride in groundwater ranged from 35 to 9,520 mg/L also exceeded the long-term irrigation guidelines of 700 mg/L in 13 boreholes monitoring all strata except the Dunda Beds and D seam. Sulphate concentrations in groundwater only exceeded the drinking water guideline (500 mg/L, ADWG 2011) in one sample with a concentration of 686 mg/L.

Concentrations of hardness corrected dissolved chromium, copper, nickel and zinc along with concentrations of dissolved aluminium, boron, manganese, selenium and silver also typically exceeded the ANZECC (2000) fresh water (95 per cent level of protection) guidelines, in more than one location for all of the units monitored.

Concentrations of dissolved metals in all units tested were generally below the guideline concentrations for livestock, with the exception of manganese. Manganese concentrations at 25 sampled locations exceeded the guideline value (0.1 mg/L) with concentrations in groundwater detected up to 4.81 mg/L.

Guidelines for long-term irrigation were exceeded for aluminium (3 locations), boron (13 locations), iron (26 locations), manganese (20 locations), molybdenum (5 locations), selenium (2 locations) and uranium (3 locations). Exceedances of one or more of these metals species were detected in all of the units monitored (i.e. the alluvium, Tertiary-age strata, Dunda Beds, overburden, interburden, AB seam and D seam).

Drinking water guidelines were exceeded for arsenic (7 locations), molybdenum (1 location), manganese (10 locations), nickel (3 locations), selenium (2 locations) and uranium (2 locations). Exceedances of one or more of these metals species were detected in all units monitored.

The relatively high anticipated depths to groundwater (generally greater than 20 m below ground surface) and the clayey nature of much of the Tertiary-age strata encountered across the site is considered to provide significant potential for the attenuation of any contaminants from leaks and spills before they reach the groundwater table.

In addition, leaching of contaminants to groundwater is unlikely to occur unless moderate to large quantities are released over a long period of time. Provided that storage facilities are designed in accordance with Australian standards and standard practices for management of storage and handling activities are followed, large quantity, long term releases are not expected.

Impacted geology and its geochemistry

Geology

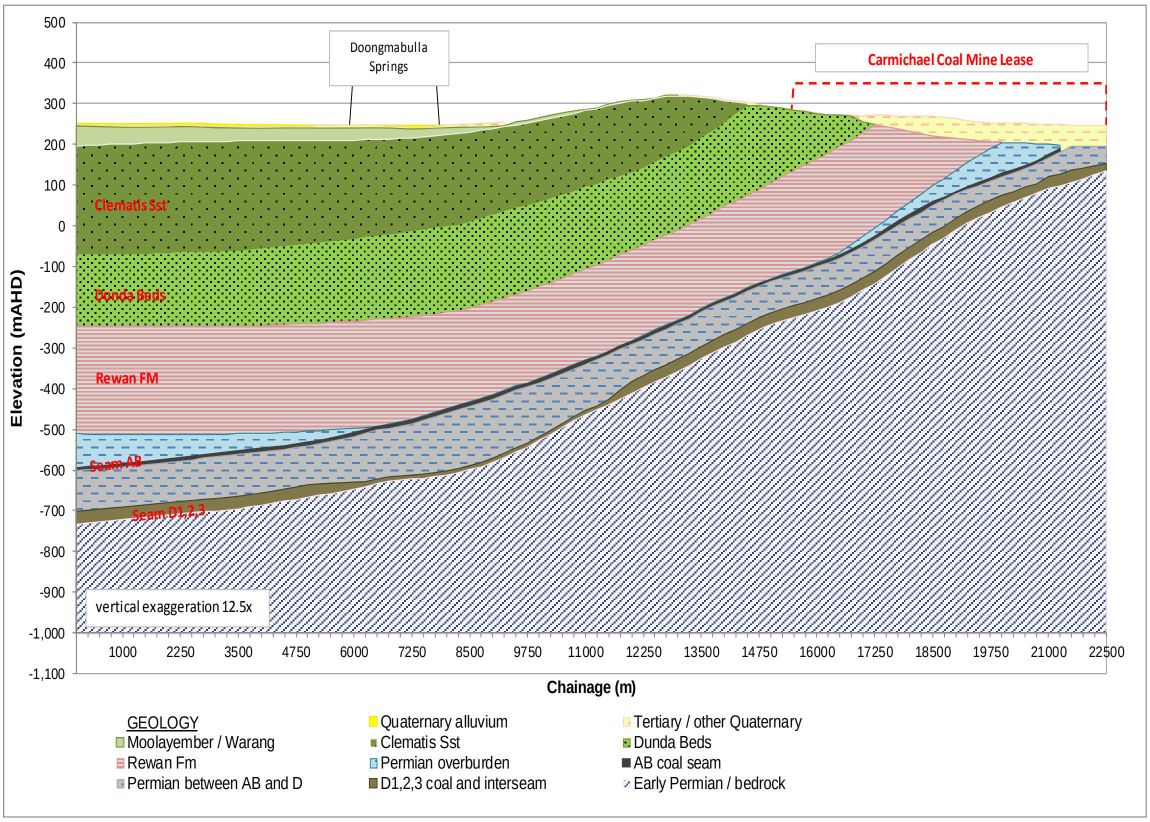
Water quality impacts associated with overburden sediment dams and MAW transfer dams remains a function of the geochemistry of the mineral waste material the water has flowed over and/or through. Therefore, a brief overview of the impacted geology and any propensity it may have to impact water quality is warranted. The following overview of site geology is reproduced from Appendix K1 of the 2013 SEIA.

The Project (Mine) lies within the Galilee Basin, an intracratonic sedimentary basin deposited in the Permian and Triassic Periods.

Tertiary-age strata (including sandstones, mudstones and conglomerates) are mapped at outcrop over much of the mine area and based on geological information available from the initial exploration program were typically thought to range in thickness from 45 to 100 m thick in the west. Based on the detailed geological information now available for the site after a sustained drilling program, it appears likely that the published mapping under-estimates the extent of the underlying Dunda Beds towards the western margin of the lease. This is broadly consistent with the results of soils mapping undertaken for the EIS which also suggests that:

- The extent of the Quaternary and underlying Tertiary units is over-estimated in the mapping; and
- That soils formed on the fine grained sandstones of the Dunda Beds (refer Figure 1) occupy the largest portion of the Mine Area.

Figure 1 Sketch geological cross-section through the Project (Mine) lease



The recent review of the available geological information also suggests that where they are present the Tertiary strata are typically thinner than previously thought since the lower Tertiary horizons have now been re-interpreted as weathered Permian age strata.

Along the Carmichael River and over much of the Belyando River system to the east of the Project (Mine) area, the Tertiary strata are indicated to be overlain by Quaternary-aged floodplain alluvium (sands, silts, gravels and clays). An unconformity defines the boundary between the Tertiary-age strata and the underlying Late Permian-age coal bearing strata (a sequence of siltstones, mudstones, sandstones, shales and coal of the Bandana Formation and Colinlea Sandstone). Geological cross sections sourced from the Geological Survey of Queensland) and modelled cross sections of the geology by GHD, indicate that the Late Permian-age strata dip at approximately 2 – 4° to the west, steepening slightly in the southern half of the lease.

Along the western margins of the Mine Area a sequence of Triassic-age strata forms an angular unconformity with the overlying Tertiary-age strata and is mapped at outcrop as the Dunda Beds (predominantly sandstone). The Rewan Group (mudstone and sandstone) underlies the Dunda Beds and overlies the Late Permian-age strata.

