24.27 Appendix AA – EPBC Protected Matters Report

EPBC Protected Matters Report (2015)

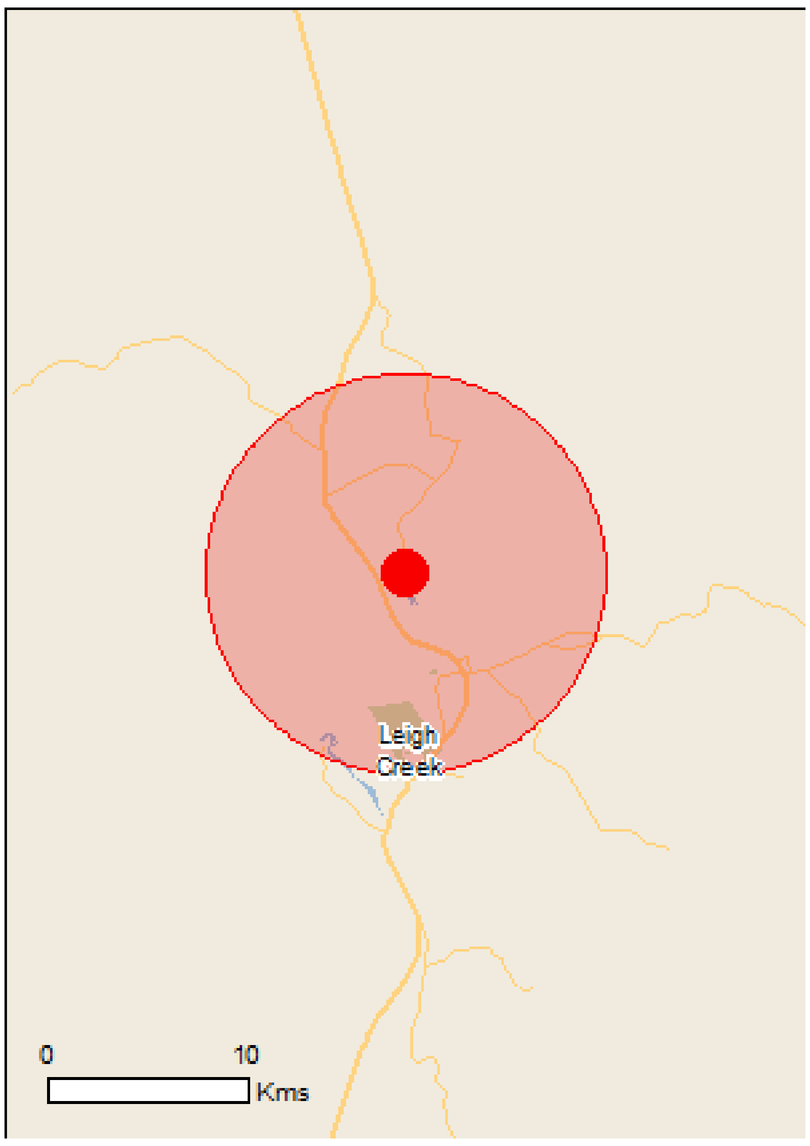
EPBC Act Protected Matters Report

This report provides general guidance on matters of national environmental significance and other matters protected by the EPBC Act in the area you have selected.

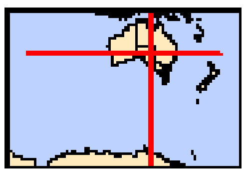
Information on the coverage of this report and qualifications on data supporting this report are contained in the caveat at the end of the report.

Information is available about Environment Assessments and the EPBC Act including significance guidelines, forms and application process details.

Report created: 16/12/15 15:35:11



Coordinates
Buffer: 10.0Km



Summary

Matters of National Environmental Significance

This part of the report summarises the matters of national environmental significance that may occur in, or may relate to, the area you nominated. Further information is available in the detail part of the report, which can be accessed by scrolling or following the links below. If you are proposing to undertake an activity that may have a significant impact on one or more matters of national environmental significance then you should consider the Administrative Guidelines on Significance.

World Heritage Properties:	None
National Heritage Places:	None
Wetlands of International Importance:	None
Great Barrier Reef Marine Park:	None
Commonwealth Marine Area:	None
Listed Threatened Ecological Communities:	None
Listed Threatened Species:	8
Listed Migratory Species:	8

Other Matters Protected by the EPBC Act

This part of the report summarises other matters protected under the Act that may relate to the area you nominated. Approval may be required for a proposed activity that significantly affects the environment on Commonwealth land, when the action is outside the Commonwealth land, or the environment anywhere when the action is taken on Commonwealth land. Approval may also be required for the Commonwealth or Commonwealth agencies proposing to take an action that is likely to have a significant impact on the environment anywhere.

The EPBC Act protects the environment on Commonwealth land, the environment from the actions taken on Commonwealth land, and the environment from actions taken by Commonwealth agencies. As heritage values of a place are part of the 'environment', these aspects of the EPBC Act protect the Commonwealth Heritage values of a Commonwealth Heritage place. Information on the new heritage laws can be found at http://www.environment.gov.au/heritage

A permit may be required for activities in or on a Commonwealth area that may affect a member of a listed threatened species or ecological community, a member of a listed migratory species, whales and other cetaceans, or a member of a listed marine species.

Commonwealth Land:	None
Commonwealth Heritage Places:	None
Listed Marine Species:	9
Whales and Other Cetaceans:	None
Critical Habitats:	None
Commonwealth Reserves Terrestrial:	None
Commonwealth Reserves Marine:	None

Extra Information

This part of the report provides information that may also be relevant to the area you have nominated.

State and Territory Reserves:	None
Regional Forest Agreements:	None
Invasive Species:	13
Nationally Important Wetlands:	None
Key Ecological Features (Marine)	None

Details

Matters of National Environmental Significance

Listed Threatened Species		[Resource Information]
Name	Status	Type of Presence
Birds		
Amytornis modestus		
Thick-billed Grasswren [84121]	Vulnerable	Species or species habitat likely to occur within area
Pedionomus torquatus		
Plains-wanderer [906]	Critically Endangered	Species or species habitat may occur within area
Pezoporus occidentalis		
Night Parrot [59350]	Endangered	Extinct within area
Rostratula australis		
Australian Painted Snipe [77037]	Endangered	Species or species habitat may occur within area
Mammals		
Petrogale xanthopus xanthopus		
Yellow-footed Rock-wallaby (SA and NSW) [66646]	Vulnerable	Species or species habitat likely to occur within area
Pseudomys australis		
Plains Rat, Palyoora [108]	Vulnerable	Species or species habitat may occur within area
Plants		
Codonocarpus pyramidalis		
Slender Bell-fruit, Camel Poison [19507]	Vulnerable	Species or species habitat likely to occur within area
Frankenia plicata		
[4225]	Endangered	Species or species habitat likely to occur within area

Listed Migratory Species		[Resource Information]
* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.		
Name	Threatened	Type of Presence
Migratory Marine Birds		
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Migratory Terrestrial Species		
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within

Name	Threatened	Type of Presence
		area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area
Migratory Wetlands Species		
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Tringa nebularia		
Common Greenshank, Greenshank [832]		Species or species habitat may occur within area

Other Matters Protected by the EPBC Act

Listed Marine Species [Resource Information]

* Species is listed under a different scientific name on the EPBC Act - Threatened Species list.

Name	Threatened	Type of Presence
Birds		
Apus pacificus		
Fork-tailed Swift [678]		Species or species habitat likely to occur within area
Ardea alba		
Great Egret, White Egret [59541]		Species or species habitat known to occur within area
Ardea ibis		
Cattle Egret [59542]		Species or species habitat may occur within area
Charadrius veredus		
Oriental Plover, Oriental Dotterel [882]		Species or species habitat may occur within area
Merops ornatus		
Rainbow Bee-eater [670]		Species or species habitat may occur within area
Motacilla cinerea		
Grey Wagtail [642]		Species or species habitat may occur within area
Motacilla flava		
Yellow Wagtail [644]		Species or species habitat may occur within area
Rostratula benghalensis (sensu lato)		
Painted Snipe [889]	Endangered*	Species or species habitat may occur within area
Tringa nebularia		
Common Greenshank, Greenshank [832]		Species or species habitat may occur within area

Extra Information

Invasive Species [Resource Information]

Weeds reported here are the 20 species of national significance (WoNS), along with other introduced plants that are considered by the States and Territories to pose a particularly significant threat to biodiversity. The following feral animals are reported: Goat, Red Fox, Cat, Rabbit, Pig, Water Buffalo and Cane Toad. Maps from Landscape Health Project, National Land and Water Resouces Audit, 2001.

Name	Status	Type of Presence
Birds		
Columba livia Rock Pigeon, Rock Dove, Domestic Pigeon [803]		Species or species habitat likely to occur within area
Passer domesticus House Sparrow [405]		Species or species habitat likely to occur within area
Sturnus vulgaris Common Starling [389]		Species or species habitat likely to occur within area
Mammals		
Bos taurus Domestic Cattle [16]		Species or species habitat likely to occur within area
Capra hircus Goat [2]		Species or species habitat likely to occur within area
Felis catus Cat, House Cat, Domestic Cat [19]		Species or species habitat likely to occur within area
Mus musculus House Mouse [120]		Species or species habitat likely to occur within area
Oryctolagus cuniculus Rabbit, European Rabbit [128]		Species or species habitat likely to occur within area
Vulpes vulpes Red Fox, Fox [18]		Species or species habitat likely to occur within area
Plants		
Carrichtera annua Ward's Weed [9511]		Species or species habitat likely to occur

Name	Status	Type of Presence
		within area
Cenchrus ciliaris Buffel-grass, Black Buffel-grass [20213]		Species or species habitat may occur within area
Parkinsonia aculeata Parkinsonia, Jerusalem Thorn, Jelly Bean Tree, Horse Bean [12301]		Species or species habitat likely to occur within area
Tamarix aphylla Athel Pine, Athel Tree, Tamarisk, Athel Tamarisk, Athel Tamarix, Desert Tamarisk, Flowering Cypress, Salt Cedar [16018]		Species or species habitat likely to occur within area

Caveat

The information presented in this report has been provided by a range of data sources as acknowledged at the end of the report.

This report is designed to assist in identifying the locations of places which may be relevant in determining obligations under the Environment Protection and Biodiversity Conservation Act 1999. It holds mapped locations of World and National Heritage properties, Wetlands of International and National Importance, Commonwealth and State/Territory reserves, listed threatened, migratory and marine species and listed threatened ecological communities. Mapping of Commonwealth land is not complete at this stage. Maps have been collated from a range of sources at various resolutions.

Not all species listed under the EPBC Act have been mapped (see below) and therefore a report is a general guide only. Where available data supports mapping, the type of presence that can be determined from the data is indicated in general terms. People using this information in making a referral may need to consider the qualifications below and may need to seek and consider other information sources.

For threatened ecological communities where the distribution is well known, maps are derived from recovery plans, State vegetation maps, remote sensing imagery and other sources. Where threatened ecological community distributions are less well known, existing vegetation maps and point location data are used to produce indicative distribution maps.

For species where the distributions are well known, maps are digitised from sources such as recovery plans and detailed habitat studies. Where appropriate, core breeding, foraging and roosting areas are indicated under 'type of presence'. For species whose distributions are less well known, point locations are collated from government wildlife authorities, museums, and non-government organisations; bioclimatic distribution models are generated and these validated by experts. In some cases, the distribution maps are based solely on expert knowledge.

Only selected species covered by the following provisions of the EPBC Act have been mapped:

- migratory and
- marine

The following species and ecological communities have not been mapped and do not appear in reports produced from this database:

- threatened species listed as extinct or considered as vagrants
- some species and ecological communities that have only recently been listed
- some terrestrial species that overfly the Commonwealth marine area
- migratory species that are very widespread, vagrant, or only occur in small numbers

The following groups have been mapped, but may not cover the complete distribution of the species:

- non-threatened seabirds which have only been mapped for recorded breeding sites
- seals which have only been mapped for breeding sites near the Australian continent

Such breeding sites may be important for the protection of the Commonwealth Marine environment.

Coordinates

-30.52 138.39556

Acknowledgements

This database has been compiled from a range of data sources. The department acknowledges the following custodians who have contributed valuable data and advice:

- -Office of Environment and Heritage, New South Wales
- -Department of Environment and Primary Industries, Victoria
- -Department of Primary Industries, Parks, Water and Environment, Tasmania
- -Department of Environment, Water and Natural Resources, South Australia
- -Parks and Wildlife Commission NT, Northern Territory Government
- -Department of Environmental and Heritage Protection, Queensland
- -Department of Parks and Wildlife, Western Australia
- -Environment and Planning Directorate, ACT
- -Birdlife Australia
- -Australian Bird and Bat Banding Scheme
- -Australian National Wildlife Collection
- -Natural history museums of Australia
- -Museum Victoria
- -Australian Museum
- -South Australian Museum
- -Queensland Museum
- -Online Zoological Collections of Australian Museums
- -Queensland Herbarium
- -National Herbarium of NSW
- -Royal Botanic Gardens and National Herbarium of Victoria
- -Tasmanian Herbarium
- -State Herbarium of South Australia
- -Northern Territory Herbarium
- -Western Australian Herbarium
- -Australian National Herbarium, Atherton and Canberra
- -University of New England
- -Ocean Biogeographic Information System
- -Australian Government, Department of Defence
- Forestry Corporation, NSW
- -Geoscience Australia
- -CSIRO
- -Other groups and individuals

The Department is extremely grateful to the many organisations and individuals who provided expert advice and information on numerous draft distributions.

Please feel free to provide feedback via the Contact Us page.

Department of the Environment
GPO Box 787
Canberra ACT 2601 Australia
+61 2 6274 1111

24.28 Appendix BB – FPP Schedule of Additional Works

FPP Schedule of Additional Works

FlindersPower

Appendix BB – Schedule of Additional Works

The following list of actions has been identified throughout the risk assessment and closure planning process, and will be implemented during the closure program.

#	Action	Plan Reference	Who	Commencement Date	Status
1	Establish a monitoring program for agreed period to provide site management post mine closure, as per MCP, including minor remedial works if required.	Sect 19.1	Program Mgr	Q1 2018	
2	Facilitate a process to review and communicate the LC Coalfields Emergency Response Plan with relevant Government and Emergency Services stakeholders	Sect 13.3	Compliance Advisor	Q1/Q2 2018	
3	Employ a facilitate process to review and communicate current site access procedures (inc. cemetery) with relevant Government and Emergency Services stakeholders	Sect 13.3 Sect 14.6	Compliance Advisor	Q1/Q2 2018	
4	Implement final retention dam overflow configuration	Sect 14.2.1	Mine Manager	Q1/Q2 2018	
5	Implement a water quality monitoring program	Sect 16.4	Compliance Advisor	Q4 2016	In progress
6	Facilitate a process with relevant stakeholders (SA Government and ATLA) to determine future management of Indigenous artifacts and sites	Sect 9.10	Compliance Advisor	Q3/Q4 2017	In progress
7	Conduct a last round of pest control and facilitate a process to transfer the flora and fauna pest control plan with relevant stakeholders i.e. future landholders and North Flinders NRM Group	Sect 15.2	Compliance Advisor	Q1/Q2 2018	
8	Provide current relevant geotechnical information to DSD on relinquishment	Sect 22	Compliance Advisor	Q1/Q2 2018	In progress

9	Transfer of Principle Hazard Management Plan 008 Spontaneous Combustion to safely manage any instances of spontaneous combustion at Leigh Creek Coalfield provided to future landholders and DSD	Appendix L Risk Assessments for Domains 1, 3 and 6	Compliance Advisor	Q1/Q2 2018
10	Water safety signage erected at the Retention Dam	Sect 14.2	Compliance Advisor	Q2 2017
11	Remove all Coal Plant infrastructure from the Domain 5, unless future use identified and management transferred to future leaseholder	Sect 14.5	Mine Manager	Q1/Q2 2018
12	Isolation of electricity supply by ElectraNet at substation on relinquishment	Sect 14.5	Mine Manager	Q1/Q2 2018
13	Testing and removal of PCB from redundant transformers by licensed contractor	Appendix L Risk Assessments for Domain 5	Compliance Advisor	Q2 2017
14	Implement site contamination remediation measures as required	Sect 12.2	Compliance Advisor	Q3/Q4 2017 Q1/Q2 2018
15	Dispose of all hazardous substances in workshops	Sect 15	Compliance Advisor	Q1/Q2 2018
16	Drain and dispose of all waste at wash-down areas	Sect 15	Compliance Advisor	Q1/Q2 2018
17	Radiation gauges decommissioned and removed from site	Sect 15	Compliance Advisor	Q4 2016
18	Tooling containing hazardous materials removed from site	Sect 15	Compliance Advisor	Q1/Q2 2018
19	Dispose of Asbestos-Containing Material at Drill and Blast facilities	Sect 14.5	Mine Manager	Q3/Q4 2017
20	Mine Access gate remains to restrict access post lease hand back	Sect 13.3	Compliance Advisor	Q2 2018
21	Access points and surface water inflows to Lobe C & D to be blocked.	Sect 14.7 & Sect 14.8	Mine Manager	Q4 2017

22	Completion of boundary stock fencing & signage to agreed standard	Sect 13.3	Mine Manager	Q1/Q2 2018	
23	Management and closure of all landfills in accordance with the agreed Landfill Environmental Management Plan	Sect 14.5 Sect 14.6 Sect 14.9 Sect 15.1	Compliance Advisor	Q1/Q2 2018	
26	Provide access gate keys, passes etc. to relevant SA Government stakeholders	Sect 13.3	Compliance Advisor	Q1/Q2 2018	
27	Ensure all agreed remaining infrastructure is left with safety risks managed ALARP	Sect 14.5	Compliance Advisor	Q1/Q2 2018	
28	Ensure remaining plant and equipment is left onsite in sound working order and maintenance records passed to future leaseholder	Sect 19.1	Mine Manager	Q1/Q2 2018	
29	Update the Statutory Mine Plans and provide to Government prior to relinquishment	App OO	Mine Manager	Q2 2018	
30	Provide the final asbestos register to SA Government (following the completion of all works)	Sect 22	Compliance Advisor	Q2 2018	
31	Develop a Post-Completion Monitoring and Minor Works Plan	Sect 19.1	Mine Manager / Program Director	Q1/Q2 2018	
32	Develop a Post-Relinquishment Monitoring and Minor Works Plan. Specifically consider the need for maintenance of fencing, signage and exclusion bunds.	Sect 19.2	Mine Manager / Program Director	Q1/Q2 2018	
33	Conduct minor remedial earthworks to Eastern Bund	Sect 14.9	Mine Manager	Q2 2018	

24.29 Appendix CC – Notification of Mining Operations June 2016

Letter from Peter Kelly to Paul De Ionno (DSD/DPC) dated 16 June 2016 alintaenergy

16 June 2016

Mr Paul De Ionno
Manager, Mining Compliance and Regulation
Mining Regulation
Department of State Development

By email: Paul.DeIonno2@sa.gov.au

Dear Paul

NOTIFICATION OF MINING OPERATIONS – LEIGH CREEK COALFIELDS

This note is to provide you with an update of:

1. the operational works that have been and are currently underway, since the last notification in November 2015; and
2. intended operations at the mine prior to finalisation and approval of the Mine Closure Plan, anticipated in August 2016.

Coal mining operations at Leigh Creek Coalfields have ceased.

The significant dates of the mine operations closure were:

1. Major mining and mine development ceased on 17th November 2015
2. Coal mining, crushing, stockpiling and rail operations ceased on 27th April 2016.

Since the cessation of coal mining operations, site operations have been focused on minor rehabilitation works and control of spontaneous combustion active areas.

Several major projects have also been initiated during this period, including:

- Crushed & ROM stockpiled coal removed and buried. Sites prepared for final rehabilitation requirements
- Decommissioning of coal plant commenced
- Rail bins made safe, and removal of coal process commenced
- Baseline heat monitoring survey of in pit and historical surface dumps completed in April 2016

In conjunction with the Department of State Development (DSD), the Environment Protection Authority (EPA), and SafeWork SA, work has continued in developing a Mine Closure Plan that will confirm the specific details of closure activities (including, where appropriate, ratification of such by necessary technical experts) ensuring the activities comply with all applicable laws and other statutory/regulatory requirements. A draft Mine Closure Plan was submitted for comment and review on April 15th 2016.

Preliminary rehabilitation works were commenced on 11th May 2016, through day shift only operational works, that are consistent with the Draft Mine Closure Plan. The primary project areas that have been commenced since the implementation of this plan are:

- MT21 (Main Series Terrace 21, Mine Area M10/M11) internal dumps battering
- MT21 Low wall battering
- Western bund (Northern section) battering
- UT07 (Upper Series Terrace 7) internal dumps battering
- Continued control of active spontaneous combustion areas
- Continued heat monitoring of areas designated in Draft Mine Closure Plan
- Rationalisation of on-site equipment to facilitate removal as required
- Site security process updated to meet new operational requirements

During this operational phase, Flinders Power Partnership will continue to maintain the mine in a safe condition, under the existing Leigh Creek Coalfields Safety Management System and in compliance with statutory obligations. Mine Emergency Services personnel will remain on site through this phase.

