Appendix AC

Stygofauna Habitat Assessment

Elimatta stygofauna habitat assessment

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DOCUMENT TRACKING

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Project Number	13ARMECO-0023
Project Manager	Dr Peter Hancock 0418 984 892 92 Taylor St, Armidale, NSW 2350
Prepared by	Dr Peter Hancock
Reviewed by	Dr Paul Frazier
Approved by	Dr Paul Frazier
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Contents

1 Background

1.1 Summary of the project

The Elimatta Project is a proposed open cut thermal coal mine located approximately 45 km south west of Taroom in southern Queensland. An Environmental Impact Statement (EIS) for the project has been prepared on behalf of Taroom Coal Proprietary Ltd, and a supplementary EIS is proposed for submission in early-mid 2014.

As part of the initial EIS, four rounds of stygofauna (groundwater animals) sampling were conducted, the first and second in September 2009, and between June and November 2011 (Subterranean Ecology 2012a) and the third and fourth in March/April 2012 and July 2012 respectively.

Four obligate groundwater species were collected during these surveys, including two that are only known from inside the predicted impact area for the project. These were Bathynellidae sp. ELIM and *Dussartcyclops* sp. ELIM, and are considered as having a significant conservation status because of their apparently restricted distribution. Seven other species of fauna were collected during the surveys, and although these occurred in groundwater, they are not completely dependent on it and can survive in surface waters.

1.2 Scope of works for this report

Fauna have been collected from both coal and alluvial aquifers at the Elimatta Project site. The purpose of this assessment is to examine groundwater and geological information to determine the likelihood of suitable stygofauna habitat extending beyond the Project boundaries. As the principal stygofauna habitat on-site is the Horse Creek Alluvial Aquifer and this is proposed for excavation during mining, the focus of this assessment will be to determine the suitability of upstream and downstream reaches for stygofauna

2 Factors influencing biological distribution in aquifers

Groundwater invertebrates require favourable conditions to allow them to inhabit an aquifer. Not all aquifers are suitable for stygofauna, and those that are suitable may become unsuitable as a result of change over time through natural events or by human-induced impacts.

Biological distribution in groundwater is influenced by historical, geological, hydrological, physico-chemical, and biological properties (Strayer 1994, Hancock et al 2005). There is still a lot being learned about stygofauna ecology, but it is possible to briefly summarise what is already known about the aquifer conditions likely to influence distribution.

2.1.1 Aquifer type

Stygofauna have been collected from many aquifer types, including fractured basalt, fractured sandstone aquifers, and pesolithic aquifers, but are most common in karstic and alluvial aquifers (Hancock et al 2005, Humphreys 2008). These aquifers are often suitable because of their high hydraulic conductivity, shallow water table, and relatively high porosity.

Alluvial aquifers often have the following conditions favourable to stygofauna:

- Water table is shallow, so there is recharge of infiltrating rainwater and organic matter, and the water table is accessible to floodplain tree roots
- They are often hydrologically connected to surface rivers. This is particularly important in regulated rivers where flows released from dams provide aquifer recharge through the stream bed. Recharging water brings with it organic matter (food) and oxygen in periods where natural surface flow would be absent
- Compared to deeper aquifers, water in alluvial aquifers is young and has a rapid flux.

2.1.2 Hydraulic conductivity

Hydraulic conductivity indicates how rapidly water flows through an aquifer. This is important to stygofauna communities because the flux of water through an aquifer often influences how rapidly organic matter and oxygen concentrations can be replenished.

2.1.3 Depth of water table

Depth to water table influences the amount of organic matter and oxygen available to aquifer foodwebs. With increasing depth below the land surface, the concentration of organic matter dissolved in recharge water diminishes as it is absorbed in transit by soil bacteria and plant roots. Shallow water tables of less than 15 m have been found to favour high diversity in alluvial aquifers in eastern Australia (Hancock and Boulton 2008).

Organic matter can also enter the aquifer food web from phreatophytic trees, either as root leachates that feed bacteria, or as fine particulate organic matter from the fine roots themselves (Jasinska et al. 1996). Phreatophytic roots are likely to grow more densely in shallower aquifers than in deep aquifers, providing higher amounts of particulate and dissolved organic matter to support stygofauna communities (Hancock and Boulton 2008).