A stratigraphic column to illustrate the main geological units within the lease area is summarised in Figure 2. Quaternary-age strata (which lie stratigraphically above Tertiary-age strata) are not shown in Figure 2.

Figure 2 Stratigraphic column

Age		Lithology	Stratigraphy	Thickness
Tertiary		Clays / Mudstones		40 - 100m
Triassic		Mudstone / Siltstone	Rewan Formation	
Late Permian		Sandstone	Bandanna Formation	
		COAL - AB Seam		12 - 18m Resource Seam
		Sandstone / Siltstone		10m
		COAL - B splits		1 - 2m
		Siltstone / Mudstone		60 - 70m
		COAL - C Seam (carbonaceous)		3 - 4m
		Siltstone / Sandstone	Colinlea Sandstone	2 - 20m
		COAL - D1 Seam		4 - 6m Resource Seam
		Sandstone		5 - 30m
		COAL D2/D3 Seam		8 - 10m Resource Seam
		Siltstone / Mudstone		10 - 20m
		COAL - E Seam		1 - 3m Resource Seam
		Sandstone / Siltstone		5 - 10m
		COAL - F Seam		1 - 5m Resource Seam
Early Permian		Sandstone		

The Bandanna Coal Measures and Colinlea Sandstone conformably underlie the Triassic sequences and consist of interbedded coal, sandstones, siltstones and mudstones. The combined sequence is up to 150 m thick. Sandstones are dominant with generally thin mudstone bands, often carbonaceous, usually found both above, below and as partings within coal seams. The larger interburden units are predominantly interbedded sandstone and siltstone (SRK 2013).

Mining development has been described in the 2012 EIS and 2013 SEIS; however, it remains important to note that with respect to potential water quality in sediment and MAW dams, water quality would be influenced by excavated and placed mine waste, including tailings encapsulated in waste rock dumps D and E.

Geochemistry

SRK (2013) completed a geochemical assessment on the mine waste at Carmichael. Four hundred and seventy samples of potential mine wastes and coal materials were taken from drill core and assessed for their potential to produce acid and metalliferous drainage (AMD). Four hundred and thirteen samples were of overburden and interburden, 57 samples were roof, floor or coal materials. No coal reject samples were available for characterisation, so the coal seam samples were used as surrogates. Standard static geochemical tests were conducted to characterise the samples. In addition, ten samples classed as potentially acid forming (PAF) or uncertain (UC) (based on static tests) were subjected to kinetic leach testing.

SRK (2013) reported that sulfur speciation testing indicated that a proportion of the sulfur present may not be sulfidic. Thus, acid generating capacity determined from total sulfur may over-estimate acid potential. Similarly, acid buffering characteristic curve (ABCC) testing indicated that not all acid neutralising capacity determined from acid neutralising capacity (ANC) testing may be available to neutralise acid.

Based on the available results, the majority of the overburden and interburden materials proposed for mining at Carmichael (not immediately adjacent to the coal seams), and roof and floor wastes are not likely to be a source of acid immediately after mining. Nor would most of these materials be expected to an immediate source of salinity; however, some portion could be a source of salinity. The clay materials of the overburden and interburden could have a markedly higher potential to release salts and metals to contact water even though the pH may remain alkaline. Typically however, the concentrations of metals in water contacting the waste would be expected to be low while waters remain circum-neutral.

The majority of the overburden and interburden waste from all lithological groups is likely to be non-acid forming in the longer term. Some carbonaceous mudstone, carbonaceous sandstone, carbonaceous siltstone, clay, claystone, mudstone, sandstone, sandy clay, siltstone and tuff may be acid forming in the long term and there may be a requirement to manage these materials to prevent or limit the longer-term development of AMD. Some portion of the roof, floor and coal could be expected to be acid forming in the long term.

Ten kinetic leach columns were operated from May until December 2013; and are continuing. Results from the initial 20 weeks of analysis indicate that leachates from two kinetic columns were between pH 4.5 and 5.5 at week 20 and trending towards lower pH values. Five other columns were expected to produce acidic leachate in the longer term. Rates of leaching of some metals had not stabilised by week 20 and although the metal release rates were generally low the release rates would be expected to increase if the leachate pH becomes acidic.

Initial water quality modelling from rainfall interaction with the mineral waste suggests that concentrations of sulfate, fluoride, boron and molybdenum in surface runoff from the overburden dump could exceed the cattle drinking water quality guidelines (ANZECC/ARMCANZ 2000). Similarly, estimated concentrations of the above solutes and zinc in percolate from the overburden dumps are predicted to exceed the cattle drinking water quality guidelines. However, based on the proposed water management strategy for the project, under normal operating conditions the runoff will be captured in the dams and will be recycled or used in the process.

The estimated concentrations are intended to indicate concentrations that might be expected as a result of the first flushing of the overburden. They would not be expected to be sustained in the longer term as readily available solutes would be transported from the overburden. i.e: they represent a conservative, worst case scenario.

Water quality in the longer term would be expected to be dependent on the presence and distribution of PAF materials within the dumps including the tailings. However, SRK (2013) concluded that additional results from longer term kinetic testing would be required to complete these estimates.

Water impacting the Phased Undisturbed Sediment Dams at Pits, B, C, D, E, F, and G would be sourced from inflows running over undisturbed land. Appendix L of the 2012 EIS indicated that by and large, soils on the Carmichael site were alkaline. Alkaline surface water quality in the Carmichael River would support the likelihood of surface runoff from *in situ* material into the Phased Undisturbed Sediment Dams at Pits, B, C, D, E, F, and G would also likely be alkaline.

Tailings geochemistry

As the water in MAW Transfer Dams at Pits D and E is a function of mineral waste and encapsulated tailings stored in waste rock dumps D and E, an understanding of tailings geochemistry is required.

At the time of writing, no tailings samples were available for geochemical testing to ascertain the risk of acid and metalliferous drainage (AMD). Therefore, coal samples were assessed as a surrogate for the tailings; the logic being that all tailings content is derived from the coal, and therefore, the coal geochemistry is indicative of the tailings geochemistry.

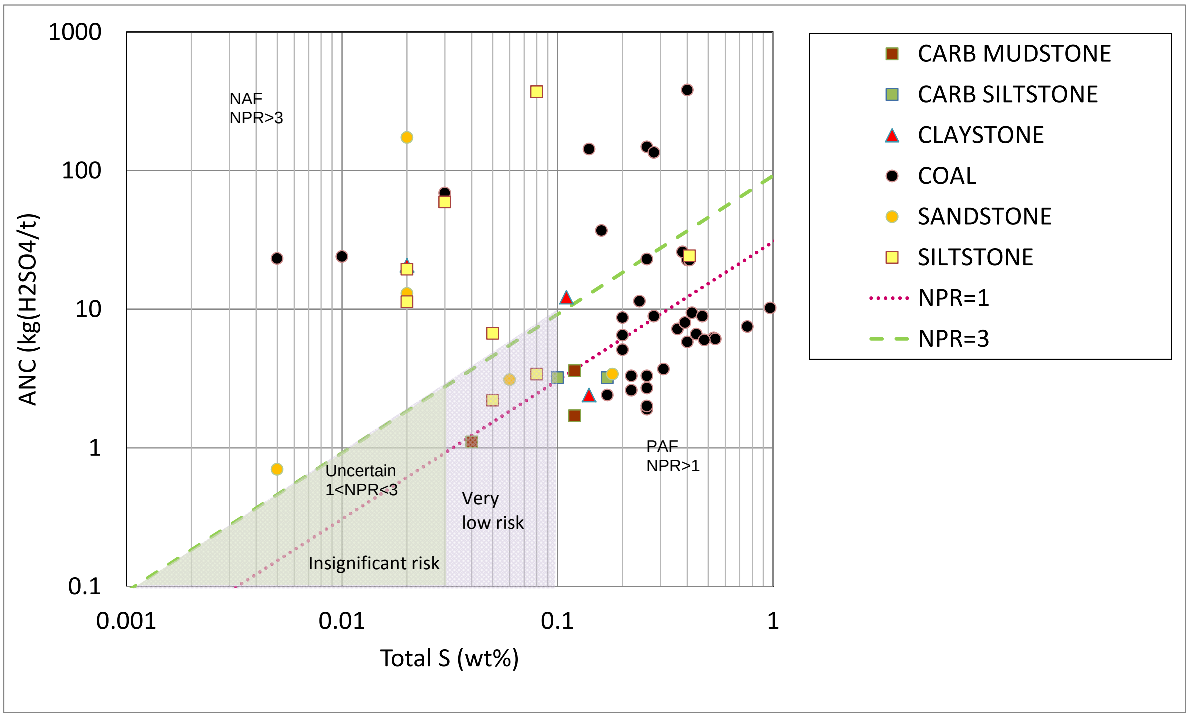
Of these 470 samples SRK (2013) had analysed for static testing, 36 coal samples were assessed, which were assessed along with 21 coal seam roof and floor samples for reasons described below. The coal seam roof and floor materials comprised carbonaceous mudstone, carbonaceous siltstone, claystone, sandstone and/or siltstone.