The ongoing spontaneous combustion management procedures and processes ensure that any spontaneous combustion hot spots are actively controlled. The existing (and updated) Spontaneous Combustion Hazard Management Plan forms the basis for this work.

The Spontaneous Combustion Hazard Management Plan has been reviewed and updated by utilising:

1. Baseline heat monitoring data
2. Knowledge and experience gained since November 2015
3. The advice from independent experts
4. Ongoing heat monitoring data

The updated Spontaneous Combustion Hazard Management plan has also been utilised in the Draft Mine Closure Plan.

EMPLOYMENT

Employment for the Rehabilitation Plan works that commenced in May 2016, is as follows

- All management, administration and supervisory roles are Flinders Power employees;

- The operational workforce will primarily be derived from Ranstad, a labour resource organisation. Flinders Power Partnership and Ranstad have entered into an agreement for the provision of competent and experienced labour to perform rehabilitation works.
- Maintenance workforce is a mix of contracted employees (through Komatsu and Cavpower) with additional personnel supplied through Ranstad as required.

All personnel have been inducted and trained so as to meet site standards and requirements.

HUMAN RESOURCES

Mine Operations will require 29 personnel, as detailed below, and are based around two rehabilitation crews:

1. Rehabilitation Crews (x2) - rostered 37.5hrs, Day Shift Wednesday – Tuesday on a one week on and week off basis.
2. Spontaneous combustion / rehabilitation planning personnel - rostered 37.5hrs, Day Shift Monday – Friday. (Emergency Management Officers will be on site at other times to manage any spontaneous combustion or to contact on-call resources to assist.)

In addition during the period to 31 December 2016, when transition of the Leigh Creek Township to SA Government is intended to occur, Flinders Power Partnership will utilise a further 40-50 personnel, as required for Town Services.

Positions (excluding Town Services) are detailed below:

Role	Number personnel
Rehabilitation Plan Implementation	**11**
Supervisor	2
Pump Crew Team Leader	1
Operators	8
Operations and Technical Support	**18**
Statutory Mine Manager	1
Manager Health Safety Security and Environment	1
Emergency Services and Security Officers	1
Production Manager	1
Maintenance & Supply Supervisor	1
Geologist and Spontaneous Combustion Officer	1
Surveyor and Spontaneous Combustion Officer	1
Commercial Manager	1
Accountant	1
Administration assistant	1
Purchasing / inventory officer	1

Supply officer	1
Security officer (casual)	4
Mine Planner (contract, as required)	1
Senior Geotechnical Engineer (contract, as required)	1
Total	**29**

This resourcing is designed to allow for some expansion upon commencement of later stages of the rehabilitation works. An organizational structure for the Transition Phase is available upon request.

CHANGES TO MINING FLEET AND EQUIPMENT

A review of the Rehabilitation Plan equipment requirements has been completed; this is inclusive of the provision of additional equipment to be retained to ensure that availability of equipment is maintained at the required level to ensure that closure activities are not constrained.

Please don't hesitate to contact me directly should you require further information or clarification on any of the above matters in relation to the Leigh Creek mine transition activities.

Yours sincerely

Peter Kelly
Manager - Leigh Creek Coalfields

Example Geotechnical Inspection Monthly Report – August 2016, CLD Mining

AUGUST 2016
GEOTECHNICAL STABILITY ASSESMENT

Leigh Creek Coalfield

Craig Franklin
craig.franklin@cldmining.com

Executive Summary

Flinders Power commissioned CLD Mining to conduct a geotechnical stability assessment required under the Geotechnical Management System (GMS) during the mine rehabilitation period. An assessment will be completed on a monthly basis and this report refers to the assessment completed in August 2016. The purpose of this report is to identify any geotechnical stability issues and provide recommendations to reduce the risk of geotechnical issues on current pit walls. Water levels of pit voids will also be reviewed in this document.

A site inspection of Leigh Creek Coalfield was completed on Tuesday the 23rd of August. The areas that were inspected:

- Main Series
- Lower Series
- Upper Series

No significant geotechnical stability issues were observed by the author during the site inspection. Areas MT21 and MT15 re-profile has been completed during August 2016 as per the proposed Leigh Creek Closure Plan. No geotechnical issues were reported during the re-profiling and inert material coverage of these areas are scheduled to be completed for October 2016. It is recommended that a review of Leigh Creek Coalfield dumping procedures should be completed before the commencement of inert material covering.

Main Series pit inspection

The rehabilitation of Main Series pit in August 2016 is focused on MT21 and MT15 as per the proposed Leigh Creek Coalfield Closure Plan. No stability issues in these two areas have been reported during this period and during the pit inspection no cracking at the crest and toe of the slopes was observed.

Area MT21 has been re-profiled as per design D6_M13_3_S1 (see Appendix A) of the proposed Leigh Creek Coalfield Closure Plan. This area is currently scheduled for inert material covering in October 2016 were material from stockpile D6_M10_1_insk will be dumped in two stages to reduce the risk of hauler break failure. Inert material will be dumped off the EL140 high wall haul road onto EL85. This material will be re-handled from EL85 and dumped on the crest of EL85 haul road, then profiled down the slope of 1:3 grade. The author recommends the current dumping procedure be reviewed to ensure the risks of dumping off the high wall and EL85 haul road has been adequately risk assessed.

Area MT15 re-profiling as per designs D6_M11_20_S1 (see Appendix B) and D6_M11_22_S1 (see Appendix C) has been completed during August 2016 and no geotechnical issues were noted. The re-profiling designs didn't allow material to be dozed into the water of the void which is at EL47, it was observed during the pit inspection that this was achieved. Inert material coverage of the slopes is currently scheduled for October 2016 and will be sourced from D6_M10_1_insk. This material will also be hauled in two stages, locations of which is still to be finalised. Due to the height of slopes D6_M11_20_S1 and D6_M11_22_S1 it is recommended that a review of the inert material dumping procedure be completed.

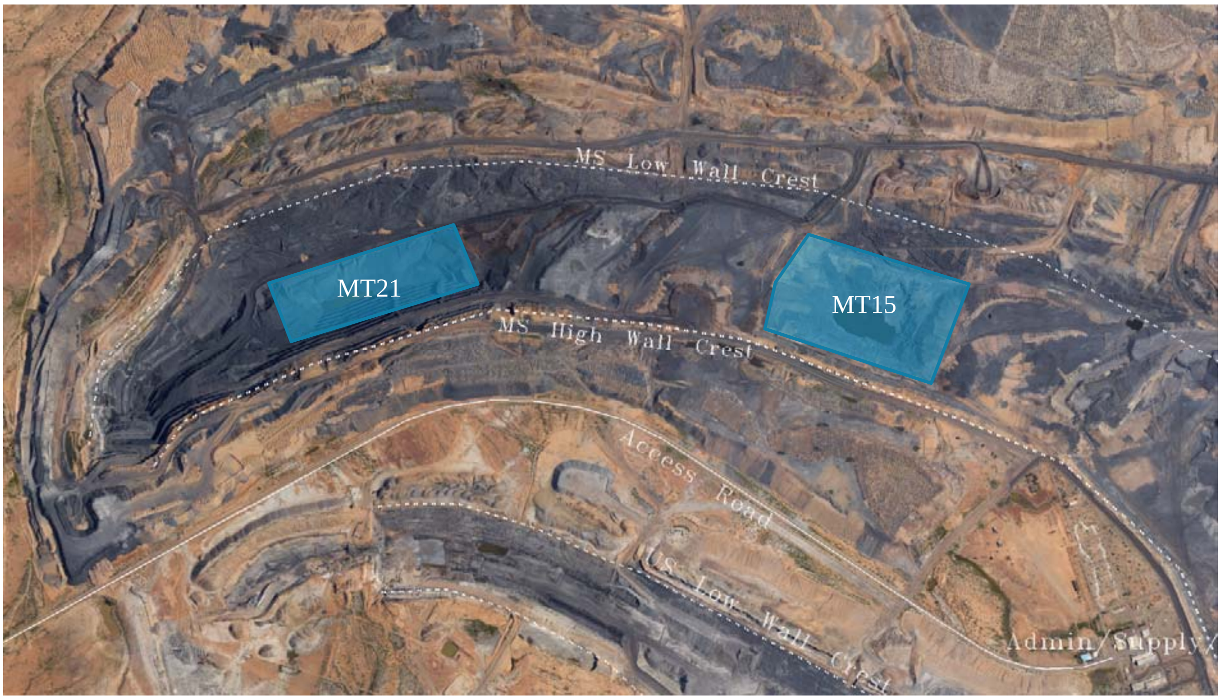


Figure 1.1 Aerial image December 2015 showing MT21 and MT15

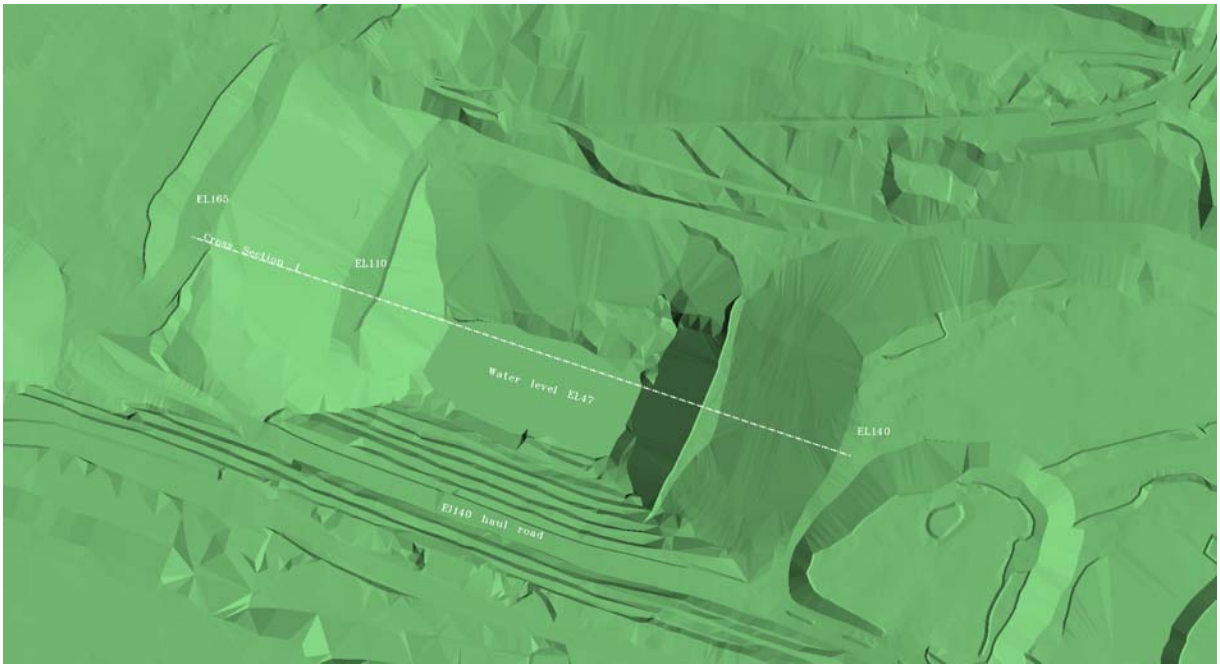


Figure 1.2 August 2016 survey showing cross section 01 location of MT15 area

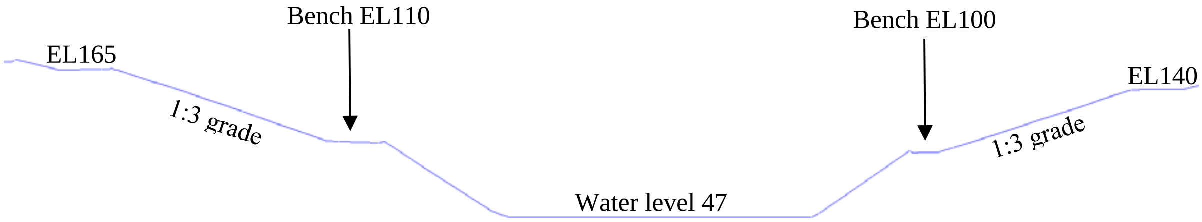


Figure 1.2 Cross section 01 view of MT15

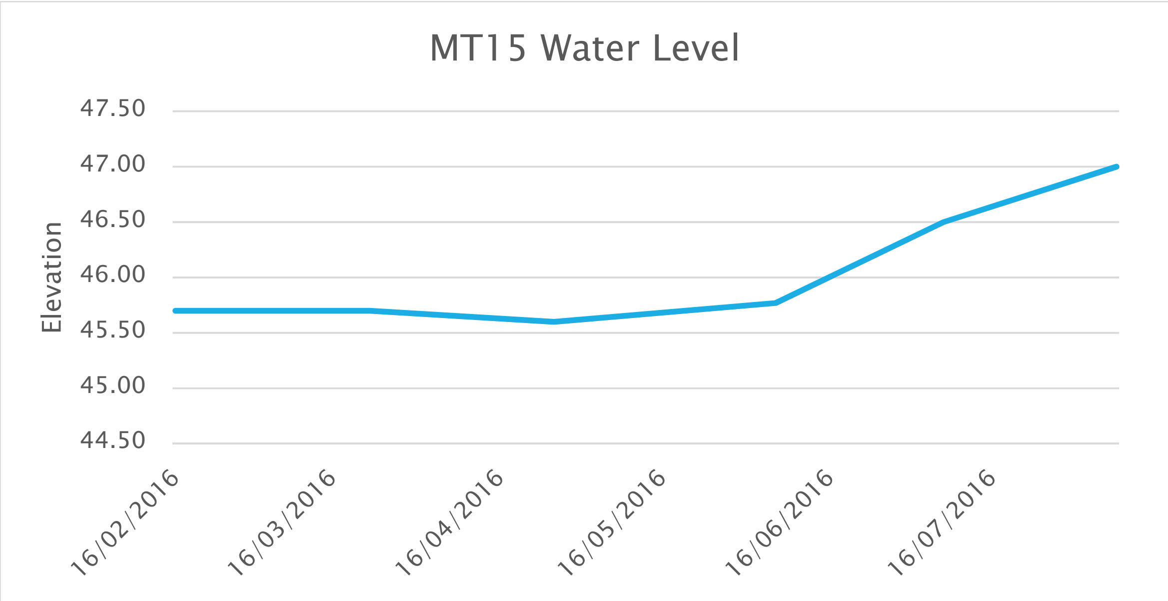


Figure 1.4 Recorded water levels of MT15

The water level in the MT15 area has increased by 1.5m since April 2016 (see figure 1.4). This slight increase is due to local rainfall events and minor inflows from the Telford gravels. This minor increase in water level does not pose any risk to the stability of the high wall and low wall.

Main series high wall haul road EL 140 was inspected and no visible signs of cracking was observed. A drain has been excavated along the haul road to reduce the risk of water pooling and appears to be working effectively (see figure 1.5).

Figure 1.5 Excavated drain on Main Series EL140 haul road

Main Series high wall surface road was inspected. Previously known cracks (see figure 1.6) were observed along the high wall but no new cracking was evident. The cracking is due to a previously mapped fault system and a safety bund has been built around the area.

Figure 1.6 Previously known cracking of M14 high wall

An inspection of the low wall of the Main Series identified no cracking or slumping.

Upper Series pit inspection

The inspection of the Upper Series identified no significant stability issues. No visible signs of cracking, slumping were observed on the high wall, low wall or in pit.

Water ingress from the Upper Series aquafers is still visible from the high wall (see figure 2.3) as pumping from the high wall bores has ceased. UT05 void water level has increased by approximately 2m since February 2016 (see figure 2.2) which is expected. This minor increase in water level does not pose any risk to the stability of the high wall and low wall.

Water pooling in UT07 area is still visible. This water pooling doesn't pose any risk to stability of the low wall or high wall but will be managed to reduce the risk of erosion of in pit waste dumps and inturn reduce the risk of spontaneous combustion of the Upper Series coal units. The management of the UT07 surface water will be designed when the surface water management plan for this area is finalised.

Figure 2.1 Aerial Image December 2015 of Upper Series showing UT07 and UT05 areas

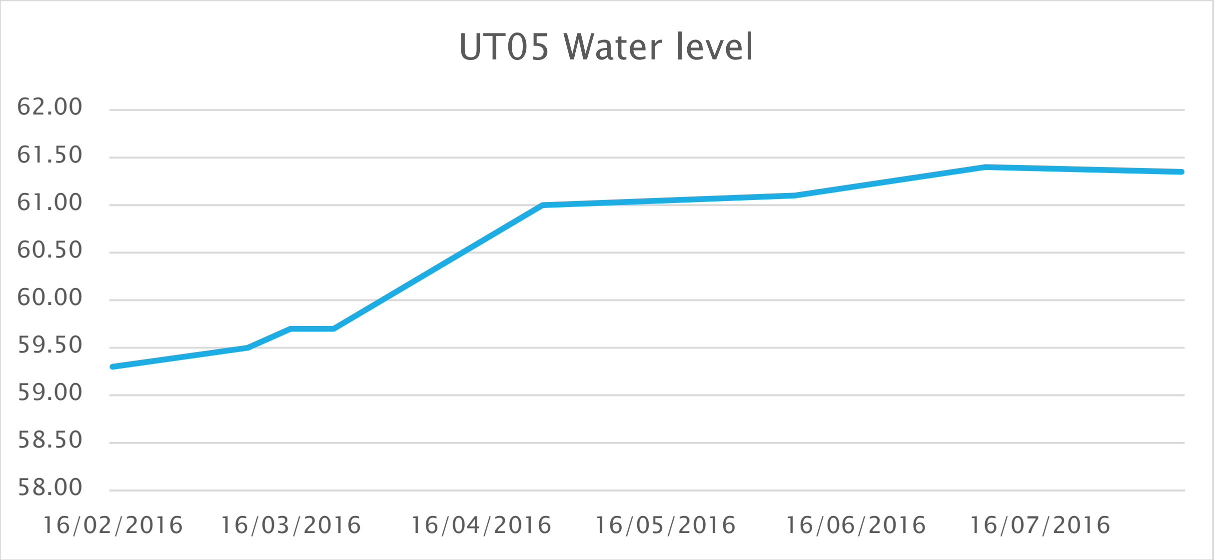


Figure 2.2 UT05 water level

Figure 2.3 Upper Series high wall

Figure 2.2 UT07 looking West to East showing water pooling

Lower Series pit inspection

The areas inspected in the Lower Series were LT1 and L7 box cut area. The inspection of the Lower Series identified no significant stability issues. No visible signs of cracking, slumping were observed on the high wall, low wall or in pit. Access to both LT1 and L7 Box cut are closed to normal traffic.

Water levels have slightly increased in the L7 Box cut area since mining has ceased (see figure 3.2). The source of the water is from the Telford gravels and local rain events. The increase in water level poses no stability risk.