2.1.4 Connectivity to recharge areas

Most of the organic matter that fuels aquifer food webs has its origin at the surface and enters groundwater in particulate or dissolved forms. Therefore, aquifers will have higher biological diversity and abundance near recharge than further away, since the transfer of organic matter and oxygen is greater (Datry et al 2004).

2.1.5 A space for living

Stygofauna can only live in aquifers with enough space for them to move around in. Space is present in the solute cavities in karst, between pesolithic sediments in calcrete, and fractures in sandstone and basalt. For rock aquifers such as sandstone and basalt, secondary porosity is more important than primary porosity. In unconsolidated sedimentary aquifers such as alluvium, the size of pore space between particles often correlates to the size of the animals present, with larger species occurring in aquifers of coarser material (Strayer 1994).

Also important when considering the space available for living is the connectivity between pores, cavities, and fractures. These act as migration pathways to allow fauna to move around in the aquifer and are likely to be important for recolonisation following disturbance.

2.1.6 Evolutionary history

Most stygofauna evolved from ancestors that once lived in surface freshwater or marine environments. As a result, they have retained some of the traits and environmental tolerances of their ancestry. As an example, in coastal areas where ancestral stygofauna species may have come from a marine origin, contemporary taxa may be tolerant of high salinity (Humphreys 2008). Conversely, taxa with a freshwater ancestry may prefer lower salinities (Hancock and Boulton 2008).

2.1.7 Food availability

Stygofauna have adapted to the resource-starved conditions in aquifers and can tolerate low concentrations of organic matter (Hahn 2006, Strayer 1994). Food is available to stygofauna as particulate organic matter, groundwater bacteria, or as roots of phreatic trees. In its dissolved or fine particulate form, organic matter enters aquifers with recharging water. Dissolved organic matter is taken up by groundwater bacteria, which are then consumed by stygofauna. Most stygofauna are opportunistic omnivores.

2.1.8 Water regime

Climate and river-flow regimes can influence groundwater recharge, and so affect the organic matter flux in the aquifer. Periods of high, steady rainfall can increase hydrological connectivity between the land surface and the aquifer and can reduce depth to water table. Exchange between rivers, the hyporheic zone, and aquifers can be an important source of nutrients to stygofauna communities (Dole-Olivier et al 1994), so flow fluctuations that enhance hyporheic exchange can subsequently enrich stygofauna communities in deeper parts of the aquifer.

2.1.9 Salinity

Stygofauna in inland aquifers are generally restricted to fresh or partly brackish water. Hancock and Boulton (2008) suggest that most taxa collected from alluvial aquifers in NSW and Queensland prefer EC less than 5,000 μS/cm. In surveys of coastal areas and near salt lakes in Western Australia, stygofauna were collected from aquifers with salinities at or exceeding sea water (Watts and

Humphreys 2004). *EPA Guidance Statement 54a* recommends 60 000 mg/L as the salinity above which stygofauna are unlikely (WA EPA 2007).

2.1.10 Dissolved oxygen

Stygofauna are able to tolerate very low concentrations of dissolved oxygen. Hahn (2006) observed a strong decrease in faunal abundance below 1.0 mg/L, but found some fauna in concentrations down to 0.5 mg/L. Some taxa are able to survive virtually no oxygen for temporary periods for up to 6 months (Henry and Danielopol 1999, Malard and Hervant 1999). Aquifers can be heterogeneous environments, so may contain patches of water with sufficient oxygen concentration to be suitable for stygofauna. As dissolved oxygen is measured from water pumped from bores, it can be difficult to identify where these micro habitats occur.

3 Current groundwater setting

3.1 Hydrogeology

Three geological units constitute the main groundwater systems in the Project area:

- The multi-layered sequence of interbedded aquifers that make up the Great Artesian Basin;
- Walloon Coal Seam Aquifers; and
- Unconsolidated sedimentary aquifers associated with Horse Creek.