Sulfide minerals which can oxidise to generate acid, often thereby liberating metals into solution, can form as a result of sulfate reduction during the formation of coal. Therefore, the potential for sulfides to be present in material in and adjacent to coal seams is significantly greater than the potential in the overlying bedrock and regolith. Such material may report to the coarse rejects bin during coal processing, and would ultimately therefore, report to the co-disposal cells within out of pit storage emplacements at Pits D and E.

A summary of the findings on the acid generating potential of the coal, and coal seam roof and floor samples, is reproduced below.

Figure 3 provides a plot of the acid neutralising capacity (ANC) versus total sulfur for the samples of coal, roof and floor material. The green dashed line in the plot differentiates samples with characteristics that are not acid forming (NAF) from those that are classified as uncertain (UC). The classification scheme is provided below. The dotted pink line differentiates the samples with potentially acid forming (PAF) characteristics from those that are UC. The samples below the dotted pink line also have a positive net acid production potential (NAPP); that is, they contain a net of more acid producing minerals (reduced sulfur) relative to acid neutralising minerals (carbonate).

Figure 3 Acid base accounting plot of coal, roof and floor samples



Sample classification is based on the acid generating and acid neutralisation potentials of a material. Whilst the neutralisation potential may be assessed using the NAPP, an alternative method is based on the neutralisation potential ratio (NPR). The NPR is defined as the ratio of ANC to maximum potential acidity (MPA); the latter being the percent reactive sulfur times 30.6, a number derived from reaction stoichiometry. The geochemical samples were classified using the NPR as follows:

- NPR < 1 – potentially acid forming (PAF)
- 1 < NPR < 3 – uncertain (UC) (materials may or may not be net acid forming)
- NPR > 3 – non-acid forming (NAF)
- Total S < 0.1 wt% – non-acid forming (net acid production is low (< 3 kg (H_2SO_4)/t).

Note the last criterion is not a part of the standard NPR method. It is adopted here because samples with acid potential values of less than 3 kg (H_2SO_4)/t have been assessed as low risk at other sites.

The results in Figure 3 indicate that a proportion of the coal would be expected to be acid generating. As much of this coal is saleable product (not waste), it is expected that it would only be stored on site for a short period of time, thus reducing the risk for generation of AMD on site. Waste reject from the coal handling and processing plant (CHPP), however, may pose a greater risk of generating AMD as this material would be disposed of on site. A proportion of the roof and floor material would also be expected to also be potentially acid forming.

Table 3 presents a summary of the coal, roof and floor sample classification. It shows that slightly over half of the coal samples are potentially acid forming. The NAPP statistics from the coal, roof and floor sample group showed a minimum of 0.2 kg H_2SO_4/tonne, a maximum of 29.7 kg H_2SO_4/tonne, and a median of 6.1 kg H_2SO_4/tonne.

Table 3 Roof, floor and coal sample classification (NPR method)

	Number of Samples				Percentage of Samples		
	NAF	UC	PAF	Totals	NAF	UC	PAF
Coal	8	8	20	36	22.2	22.2	55.6
Roof and floor	14	2	5	21	66.7	9.5	23.8
Totals	22	10	25	57	38.6	17.5	43.9

The proposed management strategy for the tailings is to place them in clay lined cells within out of pit overburden storage areas D and E. Clay cells would be designed to reduce the water flux into and out of the tailings thereby reducing the quantity of water passing through the tailings. Reduced water flux increases the potential for solubility control of dissolution of the metals and salts thereby reducing the load released from the cells, in addition to reducing oxygen ingress into the sulfidic wastes thereby lowering the oxidation and acid generation risk.

To reduce the possibility of desiccation of waste in the cells and to reduce the potential for transport of metals and salts to the surface of the out of pit overburden storage areas, the top level of the cells are planned to be at least 5 m below the surface. During out of pit overburden storage area and cell construction, contact between UC, PAF and dispersive materials are planned to be avoided. Further, dispersive materials are planned to be placed below the surface and not be used for construction of cell linings.

The two coal samples used as surrogate tailings samples in the kinetic testing currently underway (KT4 and KT8) are showing low sulfate release concentrations and circumneutral pH values after 20 weeks.

Static and kinetic geochemical leach testing

The SRK (2013) geochemical assessment provides two useful analytical indicators of indicative water quality likely to be found in the MAW and overburden sediment dams, as a function of the mineral waste geochemistry the dams drain. These were:

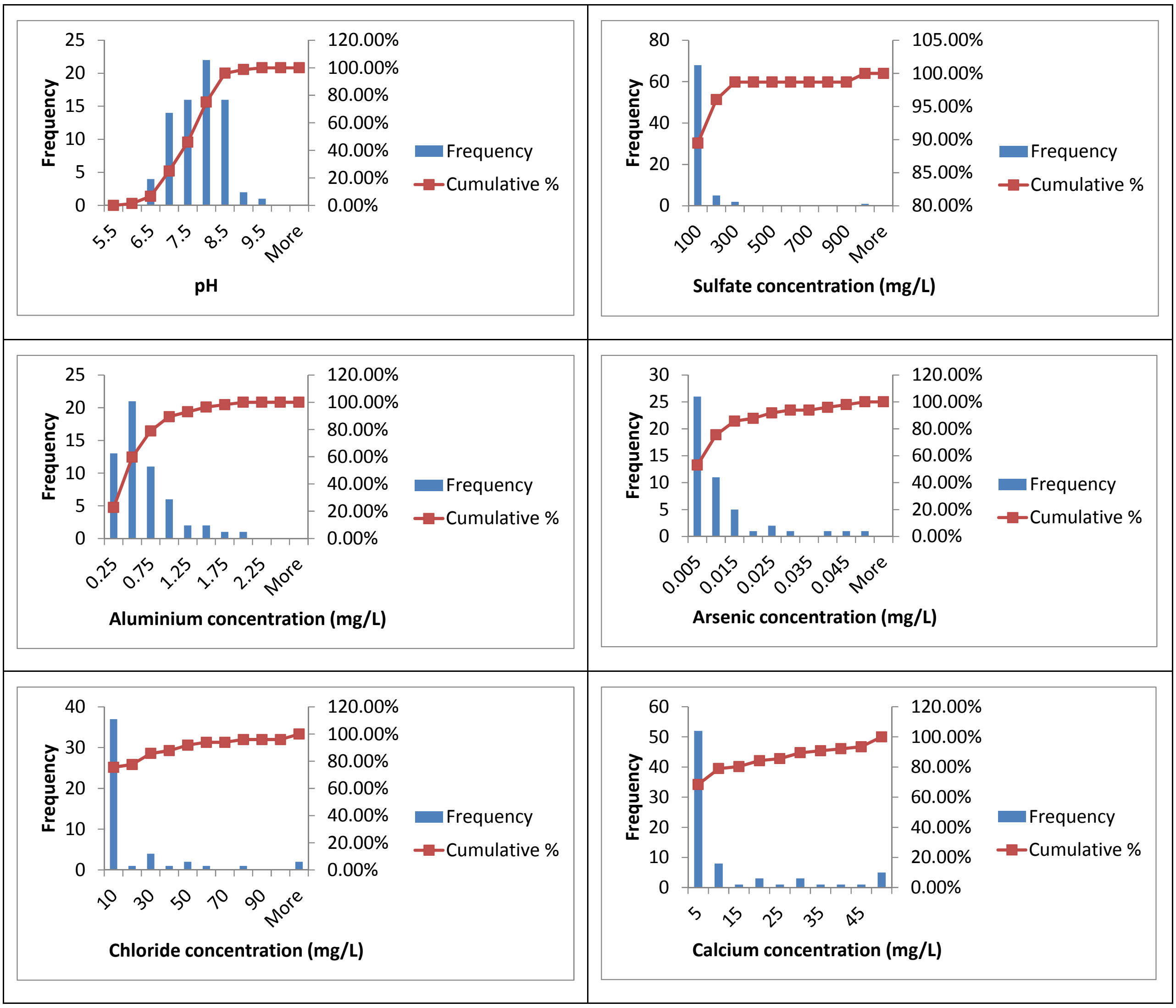
1. A geochemical abundance index (GAI) and subsequent leach test; and
2. Kinetic column studies of potentially acid forming mineral waste.

A summary of the reported results from SRK (2013) is provided below.

All 470 mineral waste geochemical samples were submitted for multi-element analysis. Elements that were identified as enriched relative to the GAI in a number of samples were sulfur (2 samples), silver (18), cobalt (1), rhenium (9) and tellurium (223).

Simple leach tests were subsequently carried out on 76 of the 470 mineral waste geochemical samples at a solid:water ratio 1:3 over a period of 24 hours. Selected parameter values are presented in Figure 4 and full results are presented in SRK (2013). The tests provide an indication of the soluble elements and salts that are already present in the samples and form a basis for an initial assessment of the potential for changes to water quality as a result of contact with the waste.

Figure 4: Selected parameters for static leach test water quality



Since the physical and chemical conditions of the leach test will not be the same as those expected in the 'as placed' environment (e.g. solubility constraints, liquid to solid ratio, particle size, etc.), the leach composition is not expected to be exactly representative of that which may develop in the field. Thus, although the results are not directly indicative of the leachate quality expected to seep from a dump of the material, they provide an indication of the leachable elements that may be present. The results can be compared to Stock Water Quality Guidelines (ANZECC/ARMCANZ 2000) only to identify solutes that potentially may be of significance.

The pH values of all leachates were circum-neutral. The electrical conductivities, alkalinity, acidity and sulfate concentration were generally low. The largest EC value (2120 µS/cm) was more than 4 times the next largest value and was observed for a clay sample. The clay sample also exhibited the largest SO_4 concentration. Electrical conductivity testing conducted when assessing the potential for samples to be dispersive also identified clays with high electrical conductivities. These results indicate that the quality of water contacting some clay materials could be adversely impacted.

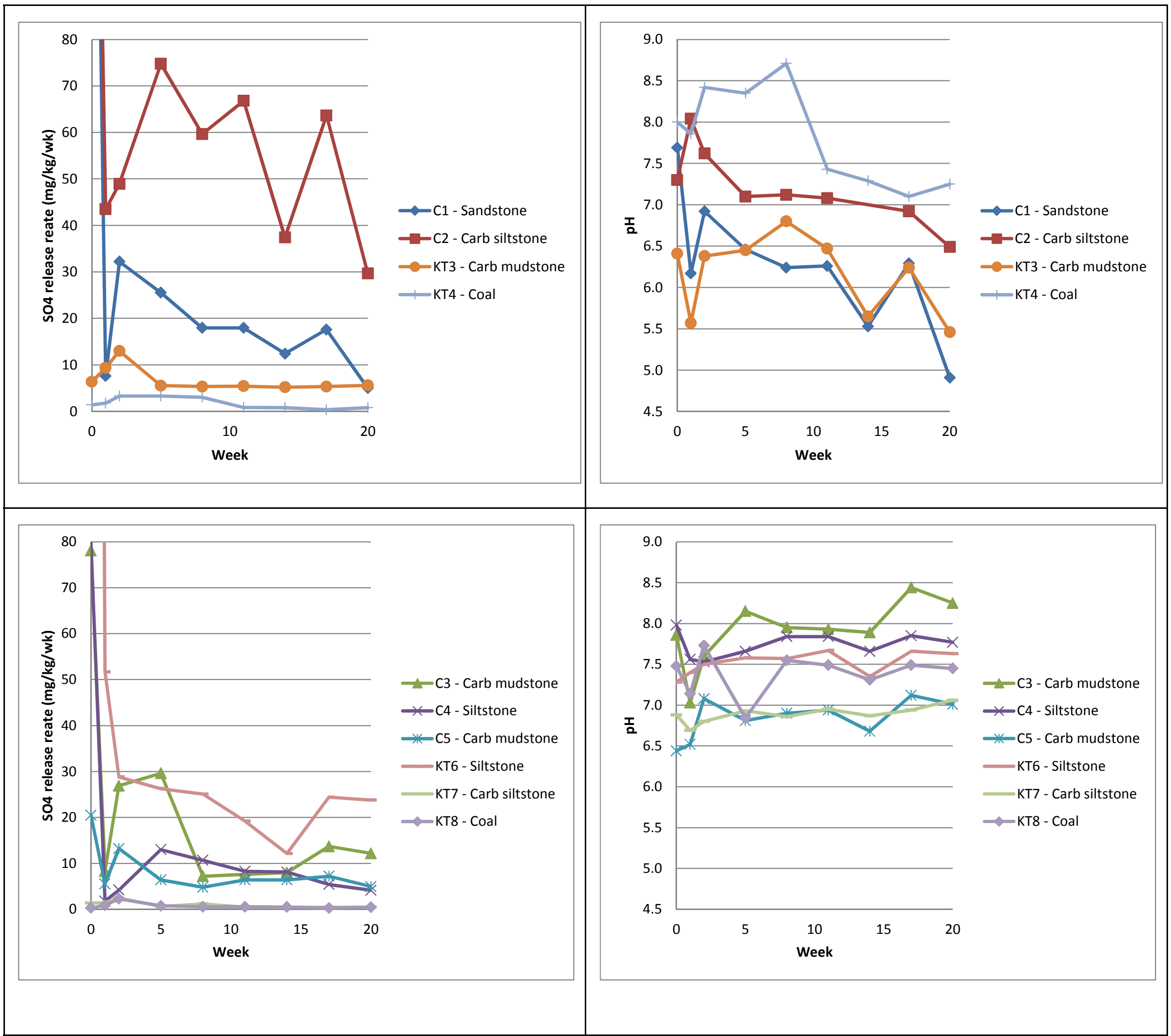
Concentrations of metals were generally low and did not exceed guideline values for livestock drinking water. However, this may not be the case for the conditions in the waste dumps. Relevant stock water guideline values are SO_4:1000 mg/L; Ca:1000 mg/L and As:0.5 mg/L.