Figure 3.1 Aerial image December 15 of the Lower Series showing LT1 and L7 Box cut areas

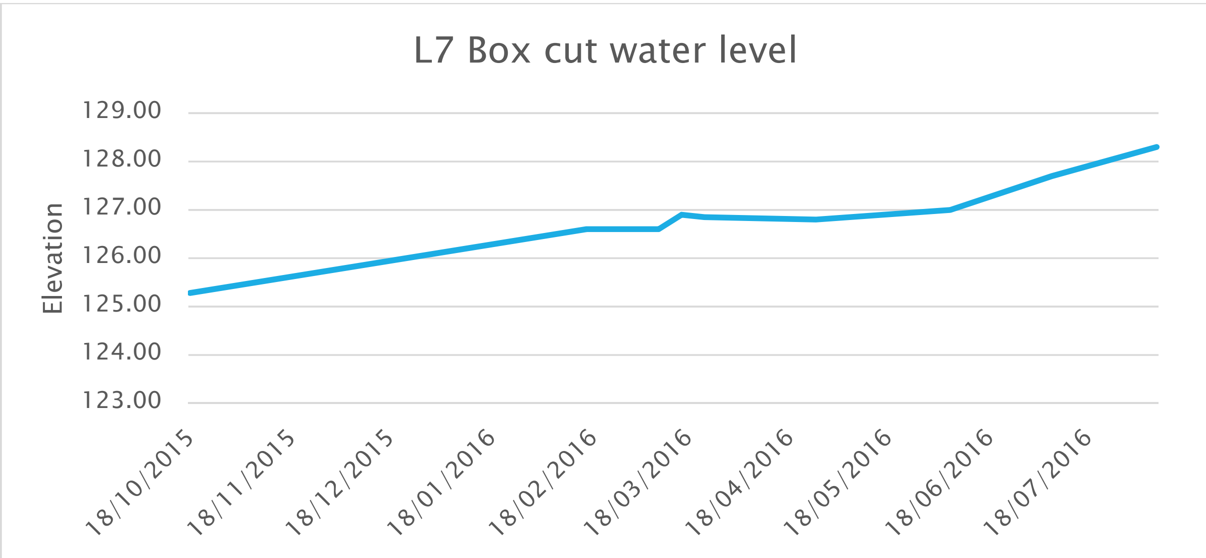


Figure 3.2 L7 Box cut water level


Figure 3.3 L7 Box cut looking in a North to South direction

Summary of key observations and recommendations

Main Series

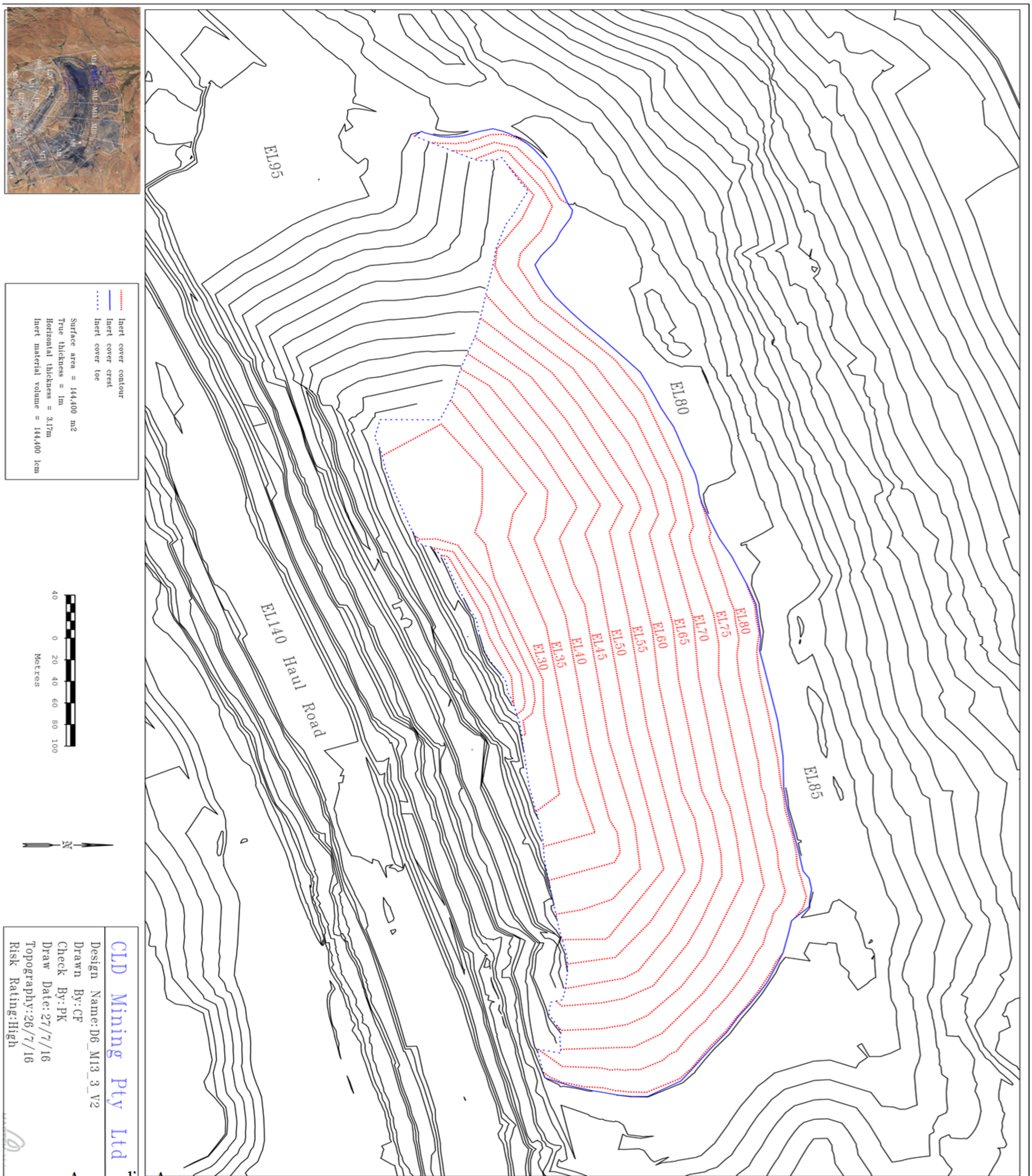
- MT21 has been re-profiled as per the proposed Leigh Creek Closure Plan and no significant issues reported or observed during site inspection. Before dumping of inert material a review of current dump procedure is recommended.
- MT15 has been re-profiled as per the proposed Leigh Creek Closure Plan and no significant issues reported or observed during site inspection. A review of current dumping procedure should also be conducted in this area.
- Main Series high wall was inspected and no new cracking was observed. Old cracking is still visible in the M14 area along the surface road but shows no signs of propagation. A safety bund has been built and the area should be continually monitored for additional cracking.
- A drain has been built to stop pooling of water on the EL140 haul road and appears to be successful. This drain will form part of the surface water management for this area.
- No cracking or slumping was observed on the Main Series low wall.

Upper Series

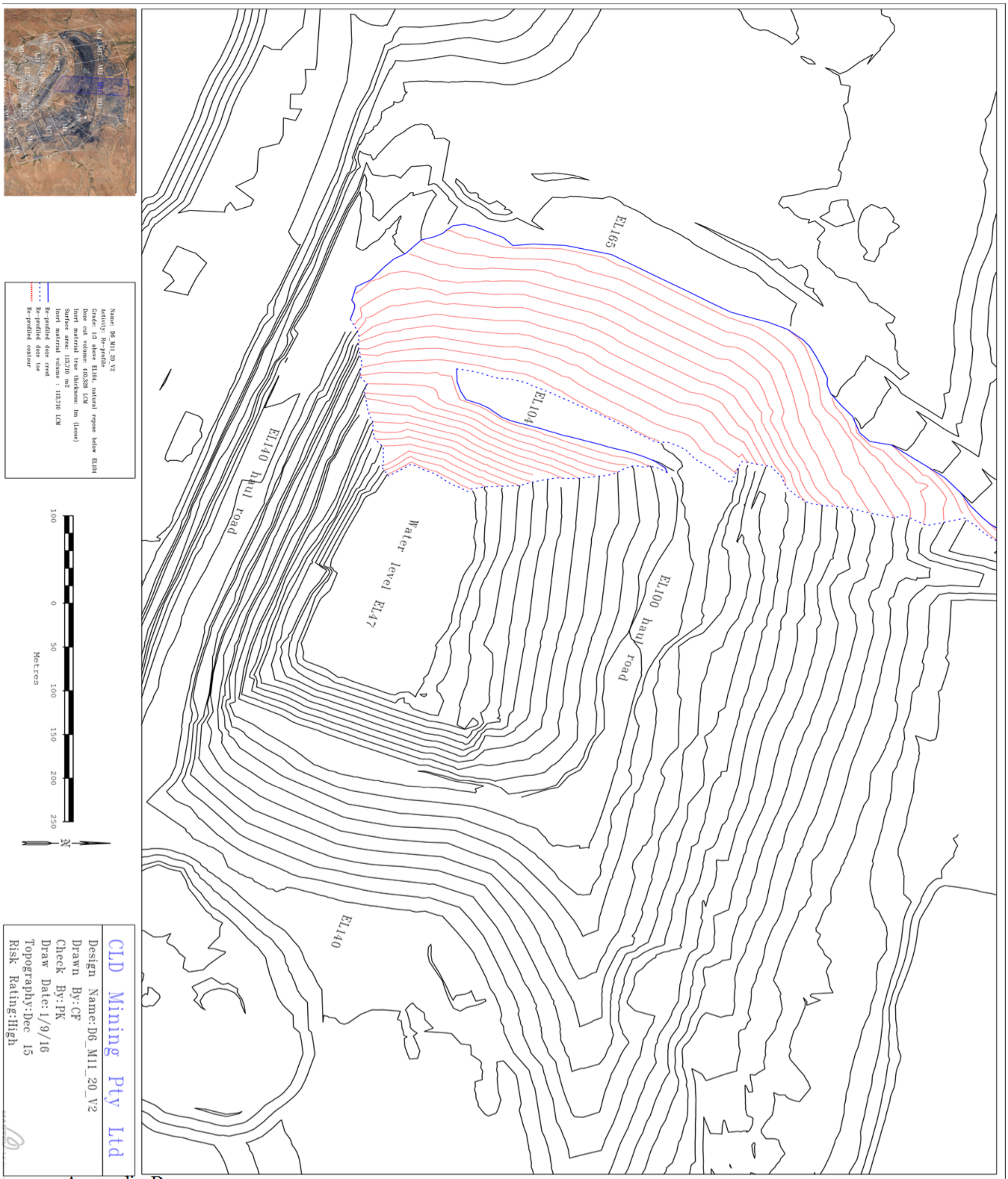
- High wall stable with no observed cracking or slumping.
- Low wall stable with no observed cracking at crest or bulging at toe
- EL140 High wall haul road stable with no observed cracking
- UT05 water level has increased as expected and will be monitored on a monthly basis
- UT07 water pooling was observed. A draft design for surface water will be completed as part of the Leigh Creek Coalfield Closure Plan.

Lower Series

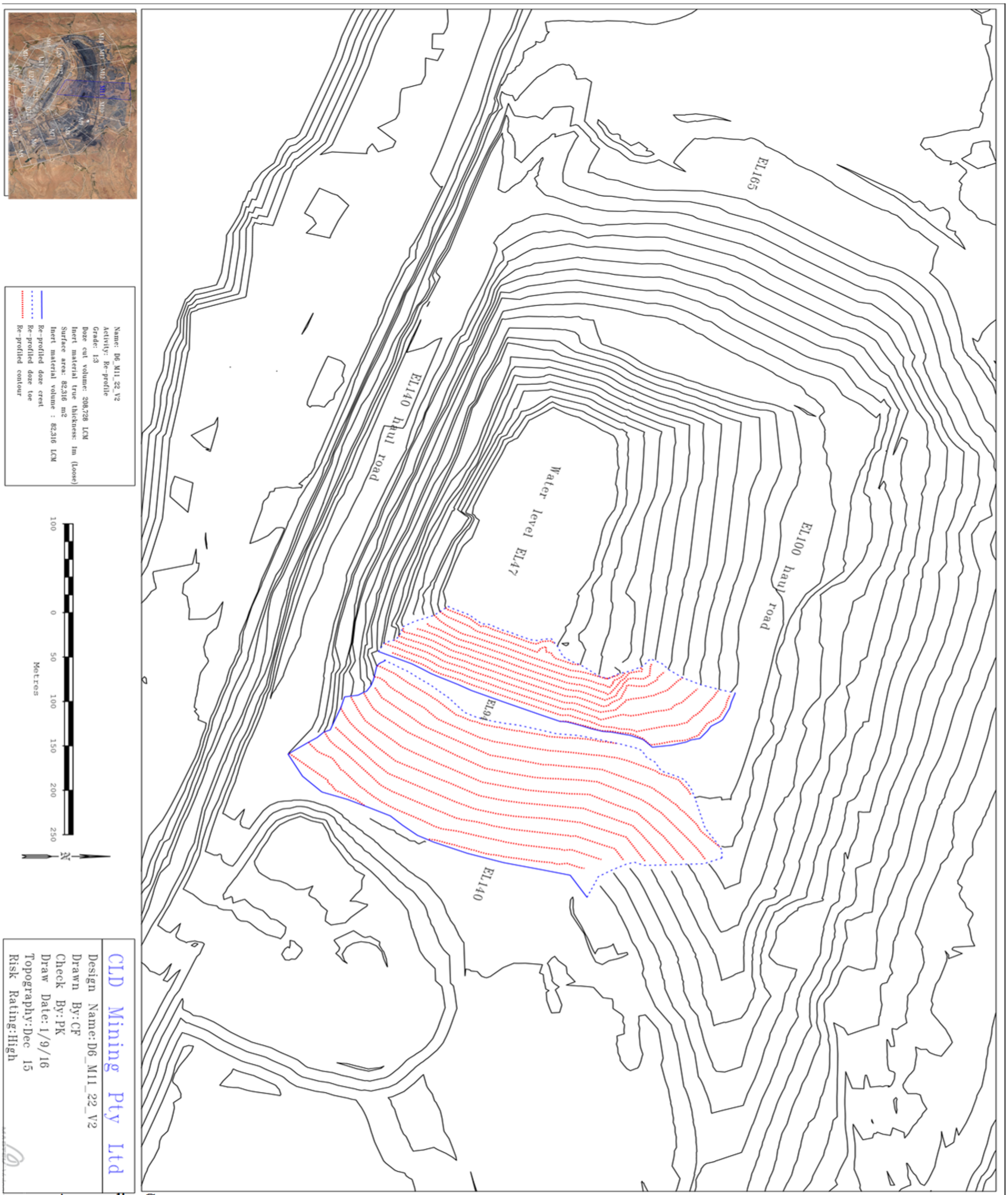
- High wall stable with no observed cracking or slumping.
- Low wall stable with no observed cracking at the crest or bulging at the toe.
- Access is closed off to normal traffic to L7 Box cut.
- Water level has increased in L7 Box cut but poses no stability risk. Water levels will be surveyed and reviewed on a monthly basis.


EL95
EL80
EL85
EL140 Haul Road
EL80
EL75
EL70
EL65
EL60
EL55
EL50
EL45
EL40
EL35
EL30
Inert cover contour
Inert cover crest
Inert cover toe
Surface area = 144,400 m2
True thickness = 1m
Horizontal thickness = 3.17m
Inert material volume = 144,400 lcm
40 0 20 40 60 80 100
Metres
N
CLD Mining Pty Ltd
Design Name:D6_M13_3_V2
Drawn By:CF
Check By:PK
Draw Date:27/7/16
Topography:26/7/16
Risk Rating:High

Appendix A


Name: D6_M11_20_V2
Activity: Re-profile
Grade: 1:3 above EL104, natural repose below EL104
Doze cut volume: 410,328 LCM
Inert material true thickness: 1m (Loose)
Surface area: 113,710 m2
Inert material volume : 113,710 LCM
Re-profiled doze crest
Re-profiled doze toe
Re-profiled contour
100
0
50
100
150
200
250
Metres
N
CLD Mining Pty Ltd
Design Name:D6_M11_20_V2
Drawn By:CF
Check By:PK
Draw Date:1/9/16
Topography:Dec 15
Risk Rating:High
EL165
EL104
EL140 haul road
Water level EL47
EL100 haul road
EL140

Appendix B


EL165
EL140 haul road
Water level EL47
EL100 haul road
EL94
EL140
Name: D6_M11_22_V2
Activity: Re-profile
Grade: 1:3
Doze cut volume: 208,728 LCM
Inert material true thickness: 1m (Loose)
Surface area: 82,316 m2
Inert material volume : 82,316 LCM
Re-profiled doze crest
Re-profiled doze toe
Re-profiled contour
100 0 50 100 150 200 250
Metres
N
CLD Mining Pty Ltd
Design Name:D6_M11_22_V2
Drawn By:CF
Check By:PK
Draw Date:1/9/16
Topography:Dec 15
Risk Rating:High

Appendix C

24.31 Appendix EE - Biological Assessment of the Leigh Creek Waterbodies

Wade, Blanch, Burns and Williams (June 1995) *A Biological Assessment of Waterbodies in Leigh Creek*. Department of Zoology, University of Adelaide.

A Biological Assessment of Waterbodies at Leigh Creek

June 1995

Report prepared for the Electricity Trust of South Australia

Sam Wade
Stuart Blanch
Adrienne Burns
Craig Williams

Department of Zoology
The University of Adelaide
South Australia 5005

Acknowledgments

Thanks to the members of the Department of Zoology for support and assistance in preparing this report. Thanks to Peter Baker for assistance with the identification of blue green algae. Staff at the State Herbarium of South Australia assisted with plant identification. Beat Odermatt and Alan Mason helped with technical advice, accommodation, maps and information about the mine site and wetlands. Ashton Thomas provided valuable help with the boat and in the field. Thanks to Wolfie for driving us around the mine site and helping us in the field despite the awful weather.

Table of Contents

Executive Summary

The landscape of the Leigh Creek area has been altered (both directly and indirectly) by coal mining. Natural water bodies have been changed and many new water bodies have been created. The physical, chemical and biological status of eight wetlands at Leigh Creek were assessed in June 1995. The aims of this survey were to:

- document the distribution and diversity of animals (frogs and aquatic macroinvertebrates), plants and algae at each site;
- examine any relationships between physical and chemical factors and the distribution of the plants and animals at each site;
- where possible to compare this data with information about other water bodies in the drier areas of South Australia; and
- to discuss some major issues of potential monitoring and rehabilitation.

Four of these water bodies were created during the mining process and four are natural water bodies that have been changed by processes associated with development of the mine. These water bodies can be split into three main groups based on their physical, chemical and biological characteristics.

The low pH of the water at **Lobe C** separates it from all other sites. An adult beetle was the only organism found at **Lobe C**. If the water level in **Lobe C** rises too far it will be a potential danger to surrounding rangeland, watercourses and groundwater.

The saline sites (**Leigh Creek, M10 Wetlands, L5/6,** and **Lobe B Quickfill**) are different to the freshwater sites (**Aroona Dam, Aroona Waters** and the **Retention Dam**). The animal and plant communities were consistently different between the saline and freshwater sites and the taxonomic richness was greater at freshwater sites. Part of this difference was certainly due to salinity differences between the sites. Some organisms are better adapted to freshwater, others to saline environments. This means the potential pool of colonising organisms will differ between saline and freshwater sites.

Other factors varied between freshwater and saline sites and these factors undoubtedly contributed to the biological differences between these sites. All the freshwater sites were located on natural watercourses while all but one of the saline sites were not. The saline sites have been established for a

shorter time than the freshwater sites. These factors allowed less time and opportunity for the introduction and establishment of new organisms at saline sites.

Saline sites typically had steep banks and soft sediments which limit plant growth. This influences other groups because plants provide food and shelter for many organisms. Plants also stabilise sediments and prevent erosion. The freshwater sites had sediments that varied in particle size and had more leaf litter and woody debris. These factors provide a greater range of habitat for invertebrates and algae at freshwater sites.

Frogs cannot survive and reproduce in saline water so they were absent from saline sites. Their absence from **Aroona Dam** and the **Retention Dam** might be explained by the lack of adequate vegetation and shelter but their absence from **Aroona Waters** is puzzling.

Compared to naturally acidic salt lakes **Lobe C** was in an appalling condition. Rehabilitation of **Lobe C** will be difficult and costly. In the short term ongoing containment and maintenance or reduction of the water level is essential.

The saline coalfield sites **(L5/6, M10 Wetlands** and **Lobe B Quickfill)** have similar macroinvertebrate fauna compared to natural saline lakes but riparian and aquatic plants were sparse or absent from these sites. These sites are in poor condition compared to natural salt lakes but rehabilitation is a viable option. The invertebrate and algal communities show that these sites can support many organisms. The biological status of these water bodies could be enhanced by altering their shape and depth, followed by revegetation.

Aroona Dam and the **Retention Dam** are large permanent freshwater lakes. This type of wetland does not occur naturally in the areas around Leigh Creek. The plant and animal communities at these sites share some taxa with Flinders Ranges streams but the diversity of flora and fauna is greater in the streams. To return these sites to their natural state the dams would have to be removed. This would reinstate the natural flow regime at these sites and at **Aroona Waters** and **Leigh Creek.** There may be environmental and economic reasons for retaining the dams, and these factors need to be considered before a decision is taken.

Aroona Waters has extensive stands of riparian and aquatic vegetation similar to a natural Flinders Ranges stream. It has the greatest range of plants, algae and macroinvertebrates of all the survey sites but the absence of frogs from this site is unusual. **Leigh Creek** has a lower taxonomic richness than **Aroona Waters** because it is a temporary lowland arid zone stream. Streams of this type are typically saline. **Leigh Creek** is the most natural site we surveyed, closely followed by **Aroona Waters.**

To ensure that rehabilitation of wetlands has the greatest chance of success an integrated approach must be used. Rehabilitation of wetlands without considering surrounding areas that are degraded by mining will only solve part of the problem. The catchment of a wetland plays a major role in determining the physical, chemical and biological status of that wetland. Wetland rehabilitation cannot be considered in isolation; catchments must also be rehabilitated.

Biological and chemical monitoring of water bodies can provide information that allows informed management decisions to be made. Aquatic monitoring at Leigh Creek could be used to assess whether products of the mining process are polluting the waterways that flow through the site, and to measure the success of wetland rehabilitation programs.

All mining activities disturb sediments and this process could release materials that are pollutants outside the mine. At Leigh Creek potential pollutants include sediments eroded from overburden piles, acid water from **Lobe C** and saline ground and surface water. Watercourses such as **Leigh Creek** provide a likely conduit for pollutants to leave the mine. Chemical and biological monitoring can assess whether pollutants are leaving the mine site. If this is occurring preventative measures can be taken to minimise these problems.