The Precipice and Hutton Sandstone are the main aquifers of the project area that occur in the GAB strata, and neither are proposed for mining. The Precipice Sandstone yields high quality water, but is approximately 825 m deep at the Project site. This aquifer is separated from overlying aquifers by impermeable strata of non-marine siltstone and mudstone units in the Evergreen Formation (AGE 2012).

Hutton Sandstone also has high yields of potable water and the shallowest sections in the Project area are 400 m below ground level. The solid structure of this unit is made of quartzose sandstones and shales with interbedded conglomerate, siltstone and mudstone. The Hutton Sandstone is hydraulically isolated from overlying aquifers by a thick layer of essentially impermeable mudstones and siltstones.

The main water bearing strata in the Walloon Coal Measures are the coal seams, which are confined by overlying siltstone and mudstone beds. These coal measures sub-crop to the north and dip gently to the south-west. The upper part of the Walloon Coal Measures is made of the Juandah Coal Measures, which consist of five main seams and are the main target for extraction. These coal measures are also the shallowest aquifers in the Walloon Coal Measures. Uppermost is the thin Kogan Seam, which is 15 to 20 m below ground. Macalister Upper and Lower Seams are also shallower than 30 m, and the Lower Nangram sits at approximately 40 m (AGE 2012).

The southern lease (MLA50254) of the Ellimatta Project Site is dominated by a subcrop of the Macalister Seam, whereas in the northern lease (MLA50270) it is the Wambo Seam that subcrops (AARC 2012). Mining at Elimatta will occur only in the southern lease.

The unconsolidated sediment of ephemeral Horse Creek consists of Quaternary gravel, sand, silt and clay. The aquifer covers the subcropped Walloon Coal measures in a band extending from the south-western corner to the north-eastern corner of MLA50254. The alluvium extends beyond this and runs beneath the south-eastern edge of MLA50270, where it connects with the alluvium of Nine Mile Creek. The alluvium is only thin and in extended periods of no rainfall is patchily saturated (AGE 2012). Water in Horse Creek Alluvium drains downwards during wet periods and recharges aquifers in the Walloon Coal Measures (AGE 2012).

3.2 Groundwater quality

Water levels in Walloon Coal Measure monitoring bores rest between 7.7 and 30.6 m below ground level, and the coal seams have a permeability of 0.05 to 1.4 m/day, which is relatively permeable for coal (AGE 2012). Water contains between 2500 and 13 500 mg/L of TDS, though in most bores is less than 5000 mg/L. Most pH values are between 7 and 8 pH units (AGE 2012).

Water in the alluvial aquifer is generally of high quality. TDS is less than 5000 mg/L and pH is between 6.6 and 7.6 units (AGE 2012). Water level in the alluvial aquifer is between 3.58 and 10.03 m below ground level (AGE 2012).

4 Suitability of aquifers as stygofauna habitat

Survey work by Subterranean Ecology (2011, 2012) confirmed that at least 12 stygofauna species live in the Horse Creek Alluvium and Walloon Coal Measures.

4.1 Great Artesian Basin Aquifers

The Precipice and Hutton Sandstone Aquifers are not proposed for mining in this project. Both are also unsuitable for stygofauna habitat. These aquifers are both isolated from the surface and devoid of oxygen and biologically available organic matter. At depths exceeding 400 m, these aquifers are too far away from any recharge areas or potential colonising aquifers adjacent to the surface. These aquifers are not considered further in this assessment.

4.2 Walloon Coal Seam Aquifers

Samples collected from the Waloon Coal Measures at MLA 50270 contained *Mesocyclops* sp. ELIM, Nematoda sp. S5. *Mesocyclops* sp. ELIM were in bores MB4A, P1103, P1104, and P1105, which had depths to water of 2.6 to 30.7 m below ground level (Subterranean Ecolocgy 2012a, b). These species are not groundwater specialists and are likely to have entered the aquifers where coal seams intercept surface streams, such as Nine Mile Creek or Horse Creek, or through the alluvial aquifers. The presence of any fauna at all in the Walloon Coal Measures demonstrates an ability of the shallower coal seams to support life and act as a potential refuge habitat when the alluvium and surface stream is dry.