A subset of ten samples that had been statically tested was selected for kinetic leach testing. Due to the limited mass of individual samples, five of the ten samples subjected to kinetic testing were composites of two or three samples. The constituent samples of each composite came from the same lithological unit and had similar sulfur contents and geochemical classifications.

Figure 5 shows sulfate and pH release results for the first 20 weeks of leaching from May to November 2013. It shows that one sandstone and carbonaceous mudstone column is trending towards becoming acid, while others remain circumneutral. No excessive concentration of sulfate is being formed within any column, with concentrations decreasing over time.

In fact, chromium reducible sulfur analysis indicated that sulfide sulfur made up only a fraction of the total sulfur present. This may reduce acidity in several of the columns, though will not reduce the potential for saline drainage. Interestingly, a comparison of depletion times in SRK (2013) indicated that the neutralising capacity of all but three samples would be depleted before the acid potential. Therefore seven of the ten samples would be expected to become acidic in the long term. It remains important to note that these columns represent a very small proportion of problematic materials, and therefore, are a conservative measure. They assist with identifying management strategies for the potentially acid forming materials such that encapsulation in the dumps can be planned such that water quality objectives may be realised.

Some metal release rates were not stable over the 20 week monitoring period. Typically, element release rates would be expected to increase as pH of the pore water of the column decreased (due to the higher solubility of many elements under acidic conditions). Therefore, if the pH of some leachates decreases, the release rates may increase. Monitoring these changes would improve the estimates of release rates used in future water quality assessments for the site by extending the range of geochemical conditions represented. The kinetic leaching program is ongoing.



(a) Sulfate release rates | **(b) pH release rates**

Figure 5: Colum sulfate and pH release results

Preliminary MAW and Overburden Sediment Dam Water Quality Estimates

Preliminary estimates of solute concentrations in run-off and percolate from the mineral waste overburden dumps were based on the combined results of initial solute releases from static leach testing and data from the first five weeks of kinetic column operation (above) (SRK 2013). These estimated concentrations are intended to indicate concentrations that might be expected as a result of the first flushing of the overburden. They would not be expected to be sustained in the longer term as these readily available solutes are leached from the overburden. They are therefore conservative, worst case, scenarios.

To estimate percolate water quality, it was assumed that rainfall would infiltrate the overburden. Flow through the overburden is expected to form selective flow paths so that only a fraction of the waste material would be contacted by the flow. In contrast to the laboratory tests (in which solids are generally saturated during the leach cycle) in the field the flow would be unsaturated and only a fraction of the total leachable solutes would be dissolved and transported out of the overburden landform. The relevant parameters are given in Table 4.

Table 4: Parameters used to estimate percolate water quality

Parameter	Units	Value
Overburden thickness	m	140
Mean average precipitation	mm	665
Fraction of the rain infiltrating the surface		0.3
Fraction of the overburden contacted by percolating water		0.3
Fraction of the solutes released		0.3

The water quality for surface run-off was based on total runoff estimates using the Green Ampt relation to assess the volume of runoff that could occur for various recurrence intervals and intensity of rainfall events. The lowest rainfall event that would be expected to generate runoff was then adopted to estimate the potential maximum concentrations that could result. (The lowest runoff yields the highest concentrations for a similar solute release as it would provide the least amount of dilution). For the purposes of the assessment it was assumed that the surface of the overburden dump would be level and trafficked so that the surface materials would generally be ground to fine clayey silt material; this assumption is conservative as it would tend to result in runoff for relatively small rainfall events (i.e. small quantities of water). The preliminary calculations suggest that a 6 minute event with a 1 year return period could result in about 6 mm of runoff.

The solute release would be restricted to the near surface materials only. When a rainfall event occurs, initially a certain amount of water would infiltrate until the soils become saturated; water would continue to infiltrate as long as the rate of rainfall does not exceed the permeability of the soils. Once the initial saturation occurs and the rainfall exceeds the rate at which water may infiltrate water would start to pond, and only once the water level exceeds local undulations would runoff commence.

Salts accumulated on the surface of the overburden dump would be dissolved and could be transported with the surface runoff. The salt accumulation would depend on the amount of salt wicking that had occurred in advance of the rainfall event; this would depend on the time between events and the depth to which wicking would occur. Since the runoff estimate noted above would be for a 1 year return period, it is anticipated that wicking would not have progressed to any significant depths. It was therefore assumed that salt wicking could have progressed from a depth of about 0.1 m below surface and that all of the solutes had moved to the surface of the dump. It should be noted that during the initial infiltration process as rainfall commences, salts would be dissolved and transported back into the dump and would be 'lost' to runoff. Furthermore, since the first event would have removed most of the available solutes, the solute concentrations in subsequent events would be lower.

For the purposes of this assessment it was therefore assumed that thirty percent of the solutes in the top 0.1 m of the overburden would be released to the flush. Table 5 summarises the preliminary estimates of concentrations in the percolate and surface runoff water. Estimates were made with and without mineral solubility controls and are compared with maximum concentrations measured in surface water at and near the project site and with water quality guideline values for stock drinking water.

Estimated concentrations of sulfate, fluoride, boron and molybdenum in surface runoff are predicted to exceed the cattle drinking water quality guidelines (ANZECC/ARMCANZ 2000). Similarly, estimated concentrations of sulfate, fluoride, boron, molybdenum and zinc in percolate from the overburden dumps (for the maximum height of the dump) are predicted to exceed the cattle drinking water quality guidelines (ANZECC/ARMCANZ 2000).

Based on the proposed operational water management plan however; surface water runoff, and toe seepage that reports to surface runoff, will be captured and recycled or reused in the plant. i.e: the runoff would report to the sediment and/or MAW Dams for appropriate management.

Water quality in the longer term would be expected to be different to those presented above; and in part, would be dictated by the presence and distribution of PAF materials within the dumps. It would be likely that the above represents a ‘first flush’ event, rather than a steady state wet season event. Therefore, appropriate monitoring and wet season managed release under controlled high flow conditions would be appropriate management. However, results from longer term kinetic testing would be required to complete the estimates.