Chapter 1 Introduction

The landscape in the Leigh Creek area has been disturbed by the mining process and this work has had a number of impacts on aquatic systems. Mining has caused the realignment of a number of minor creek channels. A section of Leigh Creek has been removed completely and its waters are stored in the **Retention Dam** to prevent them from continuing downstream and flooding the mine site. Aroona Creek has been dammed to provide water for the Leigh Creek area. The construction of dams on Aroona Creek and Leigh Creek have altered the frequency and magnitude of flooding to downstream areas. Many wetlands have been created on the mine site, some to store water and others as a consequence of mining cuts and other depressions filling with groundwater seepage or surface drainage water. Therefore mining activity in the Leigh Creek area has created new aquatic environments and changed existing water bodies.

The mine also has the potential to impact on the surrounding area. Increases in water level at **Lobe C** have the potential to release acid water to groundwater storages and surrounding land and water courses. The Leigh Creek mine is in the Lake Eyre catchment region. It is important that any substances generated that could pollute the areas downstream of the mine are maintained within the mine site.

Eight water bodies in and around the Leigh Creek coalmine were surveyed between June 12-15, 1995. Sites were chosen after consultation with Beat Odermatt, ETSA's environmental officer at Leigh Creek. The range of sites chosen represents the broad range of semi permanent and permanent water bodies in the Leigh Creek Area.

Ephemeral claypan ponds and streams were not assessed in this survey. They are common in the Leigh Creek area when rainfall is favourable and are certain to be ecologically significant. They are likely to have a unique flora and fauna which is well adapted to cope with an unpredictable environment. Due to their ephemeral nature filling of these areas is unpredictable and sampling of them can only be opportunistic. Circumstances prevented sampling of these systems during this survey. It is recommended that they be surveyed in future work.

The general aims of this project were to assess the physical, chemical and biological status of a broad range of wetlands in the Leigh Creek area. Specifically the aims were to:

- document the abundance and diversity of the biota (plants, algae, aquatic invertebrates and frogs) at each site;
- to examine any relationships between the abiotic factors (eg water chemistry, sediment structure and water regime) and the distribution of the biota at each site;

- where possible to compare this data with information about other water bodies in the nearby parts of South Australia; and
- to discuss potential monitoring in the future.

The condition of a water body is not only due to processes that occur in the water body, but also what occurs in the catchment. The size, topography, vegetation and land use of a catchment can all influence the condition of a water body. The topography, water regime, sediment structure, water chemistry, and biological integrity of a water body can all be influenced by the catchment. For example, water bodies in urban, pastoral, agricultural and mining areas each face particular problems compared to pristine catchments.

The condition of a water body can only be assessed properly using an approach which combines a number of physical, chemical and biological factors. Water chemistry is important part of water quality. It can also influence the biology of a water body. Water regime, sediment structure and topography of a wetland can all influence the water quality and biology of a wetland.

Four biological variables were assessed, macrophytes (plants), algae, macroinvertebrates (*eg* insects, crustaceans, worms etc) and frogs. Aquatic and riparian macrophytes stabilise sediments, prevent erosion and provide habitat and food for other organisms. Benthic algae are an important food source for other organisms and respond to many pollutants making them good bio-indicators. Macroinvertebrates help cycle terrestrial and aquatic organic matter within an aquatic ecosystem and provide food for other animals. Frogs are sensitive to many chemical changes due to their unprotected eggs and permeable skin. In addition all these organisms are important in their own right and are essential components of a healthy functioning ecosystem.

The water bodies sampled range from dams to smaller ponds and shallow streams. All variables were sampled in the shallows of each site and plants and frogs were also sampled around the edges. This shallow edge environment (the littoral zone) was chosen because it occurred at each site. It was important that sampling was conducted in a way which allowed meaningful comparisons between these different kinds of water bodies.

The lists of flora and fauna generated from this work are unlikely to be exhaustive. In this study sampling was restricted to the littoral zone but it is likely that different taxa exist in areas such as the planktonic or the profundal zones. In addition, many organisms occur in seasonal cycles and in response to particular events such as flooding and drying. Sampling at a single time reduces the chance of detecting all organisms that occur in a water body.

This work contains a discussion of the physical and chemical status of each wetland and provides an extensive, but probably not exhaustive list of taxa inhabiting each site. It allows strong comparisons to be made between the sampled sites and gives insight into how physical and chemical factors may be influencing the biology of wetlands. This work provides important baseline data which will be useful if future aquatic biomonitoring is undertaken at Leigh Creek.

Chapter 2 Site descriptions

2.1 Summary

Wetlands can be classified into groups based on their physical, chemical and historical nature. These factors have a strong influence over the biological character of a wetland. Factors such as sediment type, water regime, nutrient status, salinity and pH will all influence the biology of a wetland. The surveyed sites fall into five groups based on their physical and chemical characteristics. Some of these groups are similar to natural aquatic ecosystems in the drier inland areas surrounding Leigh Creek, others are unique to the area.

1. Aroona Waters is immediately downstream of **Aroona Dam** and it is similar to a natural upland Flinders Ranges stream. It is a short stretch of water in a narrow channel with low nutrient concentrations and low salinity.

2. Leigh Creek is ten kilometres downstream of the **Retention Dam.** It is a typical lowland Flinders Ranges Creek, slightly saline with high soluble nitrogen and probably only flows after rain.

These two water bodies are downstream of dams and this will have caused changes to the frequency and magnitude of flooding at these sites. Despite this they are the most natural wetlands surveyed. The remaining sites have all been constructed in conjunction with the mining process.

3. Aroona Dam and the Retention Dam are large storages with low salinity and nutrient concentrations. They are filled by intermittent creeks during floods which means water levels in them will increase rapidly during times of flood and gradually draw down due to evaporation, seepage and water use. These sites are unique, there are no other large permanent freshwater lakes in the area around Leigh Creek

4. L5/6, Lobe B and the M10 Wetlands vary in size but all have high soluble nitrogen concentrations and are slightly saline. They were constructed recently as part of the mining process. Their substrates are dominated by soft fine sediments. These sites have some similarities to natural saline lakes found in the drier areas of South Australia.

5. Lobe C is a disused mine cutting with high salinity and low pH which renders this site inhospitable to most organisms.

2.2 Introduction

Abiotic processes play a major role in determining the biological make-up of wetlands. Many organisms can only survive within a narrow range of physical and chemical conditions. A clear understanding of the history and the physical and chemical state of a water body is required to gain insight into the biological organisation and processes that occur within that water body.

ETSA provided information on the time and purpose of construction, date of filling, permanence and the source of water for each site. Dissolved oxygen, temperature, pH, conductivity, salinity and turbidity were measured at each site. Water samples were collected for the analysis of the soluble nutrients nitrate+nitrite-N (NO_x-N), ammonium-N ($NH4^+$-N), and soluble reactive phosphorus (SRP). These forms of nitrogen and phosphorus were chosen because they are bio-available in the short term and are more important to the distribution of the biota than total nitrogen and total phosphorus. Physical and chemical variables were measured at the same locations and times as the biological samples were collected.

Six of the eight sites sampled were constructed as a consequence of the mining process. The **Retention Dam, Aroona Dam** and **Lobe B Quickfill** were all built to hold water, the **M10 Wetlands** were excavated to provide topsoil for overburden dump rehabilitation and **L5/6** and **Lobe C** are disused mining cuts which have filled with water. **Leigh Creek** and **Aroona Waters** are not constructed wetlands but they are both downstream of dams. It is likely that these dams have influenced the flow regime and therefore the biology of these sites.

2.3 Methods

Conductivity, salinity, temperature, pH, dissolved oxygen and turbidity were measured on site using a Grant-YSI 3800 water quality meter. Water samples collected for nutrient analysis were filtered through 0.7 μm glass fibre filters within twelve hours of collection and stored on ice until analysis. In the laboratory ammonium nitrogen (using the phenol-hypochlorite method), nitrate and nitrite nitrogen (using the copper cadmium reduction technique) and soluble reactive phosphate-phosphorus (using the molybdate -ascorbic acid method) were measured (Wetzel and Likens 1991).

2.4 Site Descriptions

2.4.1 Retention Dam

The **Retention Dam** is a large storage; 3500 metres in length and 2200 metres wide at its broadest point. It was created when Leigh Creek was dammed in 1980 to stop creek water from flooding the coalfield and has held water continuously since that time. The northern half of this site has limited riparian vegetation and is dominated by the steep earthen dam wall. The southern half of the dam is shallow and well vegetated with river redgum (*Eucalyptus camaldulensis*) and desert paperbark (*Melaleuca glomerata*). Many dead or stressed trees occur in the lake alongside flooded stream channels. All variables were sampled at two sites on this dam.

Site 7A

Grid reference TM514183 (Map 6536-1, Copley 1:50 000)
Site 7A is located where the Leigh Creek channel flows into the lake. The aquatic substrate is typical of a stream channel with well-worn gravel and pebble with occasional light siltation. The banks of the lake are clay with sandy loams deposited at inflow points.

Site 7B

Grid reference TM504209 (Map 6536-1, Copley 1:50 000)
This site is at the eastern end of the dam wall. The substrate in this area is predominantly clay and this is covered by a deposit of coarse woody organic matter.

2.4.2 Aroona Dam

Aroona Dam was created when Aroona Creek was dammed in 1955 to provide water for the Leigh Creek township. It is approximately 3500 metres long and 200-300 metres wide for most of its length with a maximum capacity of almost 5000 megalitres. Much of the dam is surrounded by steep rock faces that prevents the establishment of riparian and aquatic vegetation. Where tributaries flow into the dam, areas of silt and clay deposition occur and riparian vegetation is better established. Many of these depositional areas occur at the western end of the dam. Here redgums of varying ages are common with an understorey of many weed species including *Sisymbrium erysmoides*, *Carrichterra annua* and *Datura* spp.

At the time of sampling the dam was close to maximum capacity, approximately 0.2 metres below full supply level, but water levels can vary widely. For example: In May 1989 the capacity of the dam was at 100%, declining to 15% in April 1992, increasing to

100% in March 1994, declining to 60% in January 1995 and filling again in March 1995 to 100%. This fluctuation has important implications for the biota in the dam.
Five sites were sampled on the dam. Benthic invertebrates and algae were sampled at sites 2B and 2C and vegetation was sampled at sites 2A, 2B, 2D, and 2E.

Site 2A

Grid reference TM465137 (Map 6536-1, Copley 1:50 000)
Site 2A is in a small rocky cove 200 metres upstream of the dam wall on the north-western side of the lake. The banks are very steep and some sediment has accumulated in the rock fissures supporting limited riparian vegetation.

Site 2B

Grid reference TM468134 (Map 6536-1, Copley 1:50 000)
Site 2B is a small circular island with an area of about 150 m^2. It is ten metres offshore but may join the mainland at times of low water levels. The substrate consists of a fractured sedimentary rock with some loose rubble. Below the water line this substrate is overlain with light silt, fine mats of tree roots and woody organic debris.

Site 2C

Grid reference TM472132 (Map 6536-1, Copley 1:50 000)
Site 2C is on the eastern side of the small bay formed where Magnetic Creek flows into **Aroona Dam**. The substrate is similar to site 2A.

Site 2D

Grid reference TM478119 (Map 6536-1, Copley 1:50 000)
Site 2D is 250 metres downstream of the Emu Creek inflow on the northern side of the dam. The gently sloping banks are formed from the deposition of clay-loam sediments which support a better developed riparian community.

Site 2E

Grid reference TM485115 (Map 6536-1, Copley 1:50 000)
Site 2E is located at the point where Emu Creek flows into the dam. Clay-loam deposits overlay creek bed cobbles with steep unstable banks that may be prone to erosion during floods.

2.4.3 Aroona Waters

Aroona Waters is a permanent water body in the channel of Aroona Creek which is fed by seepage from **Aroona Dam**. At the time of sampling water was present for approximately 2000 metres downstream of the dam wall. The channel is approximately sixty metres wide and the substrate includes bedrock outcrops and platforms, large cobble bars along with deposits of sand and finer sediments which are often stabilised by vegetation. The stream is a series of large pools often connected by surface water. There was much standing water but little flow. When the dam overflows at high discharge flooding would be catastrophic causing severe scouring. Algal and invertebrate samples were taken randomly in the area from the dam wall to 1000 metres downstream. Macrophyte surveys were taken at three sites.

Site 1A

Grid reference TM465131 (Map 6536-1, Copley 1:50 000)
Site 1A is 100 metres downstream of the **Aroona Dam** wall. Sediments are mainly cobble and boulder probably due to the severe scouring which would occur during flooding close to the dam wall. Sedges and trees are dominant in the riparian zone and pools of water support dense aquatic vegetation.

Site 1B

Grid reference TM464127 (Map 6536-1, Copley 1:50 000)
Site 1B is 600 metres downstream of the dam wall. The water in the main channel here is over two metres deep. The substrate is dominated by a smaller particle size than site 1A. This is probably due to lesser scouring during floods because of the greater distance from the dam wall. Annual plants are common with well-developed sedge-reed beds in the main channel.

Site 1C

Grid reference TM4622124 (Map 6536-1, Copley 1:50 000)
Site 1C is 1000 metres downstream of the dam wall. The main channel consists of a number of large bedrock based pools alongside several braided dry channels. This area supports dense stands of trees and an understorey of weeds in clay loam beds.

2.4.4 Leigh Creek

Grid reference TM475302 (Map 6537-II, Telford 1:50 000)
Leigh Creek was sampled fifty metres upstream of the Lyndhurst-Copley Road. At this point it is a lowland creek with a wide floodplain and an unconstrained channel. The stream was about eight metres wide and up to one meter deep but is subject to much variation. At this location **Leigh Creek** is probably intermittent, only flowing after substantial rain. The frequency and magnitude of flooding have probably been reduced since the **Retention Dam** was constructed. The sediment consists of fine red clay and the riparian vegetation is mainly limited to samphire. Benthic algae and invertebrates were sampled randomly from a 50 metre long section of this creek.

2.4.5 L5/6

Grid reference 254600/6623400 (Fig 2.1)

L5/6 is a large cut used for coal extraction until 1992. This site has held water since then and the source of that water is mainly runoff from surrounding dumps although there may be some groundwater seepage. **L5/6** has steep unstable sides and the only safe access points are the old ramps into the pit. Samples were collected at the northern ramp. Aquatic substrate is mainly silt and clay whilst riparian sediments are similar but include some coarse sands. Vegetation is minimal.

2.4.6 M 10 Wetlands

Grid reference 250250/6627750 (Fig 2.1)

The **M10 Wetlands** are on the northern edge of Lobe B. They were created in late 1991 when sediment was removed to provide topsoil for overburden dump rehabilitation. The water source for this site is runoff from overburden dumps and floodwaters from adjoining rangelands. Samples were collected from the second pond in a series of nine. The second pond is in a gently sloping basin, approximately ten metres wide, fifteen metres long and two metres deep. Vegetation is completely absent. Aquatic and riparian sediments consist of clay with pebble and sand. Benthic algae and invertebrates were sampled randomly at this site.

2.4.7 Lobe B Quickfill

Grid reference 252900/6622450 (Fig 2.1)

Lobe B Quickfill is a small pond about 400 m^2, created in 1990 as a sump for water pumped from mine workings. Much of this water seeps from associated mudstone aquifers. It also receives runoff from nearby dumps. The aquatic substrate is mainly clay with the riparian sediments consisting of clay and loam. There is no riparian or aquatic vegetation. Benthic algae and invertebrates were sampled randomly from this site.

2.4.8 Lobe C

Grid reference TM495304 (Map 6537-II, Telford 1:50 000)

Lobe C is a large coal working on the Northfield last used in 1976. From 1976 it has filled with runoff from surrounding overburden dumps and seepage from local groundwater. During 1989-1992 up to thirteen megalitres per day of ground water from upper series coal measures was discharged into **Lobe C**. Sediment is mainly overburden and aquatic and riparian vegetation is absent from this site. Benthic invertebrates and algae were sampled on a twenty metre wide ramp at the southern end of this site.

2.5 Results and Discussion

The surveyed wetlands fall into five broad groups:

1. **Aroona Dam** and the **Retention Dam** are large constructed storages formed by the damming of intermittent creeks. **Aroona Dam** has been established for 41 years and the **Retention Dam** for 16 years. This is probably sufficient time for many organisms to have migrated and established themselves at these sites. Visiting birds are a potential source of new plant, algal and invertebrate life. In addition many organisms will have arrived from upstream areas during floods.

These two sites are characterised by low salinity, near neutral pH and low soluble nutrient concentrations. Monitoring by ETSA shows the water level in **Aroona Dam** is highly variable and it is likely that the **Retention Dam** follows a similar pattern. Water level changes may not be as drastic in the **Retention Dam** due to the more gentle slope of its basin. The reason for this variability in depth is the source of the water. Lowland creeks in arid areas usually flow only after heavy rain and this often causes huge floods. Dams fed by these events undergo long draw down periods interrupted by sudden increases in water level.

2. At **Aroona Waters** water up-welled into a constrained channel from the sediments downstream of the dam wall. The water flowed in and out of the sediments over the next two kilometres before disappearing into the stream bed. This is very similar to natural upland creeks in the Flinders Ranges which are often spatially intermittent. This site is different to an upland creek because it seems to be fed by seepage from **Aroona Dam** rather than ground water springs. Its upper reach would be subject to catastrophic scouring whenever the dam spillway overflowed during a flood. Despite this, the frequency of floods would be reduced at this site. **Aroona Dam** would intercept many floods and store the water, preventing floods from reaching **Aroona Waters**. This site has low soluble nutrient concentrations, a slightly alkaline pH and low but variable salinity.

3. **Leigh Creek** is a typical Flinders Ranges lowland creek. These creeks are usually temporary, only holding water after rain. It is quite saline and mildly alkaline. Nutrient concentrations are low with the exception of Nitrate+Nitrite-N which is quite high. Rainwater often has higher concentrations of soluble nitrogen than terrestrial water bodies and **Leigh Creek** may have only filled a short time before sampling. **Leigh Creek** is the most natural water body that was surveyed but the frequency and magnitude of flooding here has decreased due to the interception of upstream waters by the **Retention Dam**.

4. **L5/6, Lobe B Quickfill** and the **M10 Wetlands** differ in size but all have high soluble nitrogen concentrations and medium salinities. All have become wetlands since 1990 and are not part of natural creek systems. Consequently there has been limited time and opportunity for organisms to migrate to these sites or for vegetation to become established in these areas. Substrates at these sites consist of soft unstable clays and there is minimal riparian and aquatic vegetation.

5. **Lobe C** is a highly acidic water body (pH 2.52) due to the leaching of pyrite minerals uncovered by the mining process. The water is also quite saline (25 g/L). This combination makes **Lobe C** a challenging environment for most aquatic organisms.