Three of the bores were in MLA50270. This lease area will be used for surface infrastructure only and will not be mined, reducing the threat to impact to any stygofauna. Mining will occur in MLA50254 where the subcropping strata are formed by the Macalister Group. In this lease, two stygofauna species were collected from the coal measures in MB4A. Both of these species are likely to have come from surface waters or soil and probably entered the aquifer from Horse Creek (Subterranean Ecology 2012a). *Mesocyclops* sp. ELIM was also collected from three bores in MLA50270, where there will be no mining, and Nematoda sp. S5 is likely to be widespread in surface water, soils, and other suitably most environments (Subterranean Ecology 2012a).

Despite the presence of fauna, the coal seams and associated weathered sandstone of the Walloon Coal Measures are likely to only to be secondary habitats for stygofauna, with the alluvial aquifers constituting the principal habitat (Subterranean Ecology 2012a,b). The suitability of Walloon Coal Measure aquifers as stygofauna habitat is reliant on there being a network of fractures and secondary porosity with hydrological connection to alluvium. As these factors are likely to decline with depth, the suitability of these aquifers to act as stygofauna habitat will also decrease with distance from the alluvial aquifer.

4.3 Horse Creek Alluvial Aquifer

The alluvial aquifer of Horse Creek is the principal stygofauna habitat on site. More species were collected from this aquifer in the southern mining lease than in the north. This may be due to the steeper topography immediately adjacent to the aquifer in the southern lease. Steeper slopes mean that water is funnelled into and through the aquifer more rapidly than further north where the valley broadens, so stygofauna are getting better access to organic matter and recharge water. With better access to organic matter, fauna are able to achieve greater densities and so are more concentrated in the upper reaches of the aquifer.

Seven stygofauna species were collected during sampling of the Horse Creek Alluvium, four of which were groundwater specialists (stygobites) with the remining three being opportunistic groundwater dwellers (stygophiles). All three of the opportunistic stygofauna are known from aquifers or surface water bodies outside the project area (Subterranean Ecology 2012a,b). Of the groundwater specialists, *Parastenocasis* sp. ELIM and *Dussartcyclops* sp. ELIM appear widespread throughout the aquifer, occurring in bores close to the main channel of Horse Creek (Subterranean Ecology 2012a, b).

Parastenocasis sp. ELIM was in MB8B on the southern boundary of MLA50254, MB15, near the south-eastern boundary of MLA50270, and in two bores in between. All bores were close to the main channel of Horse Creek. These results indicate that the species is widespread in the Horse Creek Alluvium and is likely to occur along the entire length of the aquifer. Collections of the species from MB3B and MB15 confirm that the species occurs outside of the mining lease boundaries in the intervening 5 km of aquifer between the two bores. The collection of *Parastenocasis* sp. ELIM from MB8B suggests that the species also occurs in the aquifer upstream of the mining leases.

Dussartcyclops sp. ELIM is also widespread in the Horse Creek Alluvium in MLA50254 and probably occurs both upstream and downstream of the lease boundaries. The species occurs from MB8 to MB3B along the aquifer, and since there appear to be no barriers to migration, is likely to occur further downstream of the project area.

The presence of *Parastenocasis* sp. ELIM and *Dussartcyclops* sp. in several bores along the aquifer demonstrates that there is no physical barrier, such as an outcropping of rock, that prevents stygofauna from disbursing through the aquifer.

Two stygobitic species were collected only from one bore each. These were Bathynellidae sp. ELIM in MB3B and *Dussartstencaris* sp. ELIM in MB15. Both of these bores had a total of five stygofauna taxa and had the highest biological diversity of all bores surveyed (Subterranean Ecology 2012a,b). Two species, *Parastenocaris* sp. ELIM and Enchytraeidae ELIM indet., were common to both bores and all other taxa occurred in more than one bore.

Water in MB3B had TDS between 1020 and 1820 μg/cm, and pH between 6.7 and 6.9 (AGE 2012). In MB15, TDS was 2920 μg/cm and pH was 7.3. Both of these bores had water chemistry in the range of other inhabited alluvial bores in the aquifer (pH = 7.08-8.15, TDS = 521-4610), and analysis by AGE (2012) demonstrated that water in the alluvial aquifer has a relatively homogenous chemical signature. Therefore, longitudinal variations in water chemistry are unlikely to be substantial enough to limit the distribution of Bathynellidae sp. ELIM and *Dussartstencaris* sp. ELIM in this aquifer. Further, the other species collected in association with Bathynellidae sp. ELIM and *Dussartstencaris* sp. ELIM are widespread in the aquifer, suggesting that there are neither physical nor hydrological barriers to dispersal.