Table 5: Preliminary estimate of surface and percolate water qualities

Parameter	Initial Solute Release (combined kinetic and static results)	No solubility control		Solubility control			Max. conc. In surface water	Cattle livestock drinking water guideline values*
		Short Term Percolate Concentration	Initial Runoff Concentrations	Percolate	Runoff	Mineral control		
	mg/kg	mg/L						
Chloride	57.12	5800	411	5800	411			
Sulfate	147.04	15000	1058	5800	1000	Gypsum	760	1000
Fluoride	1.47	150	11	2	2	Fluorite, fluorapatite	0.8	2
Calcium	44.27	4500	318	700	300	Gypsum	31	
Magnesium	9.43	950	68	960	68		35	2000
Potassium	10.14	1000	73	960	72		45	
Sodium	145.38	14700	1046	14700	1000		420	
Total Phosphorus as P	0.06	6	0.4	0.1	0.001	Fluorapatite	0.75	
Aluminium	1.82	180	13	0.01	0.01	Gibbsite	1.37	5
Arsenic	0.02	2	0.1	2.1	0.15		0.004	0.5
Boron	1.76	177	13	178	13		0.26	5
Barium	1.33	135	10	0.007	0.01	Barite	0.42	5
Copper	0.01	0.5	0.04	0.5	0.04		0.003	1
Iron	0.78	79	5.6	0.7	0.04	K-jarosite	2.78	
Manganese	0.09	9	0.7	10	0.7		4.49	
Molybdenum	0.07	8	0.5	8	0.5		0.002	0.15
Strontium	0.71	72	5	72	5		0.41	
Zinc	0.60	61	4	61	4		0.007	20

Note: * From Australian and New Zealand Guidelines for Fresh and Marine Water Quality Table 4.3.2

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Memorandum

Conclusions

Initial indicative qualitative / semi quantitative assessment of likely water quality in the following dams was assessed based on information available to date:

- Overburden Sediment Dams at Pits B, C, F and G (contain runoff and seepage from waste rock dumps B, C, F and G respectively);
- MAW Transfer Dams at Pits D and E (contain runoff and seepage from waste rock dumps at Pits D and E, which also contain tailings);
- Phased Undisturbed Sediment Dams at Pits, B, C, D, E, F, and G. These dams progress with the high wall. The only inflows/ contaminants entering these dams are those inflows running over undisturbed land; and
- MAW Transfer Dams at Pits B, C, D, E, F and G. These dams receive water from box cuts, underground seepage pump out and mine pits.

It would appear that water quality reporting to the phased undisturbed sediment dams at Pits B, C, D, E, F and G would be consistent with baseline surface runoff; i.e slightly alkaline on the whole. In a worst case or 'first flush' scenario, water stored in Overburden Sediment Dams at Pits B, C, F and G would likely contain concentrations of sulfate, fluoride, boron and molybdenum from surface runoff that is predicted to exceed the cattle drinking water quality guidelines (ANZECC/ARMCANZ 2000). Similarly, estimated concentrations of sulfate, fluoride, boron, molybdenum and zinc in percolate from the overburden dumps (for the maximum height of the dump) are predicted to exceed the cattle drinking water quality guidelines (ANZECC/ARMCANZ 2000).

The MAW Transfer Dams at Pits B, C, D, E, F and G would contain water of a quality commensurate with baseline ground and surface water concentrations; albeit with probable elevated total suspended solids concentrations, and potentially, elevated hydrocarbon concentrations.

Water quality in the MAW Transfer Dams at Pits D and E would likely be consistent with that in the phased undisturbed sediment dams at Pits B, C, D, E, F and G; with the additional consideration that waste rock dumps D and E contain encapsulated dried tailings. Current kinetic leach testing on the coal samples being used as surrogates for tailings show low concentrations and sulfate in leachate and circumneutral pH values after 20 weeks.

Seepage opportunities for poor quality water from the dams would appear to be somewhat limited due to the presence of Tertiary clays underlying the water holding structures that would not only retard the progress of water by acting as a natural barrier, though also retain the potential to adsorb metals to attenuate metalliferous drainage.

It should be noted that water quality in the dams mentioned above would be a dynamic cycle, and would ultimately remain a function of climate (wet/dry season), the geology and geochemistry of mined and placed materials, preferential flow pathways, amongst other factors. If managed correctly, circulated water on site, combined with controlled and managed release at high flow events, would appear to be an appropriate management strategy.

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Regards,

Dr Stuart Winchester

Principal GeoEnvironmental Scientist

02 9239 7337

Attachment 8. GHD Memo providing calculations in support to response to IESC comment 18f

GHD

Memorandum

10 February 2014

To	Adani Mining Pty Ltd		
Copy to			
From	Dave Rowlings	Tel	(07) 3316 3675
Subject	Post Mine Closure - Open Cut Standing Water Assessment	Job no.	41/26630

1 Introduction

An assessment has been undertaken to quantify the volume of water likely to be present in open cut pits after rehabilitation in the post mine closure period. The assessment has been carried out using a GoldSIM model which considers inflows and outflows from the pits during the rehabilitation and post closure period. Modelling of the pit water level has been conducted over a 110 year period with 100 simulations using various start years to assess the influence of climatic variation.

2 Qualifications

The model has been constructed with the following qualifications:

- Climate data (rainfall and evaporation) has been applied as per the SEIS water balance model as reported in Appendix K2;
- Modelling approach is consistent with SEIS water balance model, however a 100 year simulation period has been used;
- Runoff generation has been model using the AWBM model with the pit surface type as described in the water balance report, Appendix K2. This is expected to be conservative given the rehabilitated pits will have more storage capacity in the catchments and generate less runoff than the active pits. All rain falling on the water surface in the pit has been considered to have zero losses;
- Runoff areas have been taken as the entire pit rehabilitation area contributing runoff to the void less the surface area of the water in the void;
- Pit ingress (i.e. groundwater seepage rates) has been conservatively applied at a constant rate irrespective of the volume/depth of water stored in the pit as shown in Table 1; and
- Storage curves and total runoff areas have been used in the model as per rehabilitated 3D pit shells used for the numerical ground water modelling. The storage capacity of each pit and the total catchment areas are shown in Table 1.

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Table 1 Pit information used in modelling

Pit	Total Rehab. Catchment (km^2)	Storage Capacity (GL)	Groundwater Pit Ingress (m^3/day)
B	18.54	1374	309
C	9.45	253	5
D	11.88	716	771
E	6.74	414	188
F	16.68	601	426
G	22.03	716	703

3 Results

The following figures present the results of the modelling exercise undertaken. It shows that no overflow from any pit is expected, based on the information used to model the rehabilitation scenario. The results show water volumes over time for the greatest, median and least values; calculated based on the 100 simulations. There have been no overflows recorded in the modelling and each pit is shown as containing a fraction of water in relation to the total storage capacity available. In each case the water volume is reaching a steady state after a few years and the fluctuations in the water level become seasonal.

A flood frequency analysis was performed on the maximum three month wet season period as defined in the manual for assessing consequence categories. A maximum total of 849.9 mm was recorded in 1917, which falls somewhere between a 1 in 100 and 1 in 200 year ARI as per the analysis. Thus having run 120 years of climate data in the model (including 1917) with varying start years it is also shown that large weather events will have minimum impact on the water volume long term, and do not pose a risk to the pits filling completely and consequently overtopping into the environment.