Table 2.1 Water quality data for all sites July 12-15, 1995

Waterbody Site	pH	Conductivity (mS/cm)	Salinity (g/L)	Turbidity (NTU)	Phosphate (µg of P per L)	Ammonium (µg of N per L)	Nitrate + Nitrite (µg of N per L)
Retention Dam							
7A	7.73	2.74	1.4	43	4	3	9
7B	8.1	2.10	1.1	21	6	6	11
Aroona Dam							
2A (island)	7.78	0.31	0.1	17	5	1	1
2B	7.7	0.31	0.1	17	5	2	1
Aroona Waters							
100 m ds	7.8	1.22	0.6	14	5	0	2
200 m ds	7.9	1.81	0.9	16			
500 m ds	7.95	2.37	1.2	17	8	1	1
700 m ds	8.14	1.92	1	15	4	0	1
1000 m ds	8.08	2.14	1.1	14	4	1	0
Leigh Creek	8.42	26.50	16.3	18	6	9	275
L 5-6	7.87	21.81	13.1	19	4	18	123
M 10 Wetlands	8.24	23.01	13.9	23	5	24	410
Lobe B	6.46	10.36	5.9	24	2	32	400
Lobe C	2.52	39.19	25	23	*	*	*

* Nutrient status of this water was not determined due to unusual reactions during analysis possibly due to the low pH of the water.
(ds stands for downstream)

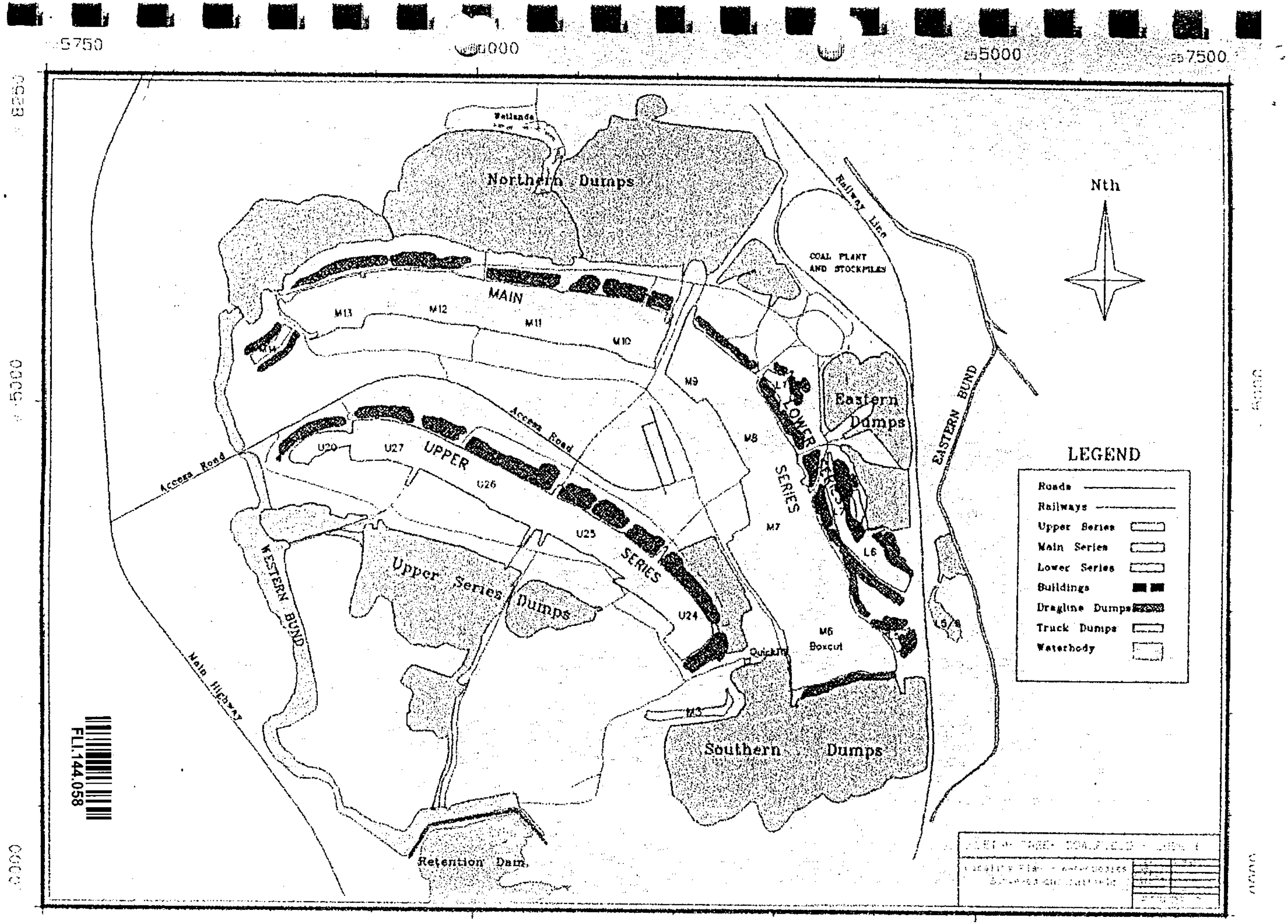
2.6 Conclusions

Based on salinity the sites can be broadly split into two groups. **L5/6, M10 Wetlands, Lobe B Quickfill, Lobe C** and **Leigh Creek** all have a salinity level greater than 3 g/L, classifying them as saline waters (Williams 1983). **Aroona Dam, Aroona Waters** and the **Retention Dam** all have less than 3 g/L of salts. They are classified as fresh water.

There are some other differences between these two groups. The fresh water wetlands have all been established for at least 16 years and are associated with natural watercourses. This provides a mechanism and time for many organisms to migrate to these sites and establish themselves. Habitat at these sites is generally more complex, with variability in both sediment structure and vegetation. This provides varying types of habitat for plants and animals.

The low pH of **Lobe C** makes it inhospitable to most organisms. If we exclude this site we can make the following conclusions about the saline sites. They have all been established for six years or less and are not associated with natural watercourses with the exception of **Leigh Creek**. This means that many aquatic organisms will have had limited time and opportunity to reach these sites. **Leigh Creek** is the only site surveyed which dries out and this means that organisms which cannot tolerate drying will have to migrate to this site each time it flows. Riparian and aquatic vegetation is limited and sediments are soft and fine at these sites. The habitats here are simple with little variability.

These physical and chemical factors will influence the biology of the surveyed wetlands. It is predicted that there will be similar flora and fauna within each group of sites.


Northern Dumps
Wetlands
Nth
COAL PLANT
AND STOCKPILES
Railway Line
MAIN
M13
M12
M11
M10
M9
M8
M7
M6
Boxcut
M3
LOWER
SERIES
L7
L6
Eastern
Dumps
EASTERN BUND
Access Road
Access Road
UPPER
SERIES
U27
U26
U25
U24
Upper Series Dumps
WESTERN BUND
Main Highway
Southern Dumps
Retention Dam
LEGEND
Roads
Railways
Upper Series
Main Series
Lower Series
Buildings
Dragline Dumps
Truck Dumps
Waterbody

Chapter 3 Aquatic and riparian plants

Stuart Blanch

3.1. Summary

Aquatic plants (which require water at or above the soil surface) and riparian plants (which occur on creek banks, floodplains and wetland edges where the water table is below the soil surface but prone to flooding) are essential to the natural functioning of aquatic ecosystems. Vegetation protects the banks from waves and currents, and roots stabilise the sediments. Invertebrates, frogs, fish, birds and mammals rely on plants for protection from predators, shelter, food and nesting material.

In addition to these physical attributes, plant growth and decay is central to the chemistry of water. Vegetation is an effective biological buffer to nutrients and sediments. Plants use these nutrients and trap nutrient-bearing sediments. In addition, bacteria thrive in root mats, and break down pollutants to less harmful substances. Finally, decaying vegetation releases carbon to bacteria and algae, which are the base of the food chain.

Plants are sensitive to water chemistry, flooding patterns and bottom sediments. Some species are tolerant of saline water, others require a constant water supply, whilst some can grow on poorly formed substrates. Hence considerable information on the general conditions of a water body may be gleaned from which species are present, and how common they are. For this reason they can be good *bioindicators*.

Very little information exists on the vegetation of water bodies in the Flinders Ranges and saline lakes near Leigh Creek. Very few plants were found in water bodies on the coalfield during this survey. This is attributed to a combination of high salinities and nitrate+nitrite levels, and unsuitable bottom sediments. Groundwater and surface water in the region are often naturally saline, and some plants have developed the ability to grow in saline water. The very acidic water in **Lobe C**, however, excludes all plants. The only aquatic plant found in coalfield water bodies was the salt tolerant *Ruppia maritima* which is common in inland saline lakes.

Between six and eighteen species were recorded in the semi-natural and man-made water bodies adjacent to the coalfield. These water bodies

generally contained freshwater, had low nitrate+nitrite levels and had bottom sediments more amenable to plant growth. **Aroona Waters** and the entrance of Leigh Creek to the **Retention Dam** supported many native species. The deeper water and cliffs of **Aroona Dam** inhibit plant growth. In addition large changes in water level prevent the development of vegetation along all but the most upstream section of the dam. Here redgums and weeds occur in patches of sediments deposited by water. The natural salinity and intermittency of the lowland **Leigh Creek** downstream of the mine greatly reduces species diversity. Salt-tolerant samphire lined the banks, with no aquatic plants present.

Several species common to the Flinders Ranges and nearby saline lakes were not recorded in the water bodies at Leigh Creek. These include waterbuttons (*Cotula coronopifolia*), watercress (*Rorippa nasturtium-aquaticum*) and charophytes (macroalgae). Further studies of the aquatic vegetation, water quality and environmental factors in Leigh Creek water bodies need to be conducted to determine the reason for such absences.

3.2 Introduction

Aquatic plants (which require water at or above the soil surface) and riparian plants (which occur on creek banks, floodplains and wetland edges where the water table is below the soil surface but prone to flooding) are important components of the aquatic ecosystem, where they have the following functions/roles:

- nesting material and shelter for birds (Frith *et al.* 1969), invertebrates (Williams 1980), and other animals (Dawson 1988).
- protection from predators.
- reducing bank erosion by dissipating wave action and exposure to current (Keddy 1982).
- migration corridors through otherwise cleared landscape.
- trapping sediments and debris, thereby causing the deposition of suspended material. Plants growing along the water's edge intercept sediments and debris, and slow the movement of water.
- nutrients (particularly nitrogen $NH4^{+}$ and $NO3^{-}$, and phosphorus as $PO4^{3-}$) adsorbed onto clay particles and suspended organic matter are retained within the riparian zone, where they may be used by plants. Vegetation can greatly reduce the nutrient load entering water bodies during stormflows, when the majority of nutrients are transported. Dense root mats create alternately oxygenated (immediately adjacent to the roots) and deoxygenated zones which, respectively, enable aerobic and anaerobic bacteria to exist in extremely close proximity. Conversion of nutrients and pollutants occurs principally *via* this process in reedbeds, than by plants *per se*.

Aquatic plants are susceptible to changes in water quality as they absorb nutrients and chemicals bound to sediments and directly from water. Hence they are useful as bioindicators ('biological indicators') (Best 1988). The long term monitoring of changes in aquatic plant composition can be informative and is increasingly being used to gauge the health of aquatic environments and effectiveness of remediation techniques in aquatic ecosystems (*e.g.* McCosker *et al.* 1993). Changes in the dominant plant types, the loss of species possessing particular morphologies and / or physiological tolerances and seedling survival can be monitored to determine the impact of alterations in water quality and quantity.

3.3 Methods

3.3.1 Sampling Sites

A general description of site locations, hydrology, sediment type and vegetation structure can be found in Table 2. Aquatic and riparian plants were surveyed at 14 sites across 8 water bodies:

Sites adjacent to the coalfield

- **Aroona Waters,** Sites 1A-C
- **Aroona Dam,** Sites 2A, B, D and E
- **Retention Dam,** Sites 7A and 7B
- **Leigh Creek,** 50 m upstream of the Copley-Lyndhurst Road crossing.

Coalfield sites

- **M10 Wetlands,** second pond
- **L5/6**
- **Lobe B Quickfill**
- **Lobe C**

3.3.2 Survey techniques

All plants from the top of the bank to a depth of 1 m were surveyed in a 25 m wide quadrat. The ecological 'species significance' for each species was estimated using the Braun-Blanquet scale (see Table 3.1) (Mueller-Dombois and Ellenberg 1974, p 59). Erect herbs, grasses and reeds are more amenable to an estimate of abundance due to their erect stature via counts of individual plants. In contrast, prostrate grasses and sedges are more easily surveyed by estimating the percent ground cover as individual plants are difficult to distinguish. The Braun-Blanquet scale is a useful compromise as it includes both cover and abundance estimates, and it can be used fairly objectively by different people over a long time period whilst retaining sufficient accuracy to be useful.

Species occurring in a water body but not within a 25 m wide quadrat were recorded and a species list constructed for each water body. Plants were identified on site, or specimens collected and identified by staff at the State Herbarium of South Australia and by using the following keys and guides: Flora of South Australia Vols I-IV (Black 1980), Flora of New South Wales Vols I-III (Harden 1992), and 'Waterplants in Australia' (Sainty and Jacobs 1994). A complete herbarium is stored in the Department of Zoology at The University of Adelaide.

A question mark '*?*' is placed in front of the species name when accurate identification in the field was impossible. In the case of *Ruppia maritima*, this was due to a lack of turions (underground storage organs) necessary for identification to the species level. There is no doubt however that it belongs to the genus *Ruppia*. In the case of *Cyperus gymnocaulos*, specimens identified by staff at the State Herbarium were considered to be probably this species, though some displayed characteristics of the morphologically similar *Cyperus vaginatus*, suggesting hybridisation. The '*?*' indicates this uncertainty of identification at the species level.

Table 3.1 Braun-Blanquet scale for recording the cover and abundance of aquatic and riparian vegetation.

Braun-Blanquet scale	Estimate of cover-abundance
1	<5% (rare, usually only 1 individual)
2	<5% (scarce, but more than 1 individual)
3	<5% (numerous, but due to small size, total cover is small)
4	5 - 24%
5	25 - 49%
6	50 - 74%
7	75 - 100%

3.3.3 Data Analysis

Examining the distribution and abundance of individual taxa at different sites can provide important information about the biology of an aquatic system. Methods of doing this include listing the most common taxa at each site or graphing the abundance of individual taxa across all sites. Although valuable, this approach ignores the more complex patterns of community structure. Simple visual examination of abundance data for many taxa across multiple sites may not detect complex patterns.

Large species by site data sets were generated in this study. To ensure a complete assessment of these data multivariate analysis was used. Multivariate analysis detects differences in the taxonomic composition of samples. These differences are potentially related to environmental factors. Classification (flexible Unweighted Paired Group Means Analysis, or UPGMA) and ordination (semi-strong hybrid Multi-Dimensional Scaling, or MDS) were used. Analyses were carried out using the PATN software package (Belbin 1993). If real patterns occur in the survey data, they should be detected by both UPGMA and MDS.

Classification analysis sorts a set of samples into groups based on their similarity to each other. Samples which are more similar are placed in the same terminal group whereas samples which are less similar are placed in different groups. UPGMA results are presented in a hierarchical dendrogram which resembles a many branched tree. Using the analogy of a tree, samples on the same 'limb' in a dendrogram have more in common with each other than they do with samples on other 'limbs'. On a finer scale, samples on the same 'branch' are more similar to each other than to samples on other 'branches' (see Figure 3.1 a and c).

Ordination analysis arranges samples on one or more axes and the results are presented in a plot (see Figure 3.1 b and d). The position of samples relative to each other is related to the similarity of the samples. Samples with more similar suites of taxa lie closer together and samples with less similar suites of taxa lie further apart.

3.4 Results and Discussion

Cover/abundance data for aquatic and riparian plants at each site can be found in Table 3.2, and arranged as a species by site matrix in Table 3.3. Presence/absence data for each water body (sites within water bodies are grouped) are given in Table 3.4. Classification and ordination results can be found in Figure 3.1.

3.4.1 Coalfield water bodies

Water bodies **Lobe B Quickfill** and **Lobe C, L5/6** and the **M10 Wetlands** had either no or very few aquatic plants. This is probably due to a combination of factors, principally salinity, NO_X-N levels and sediment structure (Table 2.1). The very acidic water in **Lobe C** (pH of 2.5) excludes aquatic plants. Submerged plants have very thin leaves which allow the direct uptake of water, nutrients and chemicals from water, making them very sensitive to water chemistry. Unstable sediments prevent strong root systems from developing, thus impinging upon nutrient acquisition. However, many other factors may contribute to the absence of aquatic plants from many of the coalfield water bodies.

Significant dispersal distances from the nearest populations of aquatic species (Flinders Ranges streams and arid zone saline lakes) undoubtedly reduces the likelihood of plant propagules reaching these water bodies. Large changes in water level and scouring during flooding may also inhibit colonisation (Keddy 1982).

Ruppia ?maritima is an inhabitant of estuaries and inland salt lakes (*e.g.* Pillie Lake, Eyre Peninsula, Williams 1985), with a recorded salinity range of 3-230 mg/L (Brock 1981). Several patches were found at the access ramp in **L5/6**. As this was the only safe access in **L5/6**, its distribution within the water body remains unknown. *Ruppia* may be common in other coalfield water bodies with semi- to permanent water and high salinities.

3.4.2 Water bodies adjacent to the coalfield

Greater numbers of species occurred at sites in **Aroona Waters**, **Aroona Dam**, the **Retention Dam** and to a lesser extent in **Leigh Creek** at the outflow from the coalfields. The former three are a source of permanent water in an otherwise arid region, with generally good water quality and low salinity (see Table 2.1). The native aquatic species *Cyperus ?gymnocaulos* (spiny flat sedge), *Schoenoplectus litoralis* (clubrush), *Typha domingensis* (cumbungi) and *Lemna disperma* (common duckweed) occurred at 1 or more of the sites. The first three occurred primarily in **Aroona Waters** whilst *Lemna* was common on **Aroona Dam**. The native tree species *Eucalyptus camaldulensis* (river redgum) and *Melaleuca glomerata* (desert paperbark) are common along Flinders Ranges streams. They are common in **Aroona Waters** and the inflow of Leigh Creek into the **Retention Dam**, and along Emu Creek at the inflow to **Aroona Dam**. They can withstand very high and low flows and are the only common native riparian trees in the region. The common shrubs were *Atriplex* spp (saltbush), *Halosarcia indica* ssp *leiostachya* (brown head samphire), *Maireana* spp (bluebushes), *Myoporum acuminatum* (western boobiala), *Pimelia microcephala* (mallee riceflower) and *Solanum nigrum* (blackberry nightshade).

3.4.3 Classification and Ordination Results

Classification and ordination indicated little similarity between the species compositions of the mainly permanent, freshwater, non-coalfield water bodies of **Aroona Waters**, **Aroona Dam** and the **Retention Dam**, and the saline L 5/6 and **Leigh Creek** downstream of the mine (Figure 3.1 a and b). **Lobe C**, **Lobe B Quickfill** and the **M 10 Wetlands** contained no aquatic plants and could not be included in the analysis. The extreme polarisation of the 2 clusters of sites (Figure 3.1 a) indicates significant dissimilarity of taxa between the two, as is evident in Tables 3.2 and 3.3. The suites of environmental factors at each cluster of sites are markedly different. NO_2/NO_3 concentrations and salinity appear to be related to Axes 1 and 2. Salinities are low in the 9 sites adjacent to the coalfield (0.1-1.2 g/L), as are NO_x-N levels (1-11 µg of N/L). Values are a magnitude or more greater in coalfield sites and in **Leigh Creek** (Table 2.1).

Amongst the 9 sites in **Aroona Waters, Aroona Dam** and the **Retention Dam,** four groups of sites could be detected based on species composition (Figure 3.1 c and d). Species compositions at sites within a water body were more similar each other, than to those of other water bodies. **Aroona Dam** sites 2A and 2B (steep, rocky with insufficient soil) were more similar to each other than to **Aroona Dam** sites 2D and 2E which occur further up the Dam where banks are shallower and sufficient soil exists for root growth. Axis 1 appears to represent an increasing soluble nitrogen gradient, with sites 1A, 1B and 2A having low NH_4 levels (0-1 mg of N/L) and sites 7A and 7B having higher levels: 3-6 mg/L of NH_4-N and 9-11 mg/L of NO_x-N respectively. Axis 2 may represent a salinity gradient, with a general increase from 0.1 mg/L at **Aroona Dam** sites to 1.4 mg/L in the **Retention Dam.**

The degree of water level fluctuation can strongly influence germination and growth (Keddy 1982, Klimesova 1994). Large fluctuations in level are likely in both storages and **Aroona Waters** following heavy rain. Rapid inundation prevents photosynthesis, and scouring will remove all but the hardiest species. Hence the development of a diverse submerged flora is unlikely.