Stygofauna generally occur at low densities in an aquifer, so are often not detected during sampling despite being present (WA EPA 2007). Although only collected from single bores, both Bathynellidae sp. ELIM and *Dussartstencaris* sp. ELIM are likely to have a broader distribution in the Horse Creek Aquifer, extending beyond the lease boundaries in an upstream and downstream direction.

The occurrence of stygofauna in MB8B provides sufficient evidence that the alluvial aquifer upstream of the southern MLA50254 boundary is suitable for fauna, and the diverse communities in MB3B and MB15 demonstrate that the expanse of aquifer that runs outside of the mining lease between these two bores, is inhabited by stygofauna. Similarities in the chemical composition of groundwater along the aquifer, and a lack of physical or hydrological barriers make it extremely likely that all taxa collected from the alluvial aquifer during the four Subterranean Ecology surveys will occur throughout the Horse Creek aquifer and extend into areas beyond the lease boundary.

4.4 Potential impacts

Both the alluvial aquifer of Horse Creek and the Walloon Coal Measures in MLA50254 will be impacted by mining, but both aquifers extend beyond the lease boundary. The two species collected from the Coal Measures aquifer are also known from areas where mining will not occur, such as in MLA50270 and nearby surface water habitats.

The Horse Creek Alluvial aquifer provides suitable habitat both upstream and downstream of the lease boundary. As there are no known major interruptions to the alluvium along the creek, it is reasonable to expect that the species collected inside the lease will also occur outside (WA EPA 2013). Stygofauna diversity along this aquifer may also increase as it is joined by aquifers associated with Back Creek and Duck Creek.

5 Conclusion

Stygofauna samples collected to date, when considered with groundwater chemistry data and aquifer reports, strongly suggest that all species known from inside MLA50254 will also occur outside of it in areas not impacted by mining.

The principal stygofauna habitat is the Horse Creek Alluvial Aquifer. Fauna collected near the southern boundary of MLA50254 provide sufficient evidence that the upstream reach of alluvium is suitable for fauna. The diverse communities in MB3B and MB15 demonstrate suitability of the aquifer between these bores.

Similarities in the chemical composition of groundwater along the aquifer, and a lack of physical or hydrological barriers make it extremely likely that all taxa collected from the alluvial aquifer during the four Subterranean Ecology surveys will occur throughout the Horse Creek aquifer and extend into areas beyond the lease boundary.

Although *Parastenocasis* sp. ELIM and *Dussartcyclops* sp. were collected from only one bore each, water chemistry and the distribution of other species in the local stygofauna community suggest that they both occur throughout the aquifer. Many stygofauna species are present at low densities, and the non-detection of these two species at other bores is probably due to this, rather than to a real absence.

Although mining will remove a section of the alluvial aquifer that passes through MLA50254, none of the stygofauna species collected from the lease area are likely to be restricted solely to the lease area. As a result of this, none of the known stygofauna species are at risk from this development.

References

Austral Asian Resource Consultants (AARC) 2012. *Elimatta Project Environmental Impact Assessment*. Report prepared for Northern Energy Corporation.

Australasian Groundwater and Environmental Consultants (AGE) Pty Ltd 2012. *Elimatta Project Groundwater Assessment*. Report prepared for Northern Energy Corporation, October 2012.

Datry, T., Malard, F. and Gibert, J. 2005. Response of invertebrate assemblages to increased groundwater recharge rates in a phreatic aquifer. *Journal of The North Benthological Society* 24(3), 461-477.

Dole-Olivier, M.-J., Marmonier, P., Creuzé des Châtelliers, M., Martin, D. 1994. Interstitial fauna associated with the alluvial floodplains of the Rhöne River (France). In: Gibert J, Danielopol DL, Stanford JA (eds) *Groundwater Ecology*. Academic Press, San Diego, 313–346

Hahn, H.J. 2006. The GW-Fauna-Index: A first approach to a quantitative ecological assessment of groundwater habitats. *Limnologica* 36, 119-137.