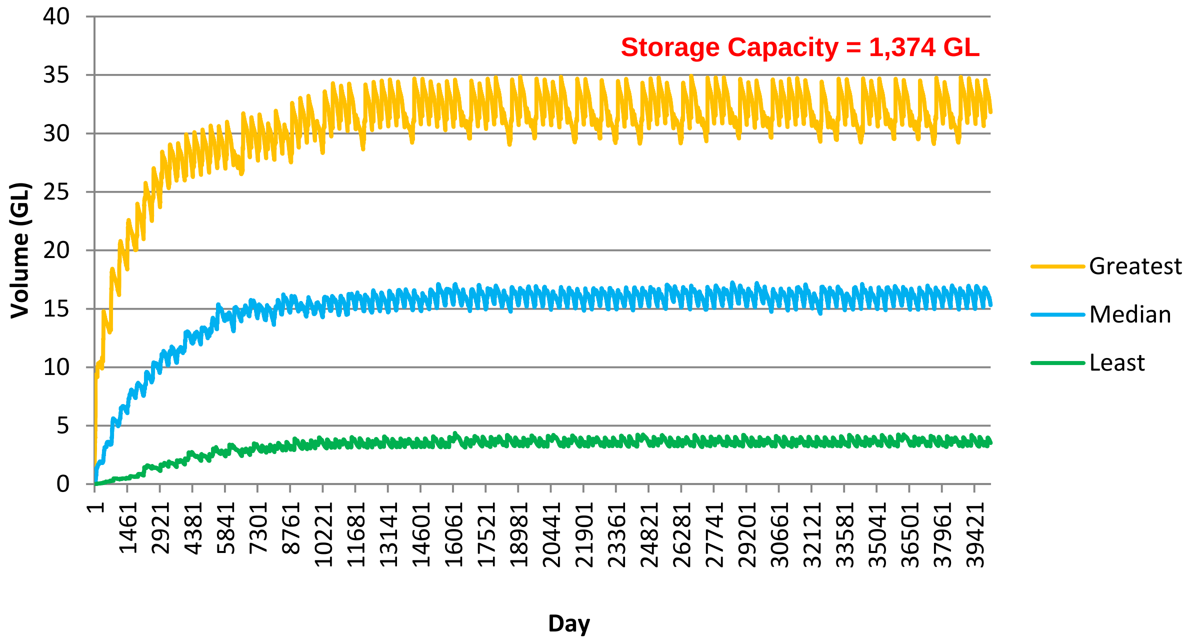

Figure 1 Pit B post rehab water volume

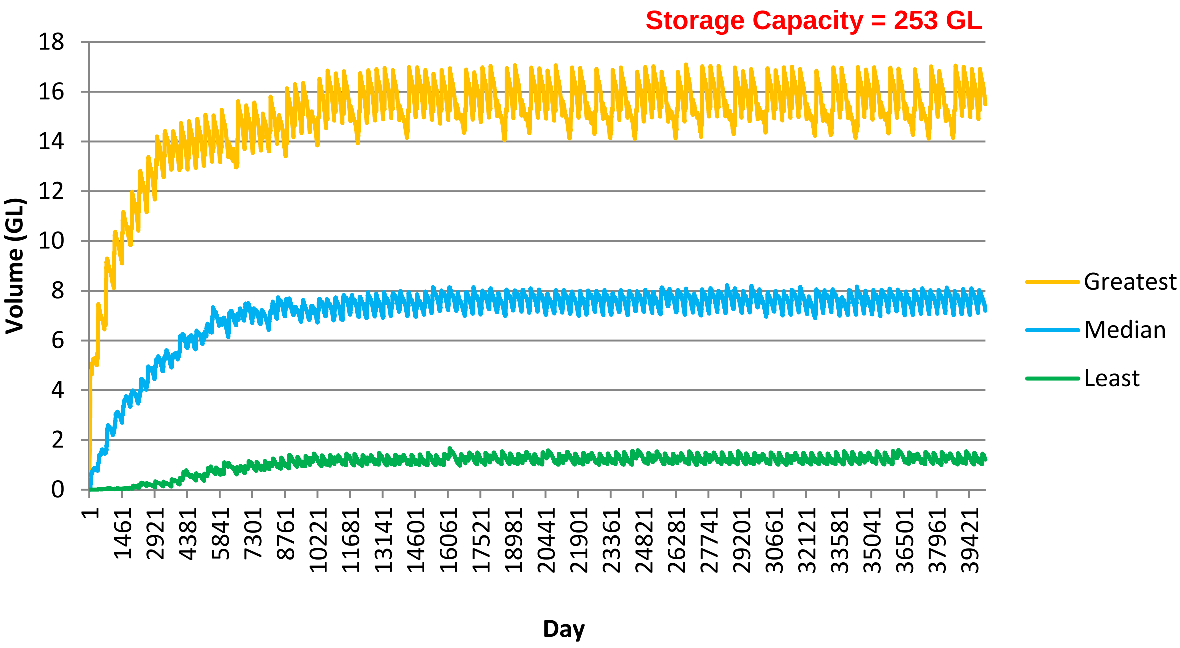

Figure 2 Pit C post rehab water volume

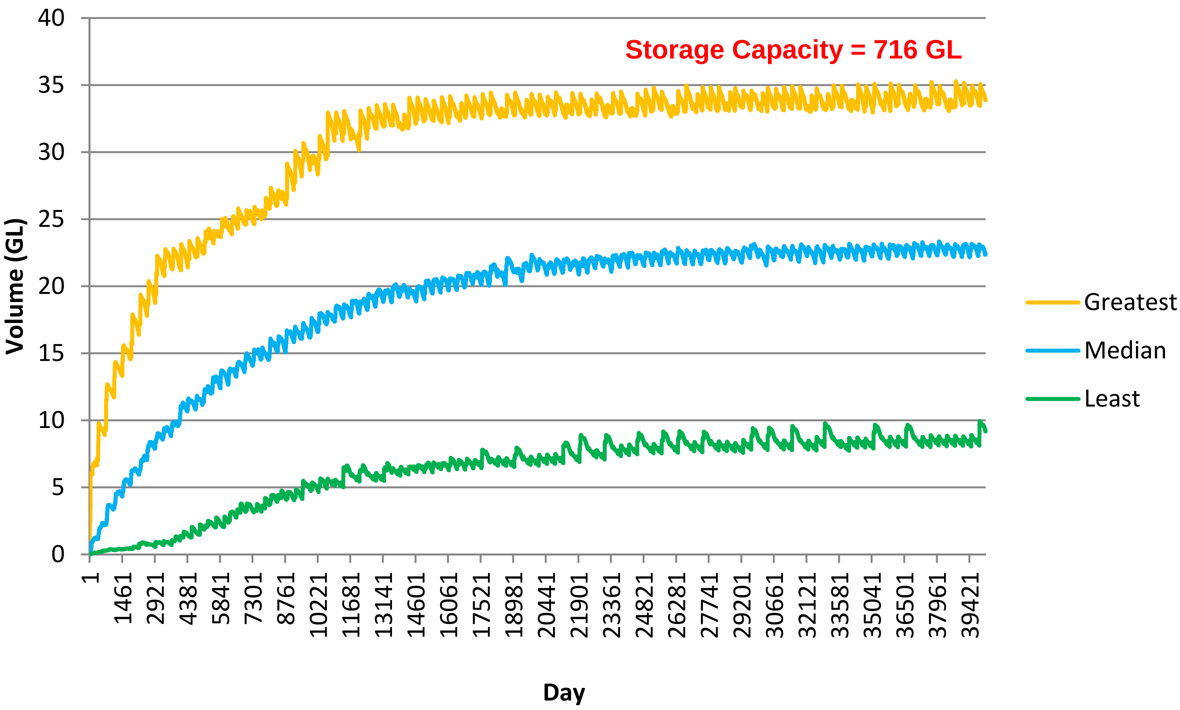

Figure 3 Pit D post rehab water volume