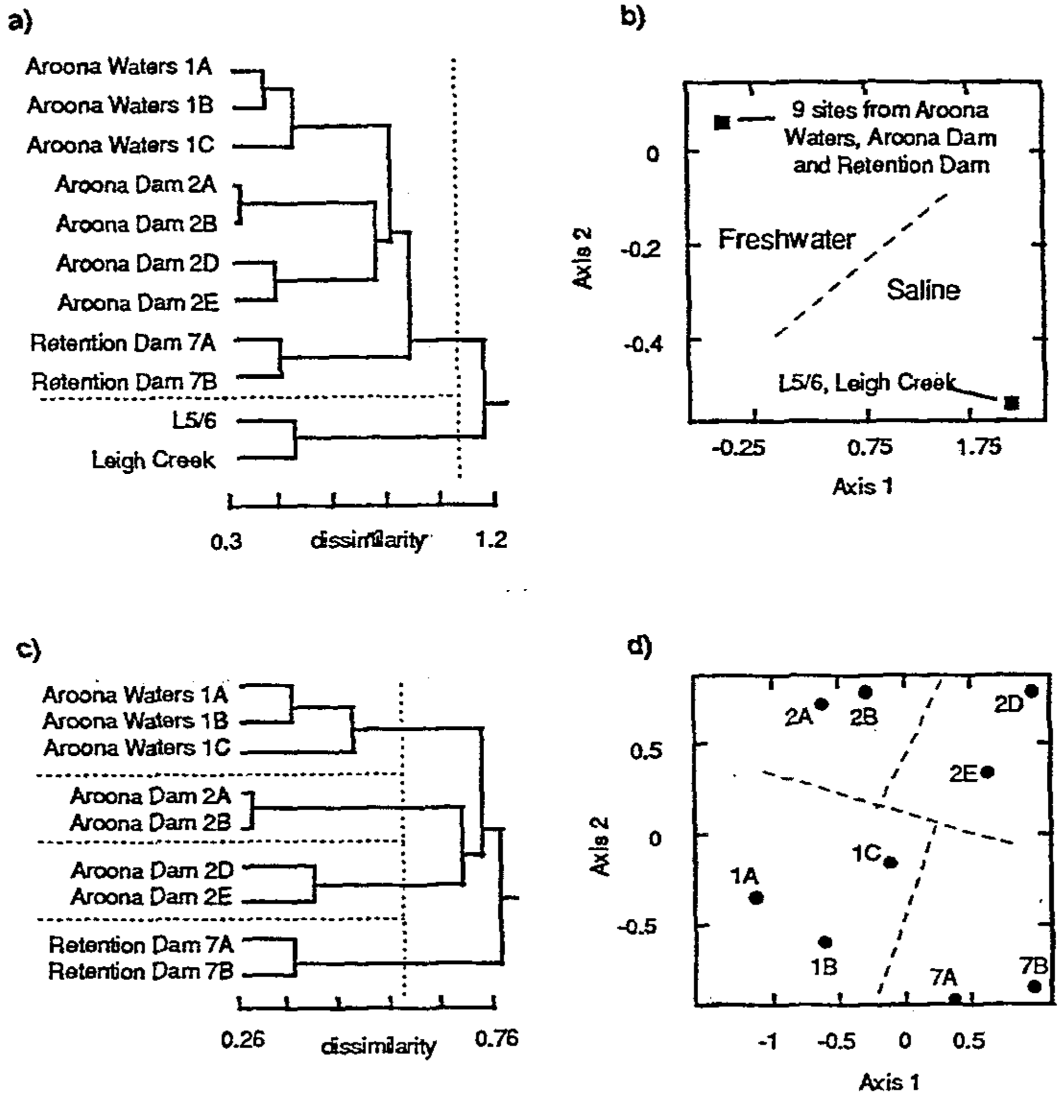


Figure 3.1 Similarity between sites based on aquatic and riparian plant species composition. a) and b) are the classification and ordination, respectively, of all sites with aquatic plants (11 sites). The principal split in the dendrogram separates the sites into 2 groups: 9 freshwater sites (all of which occur outside the mine) and 2 saline sites. The freshwater sites contained between 6 and 18 species, whilst only up to 4 species were recorded in the saline sites. The ordination indicates the same groupings. Patterns amongst non-saline sites are indicated in c) and d). Both clearly indicate 4 groups, based on water body.

3.4.4 Common species

No rare or endangered species were recorded at any site. The following is a list of native riparian herbs, shrubs and grasses, found predominantly in the non-coalfield water bodies: *Brachycome ciliaris* ssp *ciliaris* (variable daisy), *Bulbine semibarbata* (leek lily), *Cymbopogon ambiguus* (scented grass), *Datura leichhardti* (native thornapple), *Mimulus repens* (creeping monkey flower), *Pseudognaphalium luteo-album* (cudweed) and *Teucrium racemosum* (grey germander). They are generally annuals or short-lived perennials that spread by seed, with growth periods largely restricted to post-flooding periods when soil moisture is high. *Mimulus* and the shrub *Halosarcia* are common on saline soils around inland lakes. *Datura leichhardtii* is a widespread native weed.

The exotic weeds recorded included *Anagalis arvensis* (scarlet pimpernel), *Argemone subfusiformis* ssp. *subfusiformis* (mexican poppy), *Aster subulatus* (wild aster), *Carrichterra annua* (ward's weed), *Centaurea melitensis* (maltese cockspur), *Datura ferox* (fierce thornapple), *Lactuca saligna* (wild lettuce), *L. serriola* (prickly lettuce), *Nicotiana glauca* (tree tobacco) and *Sisymbrium erysmoides* (smooth mustard). Weeds occurred primarily where flooding removes the existing vegetation and disturbs soil, allowing the opportunistic annuals to invade. *Nicotiana* is common in **Aroona Dam** and the **Retention Dam**. Dead tree tobacco plants are common in shallow water where germination has occurred when the water level was low.

3.4.5 Comparison with the vegetation of Flinders Ranges streams

Little data exists concerning the distribution and abundance of aquatic and riparian plants in the adjoining Flinders Ranges. However, observations made whilst collecting specimens from several creeks in the Flinders Ranges indicate the species recorded in the natural creeks and dams around Leigh Creek are similar to those in the Flinders. This would be expected given that the principal mode of colonisation of aquatic plant propagules is along watercourses. A list of other aquatic and riparian plants found in the Flinders, Lakes Eyre and Gairdner-Torrens regions, according to the Flora of South Australia (Black 1980), is given in Table 3.5.

Despite the lack of data however, several comments can be made. Firstly, *Lemna disperma* or common duckweed is a small (0.5 cm diameter) floating aquatic plant that requires slow-moving or stationary water above the soil surface. Permanent slow-moving freshwater, nutrient inputs from the catchment and high irradiance make **Aroona Dam** an ideal habitat for *Lemna*, where it often forms extensive mats (A. Thomas, personal communication). These conditions do not occur to such an extent in the Flinders or saline lakes in the arid zone. Hence, the occurrence of *Lemna* is a direct result of altered hydrology.

Secondly, watercress (*Rorippa nasturtium-aquaticum*) and waterbuttons (*Cotula coronopifolia*) are low mat-forming herbs which are common along Flinders Ranges streams. Neither species was recorded in the Leigh Creek survey. It is unclear whether water quality/hydrology conditions are not conducive to the growth of these species in Leigh Creek water bodies, or they were simply not detected. In forming dense mats with extensive root systems, they bind sediments and trap nutrients. They also provide shelter for aquatic invertebrates. Further surveys need to be conducted to determine whether they are indeed absent from these water bodies. Macroalgae such as *Chara, Nitella* and *Lamprothamnium* often inhabit saline water bodies (*e.g.* De Deckker *et al.* 1982, Sainty and Jacobs 1993), and are common in Flinders Ranges streams (S. Wade, personal observation). None, however, were observed during the survey. Given the considerable waterbird populations known to use **Aroona Dam** and the **Retention Dam**, and the relatively short dispersal distances involved, the introduction of propagules seems likely. Unsuitable sediments and water level fluctuations may prevent their establishment.

3.4.6 Note on Introducing the Exotic *Phragmites australis*

The common reed *Phragmites australis* is naturally absent (or rare - unconfirmed sightings have been made in Wilpena Creek) in the Flinders Ranges and around Leigh Creek. It commonly occurs along the River Murray and watercourses north of Adelaide where water is ponded and soil is disturbed. It forms a dense, elevated leaf canopy which robs other plants of light, and its dense rhizome systems forage aggressively for nutrients and water. Such species are termed 'ecosystem engineers' due to their ability to greatly alter their immediate environment. Existing aquatic and riparian vegetation at Leigh Creek would undoubtedly be compromised in the event of an infestation of this species. Repeated herbicide application for control is necessary in rice irrigation areas in southwestern NSW. For this reason *Phragmites* should not be introduced to the water bodies around Leigh Creek.

3.5 Conclusion

Aquatic and riparian plants are essential to the natural functioning of aquatic ecosystems. Their roles include trapping sediments and removing nutrients, providing habitat for birds and frogs, and stabilising banks. Few species were observed in coalfield water bodies. High salinities (**Lobe C, Lobe B Quickfill, L5/6** and **M10 Wetlands**) and low pH (**Lobe C**), together with soft sediments greatly inhibit the establishment of a diverse aquatic and riparian flora. *Ruppia ?maritima*, an inhabitant of inland saline lakes, was the only aquatic species recorded on the coalfield, and was only observed in L5/6. Between six and eighteen species were recorded in off-mine site water bodies. There appears to be a strong association between salinity and NO_2/NO_3 levels and vegetation. Extremes of water levels (drought/flood) may also prevent the establishment of a diverse aquatic flora in water bodies adjacent to the coalfield.

No rare or endangered species were recorded. Typical vegetation structures were river redgum (*Eucalyptus camaldulensis*) and desert paperbark (*Melaleuca glomerata*) with a low tree-shrub understorey of western boobiala (*Myoporum acuminatum*). Along watercourses spiny flat sedge (*Cyperus gymnocaulos*) and cumbungi/bulrush (*Typha domingensis*) were most common. Riparian species include scented grass (*Cymbopogon ambiguus*), smooth mustard (*Sisymbrium erysmoides*) and thornapple (*Datura* spp). The salt-tolerant grey head samphire (*Halosarcia indica* ssp *leiostachya*) was common along Leigh Creek.

Table 3.2. Cover/abundance of aquatic and riparian plants in waterbodies at Leigh Creek.

Refer to Figure 2.1 for site locations and Section 2.4 for descriptions of the physical habitat and hydrology for each site. Brief descriptions of the major vegetation types and most given for each site. common species are

* indicates introduced species

a. Waterbodies adjacent to the coalfield

Site: Aroona Waters, 1A, 100 m downstream of Dam wall, left-hand side facing downstream

Creek bed subject to high discharge from the Dam. Overstorey of *Eucalyptus camaldulensis* and understory of *Melaleuca glomerata* and *Myoporum acuminatum*. The left-hand creek supports dense *Typha domingensis*, *Cyperus ?gymnocaulos* and some *Schoenoplectus litoralis*. These species regrow from underground rhizomes following removal of the above-ground vegetation during high discharge events. Some invasion by terrestrial exotic and native weed species is evident, but flooding prevents extensive colonisation.

Species	Braun-Blanquet scale
*Anagallis arvensis**	2
*Aster subulatus**	3
Cymbopogon ambiguus	3
Cyperus ?gynocaulos	6
Eucalyptus camaldulensis	4
Melaleuca glomerata	4
Myoporum acuminatum	3
Oxalis perennans	3
Schoenoplectus litoralis	2
Typha domingensis	6
Number of species	**10**

Site: Aroona Waters, 1B, 500 m downstream of Dam wall

One deep channel (to 2 m) runs through the centre of the creek bed whilst a secondary channel occurs on the left-hand side (facing downstream). *Eucalyptus camaldulensis* and *Melaleuca glomerata* trees line both banks. Dense *Typha domingensis* and *Cyperus ?gymnocaulos* occur in the main channel. Charophyte mats (freshwater macroalgae) and some filamentous green algae also occur in the slower moving water. Sediment size is smaller here than at 100 m downstream of the Dam wall. Terrestrial species such as *Acacia victoriae* and *Myoporum acuminatum* occur particulalrly along the right-hand bank (facing downstream).

Species	Braun-Blanquet scale
*Anagallis arvensis**	2
*Aster subulatus**	3
*Carrichtera annua**	2
Cyperus gymnocaulos	5
Datura leichhardtii	1
Enchylaena tomentosa	3

Eucalyptus camaldulensis	4
Exocarpus aphyllus	1
Lemna disperma	3
Myoporum acuminatum	4
Petalostylis labicheoides	1
Sclerolaena patenticuspis	1
*Sisymbrium erysmoides**	3
Solanum nigrum	1
*Sonchus oleraceus**	3
*Trifolium repens**	1
Typha domingensis	6
Number of species	**17**

Site: Aroona Waters, 1C, 1 km downstream of Dam wall

The creek widens with increasing distance downstream of the Dam wall. A series of pools occurs behind natural rock walls. *Typha domingensis* and to a lesser extent *Cyperus ?gymnocaulos* have colonised these pools. *Eucalyptus camaldulensis* and *Melaleuca glomerata* trees line both banks, more so on the left-hand bank. Sandy loam and clay deposits in the *Eucalyptus/Melaleuca* forest on the left-hand bank support extensive weed communities, with *Sisymbrium erysmoides, Nicotiana velutina* and *Sonchus oleraceus* most common.

Species	Braun-Blanquet scale
Acacia ligulata	2
*Carrichtera annua**	3
Cymbopogon ambiguus	3
Cyperus gymnocaulos	4
Datura leichhardtii	3
Enchylaena tomentosa	2
Eucalyptus camaldulensis	5
Melaleuca glomerata	6
Myoporum acuminatum	4
Pimelia microcephala	2
Sclerolaena patenticuspis	1
Senecio magnificus	2
*Sisymbrium erysmoides**	4
Typha domingensis	4
Number of species	**14**

Site: Aroona Dam, 2A, cove 100m to the NE of the Dam wall

Adjacent to steep rocky cliff. The bank is too steep to allow significant vegetation development. *Lemna* was the only aquatic species found.

Species	Braun-Blanquet scale
*Anagallis arvensis**	2
Cymbopogon ambiguus	6
Cynanchum floribundum	2
Eucalyptus camaldulensis	4

Lemna disperma	3
Myoporum acuminatum	2
Number of species	6

Site: Aroona Dam, 2B, on small island adjacent to boat ramp near wall.

An island at full supply level, 15 x 10 m, 10 m off land and 200 m from the dam wall. Flooding depth is likely to be less here than further up the dam due to the proximity of the dam wall. Hence plants that are restricted to where flooding is minimal may be expected to grow better here. Several large *Eucalyptus camaldulensis* occur on the sheltered side with tussocks of *Cyperus ?gymnocaulos* common.

Species	Braun-Blanquet scale
*Anagallis arvensis**	1
Cymbopogon ambiguus	4
Cyperus gymnocaulos	4
Eucalyptus camaldulensis	6
Euphorbia drummondii	1
Lemna disperma	3
Myoporum acuminatum	3
Number of species	7

Site: Aroona Dam, 2D, near top of reservoir

Near the top of the reservoir where flooding and drying are most extreme due to the inflow from Leigh Creek and other tributaries, and the constricted gorge through which floods must pass. *Eucalyptus camaldulensis* regeneration is common from just below to 2 m above full supply level. Invasive weeds such as *Datura leichhardtii, Sisymbrium erysmoides* and *Carrichtera annua* are very common in the fine sediments deposited by floodwaters. *Lemna disperma* (duckweed) occurred as thick mats in conjunction with floating woody debris in much of the top part of the reservoir where it has accumulated due to wind.

Species	Braun-Blanquet scale
*Carrichtera annua**	2
Eucalyptus camaldulensis	4
Lemna disperma	6
Nicotiana glauca	2
*Sisymbrium erysmoides**	2
Unidentified grass	3
Number of species	6

Site: Aroona Dam, 2E, at inflow of Emu Creek

Regular flooding prevents the development of a dense aquatic vegetation here. Many weed species, such as *Datura ferox* and *D. leichhardtii, Sisymbrium erysmoides, Echium plantagineum, Carrichtera annua* and *Solanum nigrum* occur along the creek bank. *Eucalyptus camaldulensis* with some *Myoporum acuminatum* lining the banks.

Species	Braun-Blanquet scale
Atriplex angulata	2
*Carrichtera annua**	3
Cymbopogon ambiguus	2
*Datura ferox**	2
*Echium plantagineum**	3
Eucalyptus camaldulensis	4
Lemna disperma	5
Myoporum acuminatum	2
*Sisymbrium erysmoides**	4
Solanum nigrum	4
Unidentified grass	5
Number of species	**11**

Site: Retention Dam, 7A, at inflow of Leigh Creek.

A rich flora exists here at the junction of the cobble and sand bed of Leigh Ck, and the deposited sediments of the Dam. Unfortunately, many species are weeds, with many exotics. Floods and dry periods prevent the establishment of a diverse aquatic flora, with seedlings of cumbungi *Tyhpa domingensis* the only true aquatic present. *Eucalyptus camaldulensis* and *Melaleuca glomerata* are common. Desirable riparian species include *Solanum nigrum, Psedognaphalium luteo-album, Enchylaena tomentosa, Mimulus repens* and *Bulbine semibarbata*. Dominant weeds are *Nicotiana glauca, Datura leichhardtii, Anagallis arvensis, Sonchus oleraceus* and *Argemone subfusiformis ssp. subfusiformis.*

Species	Braun-Blanquet scale
*Anagallis arvensis**	3
*Argemone ?subfusiformis ssp. subfusiformis**	1
Bulbine semibarbata	2
Cymbopogon ambiguus	2
Datura leichhardtii	3
*Echium plantagineum**	2
Eucalyptus camaldulensis	3
Halosarcia indica ssp leiostachya	2
*Heliotropium curassavicum**	5
Mimulus repens	1
Myoporum acuminatum	2
Nicotiana glauca	3
Pseudognaphalium luteo-album	3
Senecio magnificus	4

*Sisymbrium erysmoides**	1
Solanum nigrum	3
*Sonchus oleraceus**	1
Typha domingensis	3
Number of species	**18**

Site: Retention Dam, 7B, on N end of Dam wall, adjacent to tree plantings

Water level fluctuations appear to limit aquatic plant growth. Many dead *Nicotiana glauca* are present due to recent level changes. A rich organic matter substrate results from the deposition of woody debris following flooding and wave action. Consequently, opportunistic annuals colonise the lake edge during low water periods. A single tussock of *Cyperus ?gymnocaulos* was present, the only true aquatic recorded.

Species	Braun-Blanquet scale
Brachycome ciliaris var. ciliaris	2
Cyperus gymnocaulos	1
Enchylaena tomentosa	4
Eucalyptus camaldulensis	3
*Heliotropium curassavicum**	3
Nicotiana glauca	4
Senecio magnificus	3
Solanum nigrum	3
*Sonchus oleraceus**	2
Number of species	**9**

Site: Leigh Creek at Copley-Lydhurst Rd crossing, 50 m upstream

An intermitent creek that receives runoff water from Lobe B. Sand-clay substrate, cobbles rare or absent upstream of the road crossing. Salt tolerant samphire shrubland occurs to the creek edge. Whilst only *Halosarcia indica ssp. leiostachya* was collected, *Sarcocornia* spp, *Sclerostegia* sp and other *Halosarcia* spp (all salt tolerant but only distinguishable by patterns on the seed) may also occur.

Species	Braun-Blanquet scale
Atriplex spp	4
Cynodon dactylon	3
Eriochloa ?crebra	1
Halosarcia indica ssp leiostachya	5
Number of species	4

b. Coalfield sites

Site: L5/6 cut

Steep-sided lake of unstable sediments which receives runoff from overburden dumps and some groundwater inflows. The salt-tolerant aquatic plant *Ruppia ?maritima* was the only aquatic plant recorded. It inhabits estuaries and inland saline lakes, and spreads vegetatively *via* rhizomes and also produces tubers for overwintering.

Species	Braun-Blanquet scale
samphire sp	2
Atriplex spp	3
Ruppia ?maritima	3
Number of species	3

Site: M10 wetlands, second pond

A series of shallow ponds created by soil extraction for covering overburden dumps. They receive run-off from adjacent dumps and some saline groundwater (A. Mason, pers comm), and appear to experience rapid filling during storms. No true aquatics were present. Trial plantings of *Typha domingensis* in the adjacent pond indicate that either the planting methodology or environmental conditions are not suitable for the growth of this species. Extremely fine sediments from the dumps creates an unstabe substrate for the establishment of aquatic plants. Steep banks cause rapid flooding and an unstable substrate for plant growth.

Species

no aquatic or riparian plants recorded

Site: Lobe C cut

Aquatic plants absent at the ramp site. The existence of any aquatic plants elsewhere in the waterbody is unlikely due to the low pH and high salinity (see Table 2.1). Weeds occurred occasionally to the water's edge.

Species

no aquatic or riparian plants recorded

Site: Lobe B Quickfill

Small pond created in 1990. Reasonably shallow sided and hence amenable to plant growth. No aquatic plants recorded. Dead stems of *Typha domingensis* were found in the mud lining the pond, though it is likely the plant material was dumped there with the mud. The pond receives bore water and run-off from the adjacent overburden dumps.

Species

no aquatic or riparian plants recorded

Table 3.3. Cover/abundance scores for aquatic and riparian plants for each site.
Braun-Blanquet cover/abundance scores (see Table 2.1) within 25 m wide
* denotes an introduced species.