Hancock, P., Boulton, A., and Humphreys, W. 2005. Aquifers and hyporheic zones: toward an ecological understanding of groundwater. *Hydrogeology Journal* 13, 98-111.

Hancock, P.J. and Boulton, A.J. 2008. Stygofauna biodiversity and endemism in four alluvial aquifers in eastern Australia. *Invertebrate Systematics* 22, 117-126.

Henry, K.S. and Danielopol, D.L. 1999. Oxygen dependent habitat selection in surface and hyporheic environments by *Gammarus roesli* Gervais (Crustacea, Amphipoda): experimental evidence. *Hydrobiologia* 390, 51-60.

Humphreys, W. F. 2008. Rising from down under: developments in subterranean biodiversity in Australia from a groundwater fauna perspective. *Invertebrate Systematics* 22, 85–101.

Jasinska, E. J., Knott, B., and McComb, A. R. 1996. Root mats in ground water: a fauna-rich cave habitat. *Journal of the North American Benthological Society* 15, 508–519.

Malard, F. and Hervant, F. 1999. Oxygen supply and the adaptions of animals in groundwater. *Freshwater Biology* 41, 1-30.

Strayer, D.L. 1994. Limits to biological distributions in groundwater. In: Gibert J, Danielopol DL, Stanford JA (eds) *Groundwater Ecology*. Academic Press, San Diego, 287–313.

Subterranean Ecology. 2012a. *Elimatta Project Stygofauna Survey*. Report prepared for Taroom Coal Pty Ltd, April 2012.

Subterranean Ecology. 2012b. *Elimatta Project Stygofauna Survey and Assessment*. Report prepared for Northern Energy Corporation, November 2012.

Western Australian Environmental Protection Authority (WA EPA). 2007. *Sampling methods and survey considerations for subterranean fauna in Western Australia*. Draft Guidance Statement No 54a (Technical Appendix to Guidance Statement No 54). Environmental Protection Authority, Perth.

Western Australian Environmental Protection Authority (WA EPA). 2013. Environmental Assessment Guideline 12 (EAG), *Consideration of subterranean fauna in environmental impact assessment in Western Australia.* Environmental Protection Authority, Perth.

HEAD OFFICE
Suite 4, Level 1
2-4 Merton Street
Sutherland NSW 2232
T 02 8536 8600
F 02 9542 5622

SYDNEY
Level 6
299 Sussex Street
Sydney NSW 2000
T 02 8536 8650
F 02 9264 0717

ST GEORGES BASIN
8/128 Island Point Road
St Georges Basin NSW 2540
T 02 4443 5555
F 02 4443 6655

CANBERRA
Level 2
11 London Circuit
Canberra ACT 2601
T 02 6103 0145
F 02 6103 0148

NEWCASTLE
Suites 28 & 29, Level 7
19 Bolton Street
Newcastle NSW 2300
T 02 4910 0125
F 02 4910 0126

NAROOMA
5/20 Canty Street
Narooma NSW 2546
T 02 4476 1151
F 02 4476 1161

COFFS HARBOUR
35 Orlando Street
Coffs Harbour Jetty NSW 2450
T 02 6651 5484
F 02 6651 6890

ARMIDALE
92 Taylor Street
Armidale NSW 2350
T 02 8081 2681
F 02 6772 1279

MUDGEE
Unit 1, Level 1
79 Market Street
Mudgee NSW 2850
T 02 4302 1230
F 02 6372 9230

PERTH
Suite 1 & 2
49 Ord Street
West Perth WA 6005
T 08 9227 1070
F 08 9322 1358

WOLLONGONG
Suite 204, Level 2
62 Moore Street
Austinmer NSW 2515
T 02 4201 2200
F 02 4268 4361

GOSFORD
Suite 5, Baker One
1-5 Baker Street
Gosford NSW 2250
T 02 4302 1220
F 02 4322 2897

DARWIN
16/56 Marina Boulevard
Cullen Bay NT 0820
T 08 8989 5601

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