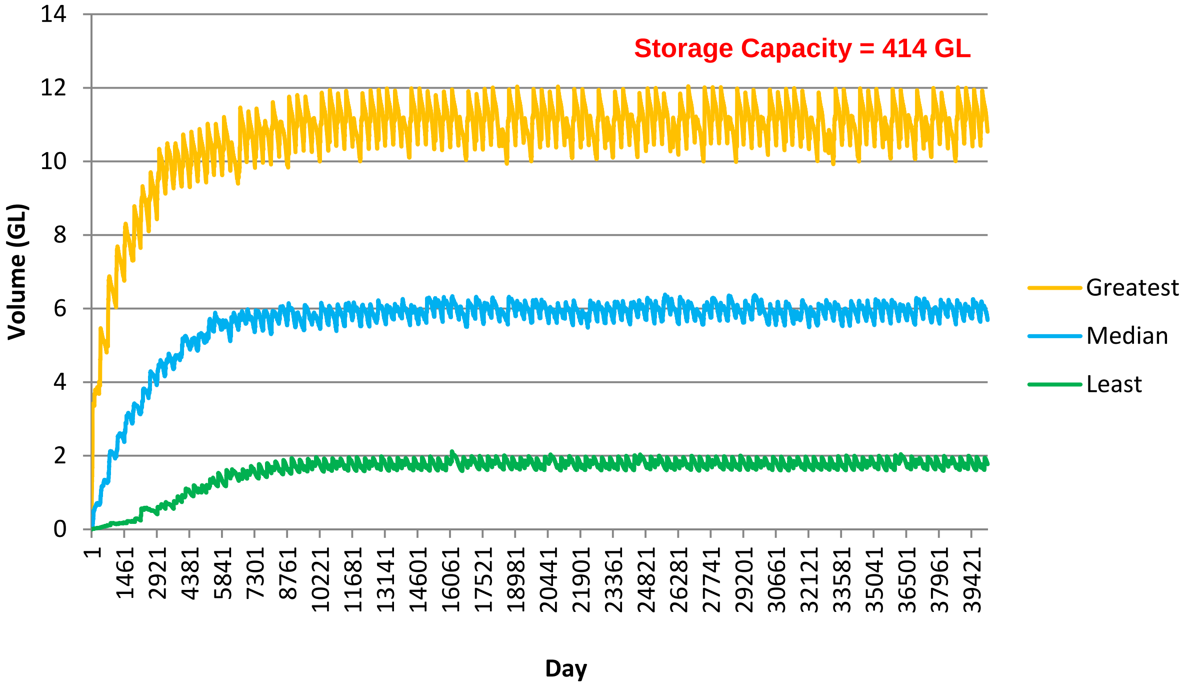

Figure 4 Pit E post rehab water volume

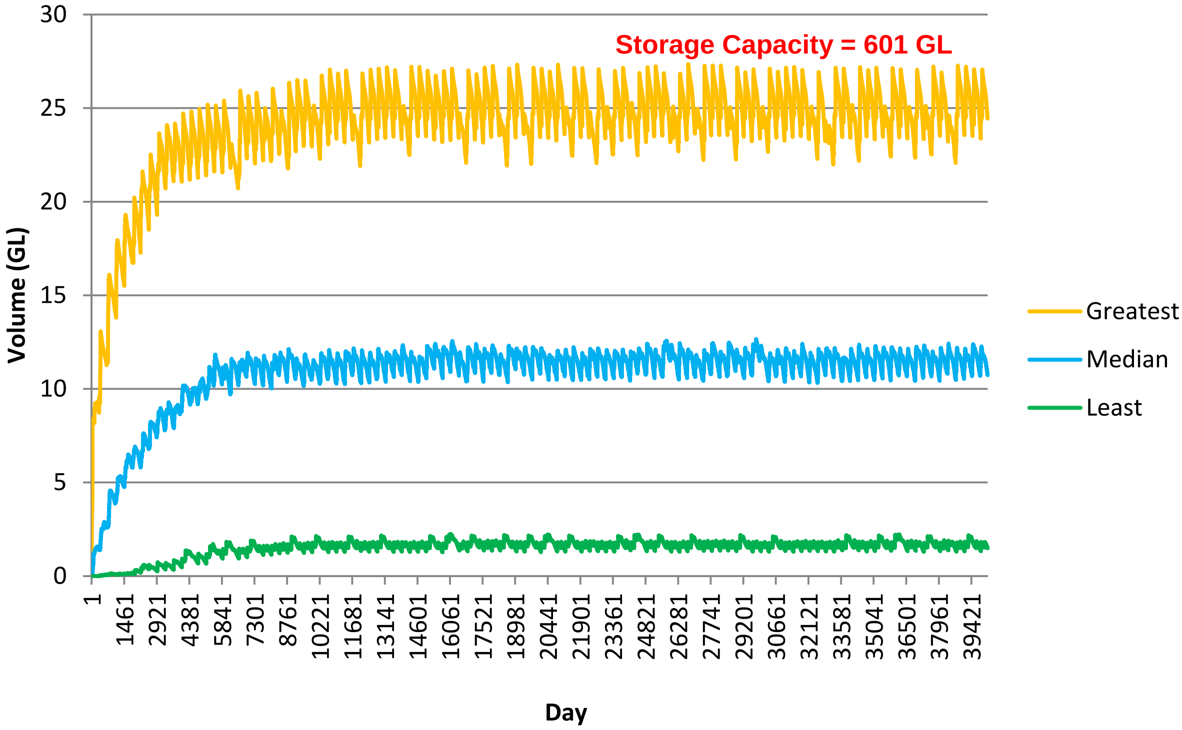

Figure 5 Pit F post rehab water volume

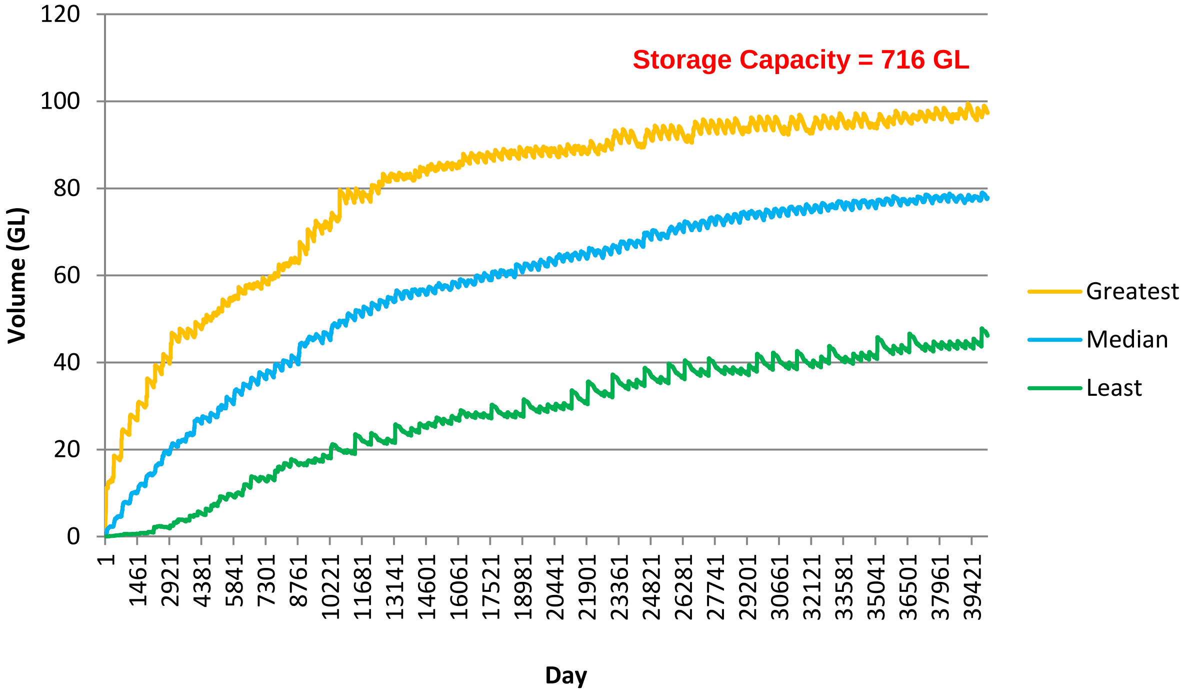

Figure 6 Pit G post rehab water volume

Regards

Dave Rowlings
Civil Engineer