		Waterbodies adjacent to coalfield										Coalfield Waterbodies			
		Aroona Waters			Aroona Dam				Retention Dam		Leigh Ck, (Copley-Lyndhurst Rd)				
Species	common name	1A	1B	1C	2A	2B	2D	2E	7A	7B		L5/6	Lobe B	Lobe C	M10 wetlands
?Agrostis sp	blown grass	[redacted]	[redacted]	[redacted]			1		[redacted]	[redacted]		[redacted]		[redacted]	
Acacia ligulata	umbrella bush	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
*Anagallis arvensis**	scarlet pimpernell	[redacted]	[redacted]	[redacted]	2	1			[redacted]	[redacted]		[redacted]		[redacted]	
Argemone subfusiformis ssp. *subfusiformis*	mexican poppy	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
*Aster subulatus**	wild aster	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Atriplex angulata	angular saltbush	[redacted]	[redacted]	[redacted]				1	[redacted]	[redacted]		[redacted]		[redacted]	
Atriplex sp	saltbush	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]	4	[redacted]		[redacted]	
Brachycome ciliaris var. *ciliaris*	variable daisy	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Bulbine semibarbata	leek lily	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
*Carrichtera annua**	ward's weed	[redacted]	[redacted]	[redacted]			4	3	[redacted]	[redacted]		[redacted]		[redacted]	
Cymbopogon ambiguus	scented grass	[redacted]	[redacted]	[redacted]	6	4		2	[redacted]	[redacted]		[redacted]		[redacted]	
Cynanchum floribundum	native pear	[redacted]	[redacted]	[redacted]	2				[redacted]	[redacted]		[redacted]		[redacted]	
Cynodon dactylon	couch	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]	3	[redacted]		[redacted]	
Cyperus gymnocaulos	spiny flat segde	[redacted]	[redacted]	[redacted]		4			[redacted]	[redacted]		[redacted]		[redacted]	
*Datura ferox**	fierce thornapple	[redacted]	[redacted]	[redacted]				2	[redacted]	[redacted]		[redacted]		[redacted]	
Datura leichhardtii	native thornapple	[redacted]	[redacted]	[redacted]				5	[redacted]	[redacted]		[redacted]		[redacted]	
*Echium plantagineum**	salvation jane	[redacted]	[redacted]	[redacted]				3	[redacted]	[redacted]		[redacted]		[redacted]	
Enchylaena tomentosa	ruby saltbush	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Eriochloa ?crebra	tall cupgrass	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]	1	[redacted]		[redacted]	
Eucalyptus camaldulensis	redgum	[redacted]	[redacted]	[redacted]	4	6	6	4	[redacted]	[redacted]		[redacted]		[redacted]	
Euphorbia drummondii	caustic weed	[redacted]	[redacted]	[redacted]		1			[redacted]	[redacted]		[redacted]		[redacted]	
Exocarpus aphyllus	leafless ballart	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Halosarcia indica ssp *leiostachya*	brown head samphire	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]	5	[redacted]		[redacted]	
*Heliotropium curassavicum**	smooth heliotrope	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Lemna disperma	common duckweed	[redacted]	[redacted]	[redacted]	3	3	6	5	[redacted]	[redacted]		[redacted]		[redacted]	
Melaleuca glomerata	desert paperbark	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Mimulus repens	creeping monkey flower	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Myoporum acuminatum	western boobialla	[redacted]	[redacted]	[redacted]	2	3		2	[redacted]	[redacted]		[redacted]		[redacted]	
Nicotiana glauca	tree tobacco	[redacted]	[redacted]	[redacted]			3		[redacted]	[redacted]		[redacted]		[redacted]	
Oxalis perennans	oxalis	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Petalostylis labicheoides	-	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Pimelia microcephala	mallee riceflower	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Pseudognaphalium luteo-album	cudweed	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Ruppia ?maritima	sea tassel	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Schoenoplectus litoralis	clubrush	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Sclerolaena patenticuspis	spearfruit copperburr	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Sclerolaena sp	-	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Senecio magnificus	showy groundsell	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
*Sisymbrium erysmoides**	smooth mustard	[redacted]	[redacted]	[redacted]			3	4	[redacted]	[redacted]		[redacted]		[redacted]	
Solanum nigrum	blackberry nightshade	[redacted]	[redacted]	[redacted]				4	[redacted]	[redacted]		[redacted]		[redacted]	
*Sonchus oleraceus**	common sow-thistle	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
*Trifolium repens**	clover	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Typha domingensis	cumbungi	[redacted]	[redacted]	[redacted]					[redacted]	[redacted]		[redacted]		[redacted]	
Total number of species per site		11	17	15	6	7	6	11	18	10	4	3	0	0	0
Number of introduced species		2	6	2	1	1	2	4	5	2	0	0	0	0	0

Table 3.4. Aquatic and riparian plant species recorded in the 8 waterbodies
+' indicates a species was present within a waterbody. Note that the species were not necessarily within the 25 m wide quadrat. No plants were recorded in the M10 wetlands, Lobe B or Lobe C.

* indicates introduced species

Species	Aroona Waters	Aroona Dam	Retention Dam	L5/6	Leigh Ck (Mine outflow)
?Agrostis sp		+			
Acacia ligulata	+				
Acacia tetragonophylla	+				
Acacia victoriae	+		+		
*Anagallis arvensis**	+	+	+		
Argemone ?subfusiformis ssp *subfusiformis*			+		
*Aster subulatus**	+				
Atriplex angulata		+			
Atriplex sp				+	+
Brachycome ciliaris var. *ciliaris*					
Brachycome ciliaris var. *lanuginosa*			+		
Bulbine semibarbata			+		
*Carrichtera annua**	+	+	+		+
Cymbopogon ambiguus	+	+	+		
Cynanchum floribundum	+	+			
Cynodon dactylon					+
Cyperus gymnocaulos	+	+	+		
*Datura ferox**		+			
Datura leichhardtii	+	+	+		
*Echium plantagineum**			+		
Enchylaena tomentosa	+	+	+		
Eragrostis dielsii var dielsii					+
Eriochloa ?crebra					+
Eucalyptus camaldulensis	+	+	+		
Euphorbia drummondii		+			+
Exocarpus aphyllus	+				
Halosarcia indica ssp *leiostachya*			+		+
*Heliotropium curassavicum**		+	+		
Lactuca saligna			+		
Lactuca serriola			+		
Lemna disperma	+	+			
*Marrubium vulgare**			+		
Melaleuca glomerata	+	+	+		

Table 3.4. (continued)

Species	Aroona Waters	Aroona Dam	Retention Dam	L5/6	Leigh Ck (Mine outflow)
Myoporum acuminatum	+	+	+		
Nicotiana glauca					
Nicotiana velutina	+	+			
Oxalis perennans	+				
Petalostylis labicheoides	+				
Pimelia microcephala					
Pseudognaphalium luteo-album		+	+		
Pterocaulon sphacelatum			+		
*Punica granatum**	+				
Ruppia ?maritima				+	
samphire sp				+	
Sclerolaena patenticuspis	+				
Sclerolaena sp	+				+
Senecio cunninghamii	+	+	+		
Senecio magnificus	+	+	+		
*Sisymbrium erysmoides**	+		+		
Solanum ellipticum	+	+	+		
Solanum nigrum	+	+	+		
Solanum sturtianum			+		
*Sonchus oleraceus**	+	+	+		+
Teucrium racemosum	+				
*Trifolium repens**	+	+	+		
Typha domingensis	+	+	+		
Number of species per waterbody	**31**	**25**	**30**	**3**	**8**
Number of introduced species	**7**	**6**	**8**	**0**	**2**

Table 3.5. Aquatic and riparian plant species found in creeks, springs and saline lakes in the Flinders Ranges, Lake Eyre and Lakes Gairdner-Torrens regions (from the Flora of South Australia, Black 1980) but not recorded during the survey.

CYPERACEAE	JUNCACEAE
Baumea arthrophylla	*Juncus aridicola*
B. articulata	*J. flavidus*
B. rubiginosa	*J. kraussii*
Bolboschoenus caldwellii	*J. prismatocarpus*
Carex appressa	*J. sarophorus*
C. gaudichaudiana	
C. gunniana	JUNCAGINACEAE
C. inversa	*Triglochin striatum*
C. tereticaulis	
Cyperus alterniflorus	POACEAE
C. exaltatus	*Glyceria australis*
C. laevigatus	
Eleocharis acuta	POTAMOGETONACEAE
E. sphacelata	*Potamogeton ochreatus*
Gahnia ancistrophylla	*P. pectinatus*
Lepidosperma laterale	*P. tricarinatus*
Schoenoplectus pungens	*Ruppia megacarpa*
S. validus	

Chapter 4 Benthic Algae

Adrienne Burns

4.1 Summary

Algae are an important group, being the dominant primary producers in most aquatic systems. They provide the energy base for many aquatic foodchains. Algae consist of a number of groups including cyanobacteria (blue-green algae), diatoms and green algae. These groups may be used individually or as a whole assemblage to assess environmental change.

Algae respond quickly to environmental change giving early warning to overall biotic changes within the system. Algae also regulate nutrient dynamics, and many studies use algae to indicate changes in organic enrichment.

Benthic algae are algae that grow on the sediment surface. They grow in isolation or within mats containing many species (biofilms). Benthic algae are most abundant in the littoral zone which is the shallow area near the banks of water bodies, where light is available for photosynthesis. Algal sampling was carried out in the littoral zone in this study. The composition and abundance of the algae was assessed in the comparison of coalfield and non-coalfield water bodies around Leigh Creek, and to evaluate potential for future use as indicators of water quality in the area.

In the samples from the Leigh Creek area, 43 algal taxa were identified. Composition and abundance of the algal assemblages were similar at **Aroona Waters, Aroona Dam** and the **Retention Dam.** This may be related to the low salinity and low nitrate concentrations characteristic of these sites when compared with sites within the mining area with high salinities and higher nitrate concentrations (ie. Lobe 5/6, **M10 Wetlands, Lobe B Quickfill**). Similarities in algal composition were found between **Leigh Creek** and the mine site due to the high salinity of the former. The benthic algal assemblages at the other sites were generally more sparse than at the latter sites, being dominated by diatoms. At a single site, **Lobe C**, no algae were found, being attributed to the low pH of the water column.

4.2 Introduction

Non vascular photosynthetic organisms live within a matrix of other microbes on benthic and other surfaces in aquatic systems. These biofilms (or periphyton) are a primary energy source for aquatic food webs (Rounik and Winterbourne, 1983; Lock et al 1984). Biofilms and more solitary benthic assemblages of algae are useful for monitoring environmental change as they have a short generation time which induces a response further up the food chain (Steinman and McIntyre, 1990). Therefore they form a direct link to the overall biological function of the system. Photosynthetic organisms dominate biofilms and benthic assemblages where light is available, in the littoral regions of lakes and deep rivers or throughout the stream bed of shallower water courses. The composition of these assemblages depend on scouring rates, tolerance to desiccation, nutrient availability, water quality and grazing. Thus biofilm composition and activity may be useful in predicting water quality and other biological responses in aquatic systems.

This section investigates the benthic algal composition of water bodies at the Leigh Creek, to elucidate any relationships between the algal composition and abundance and water quality.

4.3 Methods

Alga were sampled in two ways. Quantitative core samples were taken using a PVC tube with a diameter of 5 cm. The corer was pushed 1 cm into the sediment. A metal plate was slipped under the corer and the sample was lifted from the water and placed into a plastic snap lock bag.

Opportunistic samples of any macroalgae seen were collected by hand. These samples are referred to as grab samples and were taken to assist with establishing which taxa were present at each site. The samples were stored on ice until examination.

The core samples were homogenised and a sub-sample was taken for analysis. Under light microscopy (400X - 1000X magnification) the first 700 cells were identified to genus, in most cases, and to species where possible. Each taxa was assigned a relative abundance unit ranging from 1-10, within each sample and scaled with regards to the overall abundance depending on the density of the sample. Ordination analysis was carried out as described in Chapter 3.3.3.

4.4 Results and Discussion

From the 5 core and grab samples taken from the 7 sites 43 algal taxa were identified. The taxa were evenly spread throughout algal phyla with 16 greens, 16 diatoms and 11 cyanobacteria (Table 4.1).

The grab samples were not quantitative as they were taken only where macro filamentous algae was present. Most of the grab samples had a high species richness due to the large surface area provided by the algae. Some larger algal cells exude dissolved carbon molecules which are available to some diatom groups for synthesis. This association of some diatoms with the filamentous green algae was also seen in the cores which had a surface mat of green algae (Table 4.2).

4.4.1 Aroona Waters

comments: freshwater and low nitrate.
taxonomic richness: 19 from cores, 24 including grabs
Four of the six samples from **Aroona Waters** were dominated by the filamentous green *Spirogyra*. Two of the samples were sparse or without algae. Another two of the samples were diverse with 19 taxa, 8 of which were shared. These include the filamentous cyanobacteria *Anabaena torulosa* which can fix nitrogen being consistent with the low NO_3 concentration at that site. The latter sample was the only sample with the colonial blue-green *Merismopedia*.

4.4.2 Aroona Dam

comments: freshwater and low nitrate, turbid.
taxonomic richness: 8 from cores
Only one of the samples from **Aroona Dam** had a dominant alga, the diatom *Navicula*. Two of the samples had no algae. The small unicellular green alga *Chlorococcum* was common throughout the other samples. **Aroona Dam** was also low in NO_3 but had a higher turbidity that **Aroona Waters** so may explain the lower diversity.

4.4.3 Retention Dam

comments: freshwater, low nitrate
taxonomic richness: 7 from cores, 17 including grabs
The sample grab from **Retention Dam**, off the pontoon, had a different species composition than the other samples from that site, being dominated by the filamentous green, *Cladophora*. The diatom *Gomphonema* was only found in low numbers in this sample and was probable associated with the *Cladophora* matrix. The composition was variable between other samples from this site. The other grab samples were

dominated by the filamentous green, *Spirogyra* and related *Zygnema*. These were the only samples to contain the diatom *Melosira italica*. Two of the core samples were dominated by a blue-green mat of *Anabaena torulosa*. *Anabaena torulosa* is able to fix nitrogen which was in low concentrations at this site.

4.4.4 Lobe 5/6

comments: high nitrate
taxonomic richness: 8 from cores
From **L5/6** the large diatom *Gyrosigma* was abundant throughout all cores with algae. Only one core had no algae present. Another diatom, *Nitschzia sigmoida* was also common in these samples.

4.4.5 Leigh Creek

comments: saline, low nitrate
taxonomic richness: 13 from cores
The core samples from **Leigh Creek** were mainly dominated by diatoms although the abundances were low except in two of the cores. In these two, *Nitschzia sigmoida* was common. One of the cores was very sparse in abundance and only had filaments of small cyanobacterium, *Leptolyngbya*.

4.4.6 M10 Wetlands

comments: high nitrate
taxonomic richness: 10 from cores
The samples from the **M10 Wetlands** were also dominated by an abundant diatom, *Cymbella* and one of the cores had 9 taxa. Again one of the five samples had no algae.

4.4.7 Lobe B Quickfill

comments: high nitrate
taxonomic richness: 5 from cores
All the samples from **Lobe B Quickfill** were sparse in algal abundance. *Cymbella* was also common throughout the samples that had algae.

4.4.8 Lobe C

comments: low pH, high nitrate
taxonomic richness: 0 from cores
No algal taxa were found in the samples from **Lobe C**. This may be due to the low pH which would dissolve the silicate coating of the diatoms and generally disturb the

metabolism of other algal cells. Most microbes cannot cope with acidity lower than pH 5.

There was similarity between the species abundance and composition at **Aroona Waters** and the **Retention Dam** sites. Each of these sites had low salinities compared with the other sites and low nitrate and ammonia and concentrations (Table 2.1) which may be the cause of the dominance of *Anabaena torulosa* in samples from both sites. Both sites had plumes of macro filamentous green algae which added to the species richness of the sites. From the ordination of the core samples, the algal composition from **Aroona Dam, Aroona Waters** and **Retention Dam** were indistinguishable and separated from the other sites on axis one which represented salinity and nitrogen concentrations (Figure 4.1).

At **L5/6, Lobe B Quickfill** and the **M10 Wetlands**, which had high nitrate concentrations and salinities, diatoms were dominant (eg. *Gyrosigma* and *Cymbella*). The remainder of the algae at these sites were small, usually early successional cyanobacteria which were not nitrogen fixers. Each of these sites where separated on Axis 2 of the ordination (Figure 4.1) which did not represent any of the factors measured during the sampling period. The difference in benthic algal composition at **L5/6, Lobe B Quickfill** and the **M10 Wetlands** are probably related to some micro habitat factor specific to each site.

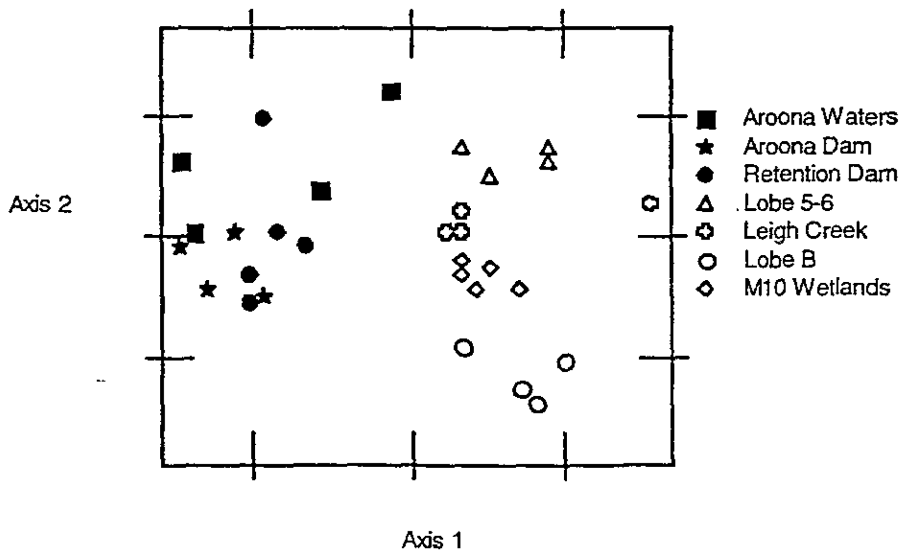


Figure 4.1 Similarity between sites from benthic algal cores.
Ordination illustrates a separation of Aroona Water, Aroona Dam and Copley Retention Dam from the other sites on Axis 1 following an increase in nitrate/ammonia and salinity concentrations. The high nutient and salinity sites (open shapes) show separate characteristics on Axis 2, in contrast to the other sites which appear as a single group (dark shapes).

The major differences in algal composition and relative abundance between sites in the Leigh Creek area were associated with salinity and nitrogen availability of the water bodies. The algal composition from **Aroona Dam, Aroona Waters** and **Retention Dam** were indistinguishable from the other sites which had 5-15 fold higher salinity and from 3-40 fold higher nitrate and ammonia concentrations. Filamentous green algae were prolific at the freshwater and nutrient sites but not at the other sites. Filamentous green algae are highly competitive and are commonly found in high nutrient areas. Salinity had the overriding influence on the presence of filamentous green algae due to their absence at the sites with higher nutrient concentrations which also had higher salinities than the low nutrient sites.

It should be noted that often one of the replicates from each site did not contain any algae indicating high spatial variability in algal distribution. A more extensive sampling regime would be required to gain a clearer picture of the distribution algal assemblages in the sediments in some areas in future studies.

4.5 Comparison with Flinders Ranges Streams

In comparison with benthic algal studies in streams in the nearby Flinders Ranges, 20 of the taxa from this present study were the same as those from a group of Flinders Ranges streams (Piller, unpublished thesis, 1994). In the Flinders Ranges a gradient of nitrate enriched to nitrate depleted streams presented similar patterns in benthic algal composition to the current study. Nitrogen fixing cyanobacteria, *Anabaena* sp. were common at low nitrate streams in the Flinders Ranges. Diatoms such as *Cymbella* were prevalent in the high nitrate reaches, also corresponding with the findings of the current study. The high nitrate sites in the Flinders Ranges studies had large plumes of filamentous green algal taxa similar to those found in the lower nitrate areas in the present study. It would be expected that most filamentous green algal taxa would favour sites with greater nutrient availability, however, at **Aroona Dam, Aroona Waters** and **Retention Dam**, most of the green algae were collected as grabs rather than cores. In this study, the microhabitats at which these plumes may have been collected probably were more favourable to green algal growth. These include attachment to substrata elevated from the bottom, exposing the assemblage to higher light than over the benthos.

4.6 Algae as bioindicators

Algae have qualities as environmental indicators as they are ubiquitous and form an ecologically important group, being sensitive to a broad range of environmental stresses. Algal composition and /or activity can be used to form a reference for environmental changes over short time frames (McCormick and Cairns, 1994). Composition and algal activity are the major methods utilised to assess changes in environmental conditions. In this study a general classification of all algal taxa was used giving clear patterns in system differences on and off the mine site. To utilise a higher taxonomic level (ie. species) a focus is placed on one algal group, and commonly the diatoms. Diatoms are recognised as a dominant group and have been routinely used for monitoring pollution levels. Functional measures of algal activity (ie. photosynthetic rates) prove to be a faster method to examine changes to algal assemblages on a larger scale. Although the equipment for such methods are more costly the results provide an instant outcome, without many hours of laboratory identification. However, use of functional techniques has yet to be standardised as a reliable measure of environmental impact although has greater potential as changes would be measured on a larger scale (McCormick and Cairns, 1994).

4.7 Conclusion

Biofilms and solitary benthic assemblages of algae are useful for monitoring environmental change as they have short generation times. Changes in benthic microorganisms induce a response further up the food chain thus forming a direct link to the overall biological function of the system. In the benthic samples from the Leigh Creek area, 43 algal taxa were identified. Composition and abundance of these assemblages were similar at **Aroona Waters, Aroona Dam** and **Retention Dam.** This may be related to the low salinity and low nitrate concentrations characteristic of these sites when compared to adjacent water bodies The nitrogen fixing cyanobacteria *Anaebaena torulosa* was common in these samples together with filamentous green algal taxa. The benthic algal assemblages at the other sites were generally more sparse than at the latter sites, being dominated by diatoms. At a single site, **Lobe C,** no algae were found, being attributed to the low pH of the water column.

Table 4.1 Benthic Algal Species List from Leigh Creek and surrounding water bodies, June 1995.

		FAMILY	*Genus (species)*	notes
Green algae				
	1	Cladophoraceae	*Cladophora*	filamentous
	2	Oedogoniaceae	*Oedogonium*	filamentous branching
	3	Zygnemataceae	*Spirogyra*	double chloroplast, filamentous
	4		*Mougoutia*	thin filament
	5		*Zygnema*	filamentous
	6	Chlorococcaceae	*Chlorococcum*	30-40 µm diameter, unicellular, solitary
	7		*Gloecystis*	10-20 µm diameter, unicellular in groups of 3-5
	8		*Urococcus*	unicellular, rings of mucus
	9	Oocystaceae	*Schroederia*	solitary
	10		*Closterium*	large, unicellular
	11		*Akinstrodesmus*	clusters
	12	Scenedesmaceae	*Scenedesmus dimorphus*	4 cells
	13		*Tetradesmus*	unicellular
	14		*Actinastrum*	unicellular
	15	Eugleinoid	*sp 1.*	25 µm long.
Diatoms				
	16	Coscinodiscaceae	*Melosira italica*	
	17	Fragilariaceae	*Fragilaria*	
	18		*Synedra*	
	19	Achnanthaceae	*Cocconeis*	
	20		*Rhopalodia*	
	21		*Pinnularia*	
	22	Naviculaceae	*Navicula sp 1*	
	23		*Navicula sp 2*	
	24	Cymbellaceae	*Cymbella*	
	25		*Gyrosigma*	
	26	Gomphonemaceae	*Gomphonema*	
	27	Bacillariaceae	*Nitzschia sigmoida*	
	28		*Nitzschia sp 1*	
	29		*Bacillaria paxillifer*	
	30		*Epithemia*	
	31	Surirellaceae	*Surirella*	

Table 4.1 (continued)

Cyanobacteria			
32	Oscillatoriaceae	*Oscillatoria (thin filament)*	filamentous
33		*Lyngbya*	filamentous
34	Phormidiaceae	*Microcoleus*	filamentous
35	Pseudoanabaenaceae	*Leptolyngbya*	filamentous, thin
36		*Pseudoanabaena*	filamentous, thin
37		*Spirulina*	filamentous
38	Nostocaceae	*Anabaena torulosa*	filamentous with akinetes, N fixer.
39		*Anabaena oscillatoriodes*	filamentous without akinetes
40	Chroococcaceae	*Gleocapsa*	unicellular
41		*Microcystis*	unicellular, colonial
42		*Merismopedia*	unicellular, colonial

Keys and identification guides used

Anagnostidis, K. and Kómerék, J. (1988) Modern approach to the classification system of the cyanophytes. 3. Oscillatoriales. *Arch.Hydrobiol.Suppl.* **80**, 327-472.

Bellinger, E.G. (1988) *A Key to Common Algae* (4th Edn).

Entwistle, T.J. (1994) *Aquatic cryptogams of Australia.* ASL special publication No.10.

Kómerék, J. and Anagnostidis, K. (1989) Modern approach to the classification system of the cyanophytes. 4. Nostocales. *Arch. Hydrobiol. Suppl.* **82**, 247-345

Prescott, G.W. (1951) *Algae of the Western Great Lakes Area.* Cranbrook Press: Michigan.

Prescott, G.W. (1984) *How to Know the Freshwater Algae.* Wm C. Brown Company: Iowa.

Table 4.2 Leigh Creek Algal taxonomic lists for individual samples

bold print = dominant taxa in sample
underlined = only present in this sample

Aroona Waters	1.1 Sparse (core) Oedogonium Chlorococcum Fragilaria **Synedra** Rhopalodia Navicula sp 1. Epithemia	1.2 (core) **Spirogyra** Euglenoid Fragilaria Synedra Cocconeis Anabaena tortulosa Chroococcoid	1.3 (core) **Spirogyra** Gleocystis Synedra Rhopalodia Navicula sp 1. Navicula sp 2. Gyrosigma Bacillaria paxillifer Epithemia Oscillatoria **Pseudoanabaena** **Anabaena tortulosa** Microcystis	1.4 (grab) Oedogonium **Spirogyra** Mougoutia *Tetradesmus* Akinstrodesmus Synedra Navicula sp 1. Gyrosigma Epithemia Lyngbya Pseudoanabaena **Anabaena tortulosa** Microcystis Merismopedia	1.5 (grab) **Spirogyra**	1.6 (grab) no algae	1.7 (core) Oedegonium Akinstrodesmus **Rhopalodia** Navicula sp 1. Anabaena torulosa Anabaena oscillatorioides
Aroona Dam	2.1 (core) no algae	2.2(core) no algae	2.3 (core) Chloroccoccoid Scenedesmus dimorphus Urococcus Pseudoanabaena	2.4 (core) Chlorococcum Navicula sp 1. Nitschzia Chroococcoid	2.5 (core) Chloroccoccoid Scenedesmus dimorphus Navicula sp 1. Chroococcoid Gleocapsa		
Lobe 5-6	3.1 (core) **Gyrosigma** Nitschzia sigmoida Lyngbya Pseudoanabaena	3.2 (core) Actinastrum Navicula sp 1. Navicula sp 2. **Gyrosigma** Nitschzia sigmoida Lyngbya Spirulina	3.3 (core 20cm) no algae	3.4 (core) Gyrosigma Nitschzia sigmoida	3.5 Sparse (core 20 cm) Gyrosigma Nitchishzia sigmoida		
M10 Wetlands	4.1 (core) **Cymbella** Gyrosigma Nitschzia sigmoida Lyngbya Pseudoanabaena	4.2 (core) Gleocystis Pinnularia Navicula sp 1. **Cymbella** Gyrosigma Nitschzia sigmoida Lyngbya Pseudoanabaena Spirulina	4.3 (core) Chlorococcoid Pinnularia Navicula sp 1. **Cymbella** Gyrosigma Nitschzia sigmoida Lyngbya	4.4 (core) Pinnularia Navicula sp 1. **Cymbella** Gyrosigma Lyngbya	4.5 (core 30 cm) no algae		
Lobe C	5.1 (core) no algae	5.2 (core) no algae	5.3 (core) no algae	5.4 (core) no algae	5.5 (core) no algae		

Lobe B	6.1 Sparse (core) Gleocystis Actinastrum Cymbella	6.2 (core) Gleocystis Actinastrum Cymbella	6.3 (core) Actinastrum Cymbella	6.4 Sparse (core 25 cm) Gleocystis Cymbella Nitschzia Pseudoanabaena	6.5 (core) no algae		
Retention Dam	7.1 (grab) Cladophora Chlorococcoid Scenedesmus dimorpha Euglenoid Fragillaria Gomphonema Synedra Navicula sp 1. Pseudoanabaena	7.2 (core) Synedra Navicula sp 1.	7.3 (core) Navicula sp 1. Nitschzia Bacillaria paxillifera Oscillatoria Anabaena torulosa	7.4 (core) Synedra Navicula sp 1. Nitschzia Bacillaria paxillifera Anabaena torulosa	7.5 (grab) Spirogyra Zygnema Actinastrum Melosira italica Navicula sp 1. Nitschzia sigmoida Nitschzia sp 1.	7.6 (core) Spirogyra Zygnema Actinastrum Melosira italica Nitschzia sigmoida Nitschzia sp 1.	7.7 (core) no algae
Leigh Creek	8.1 (core) Leptolyngbya	8.2 (core) Chlorococcoid Actinastrum Navicula sp 1. Cymbella Gyrosigma Nischia sigmoida Surirella Oscillatoria Lyngbya Leptolyngbya	8.3 (core) Chlorococcoid Actinastrum Navicula sp 2. Cymbella Gyrosigma Epithemis Lyngbya Leptolyngbya	8.4 (core) Chlorococcoid Actinastrum Navicula sp 2. Cymbella Gyrosigma Nitschzia sigmoida Oscillatoria Lyngbya	8.5 (core) Chlorococcoid Navicula sp 1. Cymbella Gyrosigma Nitschzia sigmoida Oscillatoria		

Chapter 5 Macroinvertebrates

Sam Wade

5.1 Summary

Invertebrates are multicellular animals without backbones. Ninety-five percent of all known animals are invertebrates. Aquatic macroinvertebrates are invertebrates that live in water and can be seen with the naked eye. They are the dominant animals in aquatic ecosystems.

Aquatic macroinvertebrates occupy a number of important positions in aquatic food chains. They can be detritivores, grazers, predators and prey. Invertebrates are a food resource for other invertebrates, fish, amphibians and birds.

Macroinvertebrates respond quickly to physical and chemical changes in aquatic environments. Within the large range of aquatic invertebrates there are animals which can inhabit almost any kind of aquatic system. Many of these are characteristic to a limited range of systems. This makes macroinvertebrates ideal organisms for biomonitoring.

In this study macroinvertebrates were sampled quantitatively at eight sites around Leigh Creek. Invertebrates were sampled from the shallow edge areas because this habitat existed at all sites, allowing valid comparisons of these sites. Samples were taken using a coring technique which allows estimates of the density (number of invertebrates per unit area) and the richness (number of taxonomic groups of invertebrates) at each site.

There was no relationship between macroinvertebrate density and salinity. However, saline sites had a different community structure and fewer macroinvertebrate taxa than freshwater sites. Higher salinity, simple homogeneous habitat structure, short establishment time and isolation from natural watercourses ensure that saline waterbodies have a reduced taxonomic richness. The greater taxonomic richness at freshwater sites is due to the lower salinity, more complex habitats, longer establishment time and location on natural watercourses. These factors allow greater access to freshwater sites by potentially colonising organisms, greater colonising success due to a wider choice of habitats within the freshwater sites and a larger pool of potentially colonising organisms due to lower salinity.

The fauna of the Leigh Creek sites was compared to natural water bodies in the Flinders Ranges and the drier areas of South Australia. The macroinvertebrate fauna of the freshwater sites **Aroona Dam, Aroona Waters** and the **Retention Dam** were limited when contrasted with streams of the Flinders Ranges. This was probably due to a lack of water flow and less habitat variability in the Leigh Creek sites.

The fauna of the saline wetlands (**L5/6, Lobe B Quickfill** and the **M10 Wetlands**) was similar to saline lakes in the region. **Leigh Creek** fauna was similar to Willochra Creek, a comparable lowland saline site. The fauna of **Lobe C** was very poor compared to acid salt lakes on Eyre Peninsula. These faunal comparisons with natural wetlands should be treated with caution because they have some limitations.

5.2 Introduction

Invertebrates are multicellular animals without backbones. Some common invertebrates in aquatic systems are insects, crustaceans, arachnids and annelids (worms). Ninety-five percent of all known animals are invertebrates (Barnes 1987). Aquatic macroinvertebrates are invertebrates that live in water and can be seen with the naked eye. In this study they are functionally defined as the invertebrates that were retained in a 0.25 mm mesh sieve. They are the dominant animals in aquatic ecosystems both numerically and in biomass.

Aquatic macroinvertebrates occupy a number of important positions in aquatic food chains:

- Detritivores: Many invertebrates feed on detritis (terrestrial leaf litter, dead waterplants and algae). Terrestrial organic matter is an important resource in most aquatic ecosystems. Macroinvertebrates cycle this material through aquatic systems. This makes the nutrients and energy from these resources available to other organisms.
- Grazers: Some invertebrates eat aquatic plants and algae.
- Predators: Invertebrate predators eat other invertebrates and even fish and amphibians.
- Prey: Invertebrates are a food resource for other invertebrates, fish, amphibians and birds.

The main aims of this chapter are:

- to assess the distribution and abundance of benthic macroinvertebrates at each site;
- to examine patterns in this distribution and relate them to chemical and physical data from these sites; and
- to compare the macroinvertebrate fauna with that of other wetlands in the area surrounding Leigh Creek.

This is an exploratory survey aimed at assessing the types and numbers of aquatic macroinvertebrates present in wetlands around the Leigh Creek area. General conclusions about the health of these wetlands are made by comparing these results with data from research on other wetlands such as upland and lowland Flinders Ranges creeks and saline lakes from the drier areas of South Australia. This report also provides baseline data which will be useful if a biomonitoring programme is established in the future at Leigh Creek.

The use of macroinvertebrates for the biological assessment of water quality has a long history, with standard approaches first published in 1908 (Norris and Norris 1995). Such methods have been implemented at a national scale in both the United Kingdom and the United States (Resh *et al.* 1995), and recently Australia (Commonwealth Environmental Protection Agency "National River Health

Programme"). Macroinvertebrates are excellent biological indicators. They are widespread and occur in high densities which makes sampling manageable. They respond quickly to environmental change and different taxa are sensitive to different environmental conditions (Williams 1983).

Once baseline data has been established gains and losses in the health of a wetland can be assessed using macroinvertebrates. Monitoring of macroinvertebrates can be used to assess the success of wetland rehabilitation programmes and the impact of environmental change due to pollution events.

5.3 Materials and Methods

For this study sampling was carried out on the littoral benthos. That is, the samples were taken from the sediment surface in the shallow areas of the wetlands. This ensured that sampling from all sites was comparable because this habitat occurred at all sites. Benthic samples were not taken from the profundal (deep) zone or plankton samples from the open water zone, as these habitat types do not occur in streams and other shallow wetland sites.

Macroinvertebrates were sampled using a coring technique. A PVC tube with a 10 cm diameter was pushed 5 cm into the sediment. A metal dustpan was pushed under the tube and the sample was lifted from the water and placed into a bucket. The sample was then elutriated from the bucket into a 0.25 mm mesh sieve until no macroinvertebrates could be seen in the bucket. The sample was rinsed from the sieve into a specimen jar and preserved in 70% ethanol. This collection method is simple and quantitative, enabling an equivalent area and volume to be sampled each time.

In the laboratory each sample was washed through a nest of sieves (2 mm, 1 mm, 0.5 mm and 0.25 mm). Macroinvertebrates of each size class were identified and counted under a dissecting microscope (8-140x magnification). Macroinvertebrates were identified to the most practical level given the currently available keys. In many cases identification was to genus and in some cases to the species level. Some of the taxa could only be identified to the subfamily or a higher level of classification because adequate keys are not available for some groups and many Australian taxa have not yet been described. Multivariate analysis was carried out as described in Section 3.3.3. Macroinvertebrate abundance data was log transformed to prevent very common taxa from dominating the outcome of the analysis. Taxa which occurred in fewer than three samples were excluded to prevent rare taxa having a disproportionately large impact on the results.

5.4 Results and Discussion

5.4.1 Aroona Waters

A mean of 89 macroinvertebrates per sample and a total of 27 taxa (Table 5.1) were collected at **Aroona Waters**. This site had one of the lower densities but the highest richness of all the sites. The most common taxa were Oligochaetes, Cycolpoid sp#1, the Chironomid genera *Tanytarsus* and *Chironomus* and the mayfly *Tasmanocoenis tillyardi.* A list of taxa present at each site is presented in table 5.2.

5.4.2 Aroona Dam

Overall, **Aroona Dam** had a richness of 15 taxa and a density of 428 macroinvertebrates per sample, the second highest density of all the sites. When considered separately, site 2A had a richness of 8 and a mean density of 464 macroinvertebrates per sample. Cyclopoid sp#1 was the most common taxa here with a density of 425 per sample. At site 2B the density was slightly lower (392 macroinvertebrates per sample) however there were more taxa (14). Oligochaetes (299 per sample) were the most common taxa at this site. The other common macroinvertebrate at **Aroona Dam** was the Chironomid *Chironomus.*

5.4.3 Retention Dam

The **Retention Dam** had a density of 287 macroinvertebrates per sample and the second highest richness of 20 taxa. The richness was not as great within the individual sites; 12 taxa at site 7A and 14 taxa at site 7B (with a density of 276 and 165 per sample respectively). Common taxa at both of the sites were Cyclopoid sp#1, Ceratopogonidae sp#1 and the Chironomids *Harnischia* and *Cladotanytarsus*. The Chironomids *Tanytarsus* and *Procladius* and the mayfly *Cloeon fluviatile* were common at site 7A whilst Oligochaetes were common at site 7B.

5.4.4 Leigh Creek

This site had a mean density of 132 macroinvertebrates per sample and a richness of 14 taxa. The most common taxa were Ostracoda sp#2, Cyclopoid sp#1, Ceratopogonidae sp#1 and 3, and the Chironomid *Procladius* sp.

5.4.5 L5/6

L5/6 had the second lowest density of all of the sites (52 macroinvertebrates per sample). It had a richness of 13 taxa. Common taxa were Cyclopoid sp#1, the beetle larvae *Necterosoma,* Ceratopogonid sp#1 and the Chironomid *Procladius.*

Table 5.1 Mean macroinvertebrate abundance, standard error and taxonomic richness by site.

Site	*Mean*	*Standard Error*	*Richness*
Aroona Dam (all sites)	428	109.6	15
Aroona Dam 2B	464	230.5	8
Aroona Dam 2C	392	75.2	14
Retention Dam (all sites)	286.7	79.7	20
Retention Dam 7A	276	67.6	12
Retention Dam 7B	297.3	164.5	14
Aroona Waters	89.8	33.4	27
LeighCreek	131.8	22	14
L5/6	52.2	13.4	13
M10 Wetlands	620.4	341.7	14
Lobe B	117.4	13.7	13
Lobe C	0.7	0.3	1

5.4.6 Lobe B Quickfill

At **Lobe B Quickfill** there was a density of 117 macroinvertebrates per sample and a richness of 13 taxa. The fauna was dominated by Ceratopogonidae sp#3 (73 per sample). The Chironomid *Procladius* and Cyclopoid sp#1 were also common.

5.4.7 M10 Wetlands

The **M10 Wetlands** had the highest density of all the sites, with a mean of 620 macroinvertebrates per sample. This site had a richness of 14 taxa. Cyclopoid sp#1, the beetle larvae *Necterosoma,* Ceratopogonid sp#3 and 7 and the Chironomid *Tanytarsus* were all common. Ceratopogonid sp#1 (498 per sample) and the Chironomid *Procladius* (87 per sample) dominated the fauna at this site.

5.4.8 Lobe C

There was a density of 0.7 and a richness of only a single taxa at this site. The only animal found was the adult form of the beetle Dytiscidae: *Necterosoma.* No larvae were found at this site, this suggests that *Necterosoma* does not complete its life-cycle at **Lobe C**. These beetles are strong fliers and are probably only temporary residents at this site.

5.4.9 Macroinvertebrate Community Structure

These results suggest a possible relationship between salinity and taxonomic richness. **Aroona Dam, Aroona Waters** and the **Retention Dam** all have higher richness than the saline sites. There is no relationship between macroinvertebrate density and salinity. A strong association can be seen between low pH, low macroinvertebrate density and low richness. The low pH of the water in **Lobe C** would prevent most aquatic macroinvertebrates from completing their life cycles.

Figure 5.1 shows the results of an MDS ordination of macroinvertebrate taxa by sample. The results show that a number of sites are distinct: **Aroona Waters, Aroona Dam** and the **Retention Dam** cluster out individually. These freshwater sites are clearly separated from the saline sites. Within the saline sites **Lobe B Quickfill** is distinct from the remainder. The salinity at **Lobe B Quickfill** is less than half that of **L5/6, Leigh Creek** and the **M10 Wetlands** which overlap in their distribution on the plot.

The classification analysis (Figure 5.2) shows a similar result. The major split occurs between sites of high and low salinity. The freshwater sites split out separately with a slight overlap between **Aroona Dam** site B and **Aroona Waters.** Among the saline sites **Lobe B Quickfill** is distinct, while **L5/6, Leigh Creek** and the **M10 Wetlands** all show substantial overlap.

The ordination and classification analyses have highlighted the same patterns in the data. The results show that there is a clear distinction between the macroinvertebrate community structure at the saline and freshwater sites. **Lobe B Quickfill** (which is half the salinity of the other saline sites) is distinct from the other saline sites. The samples taken from the remaining saline sites overlap in both analyses. There is not a clear distinction between the macroinvertebrate communities at **L5/6, M10 Wetlands** and **Leigh Creek.**

These results suggest a broad relationship between salinity and both richness of taxa and macroinvertebrate community structure. This relationship has been demonstrated in other studies (Geddes 1976, Williams *et al.* 1990). Many aquatic macroinvertebrates have physiological adaptations which only allow them to survive in a limited range of salinities (Wetzel 1975). There may be a larger number of potential colonists adapted to freshwater compared to saline water. Therefore salinity is important in determining the macroinvertebrate community structure of a water body.

As outlined in Chapter 2 there are other factors which may contribute to the differences in richness and community structure between the saline and freshwater sites. The freshwater sites are located on natural watercourses and have been established for longer than the saline sites. These factors afford the time and

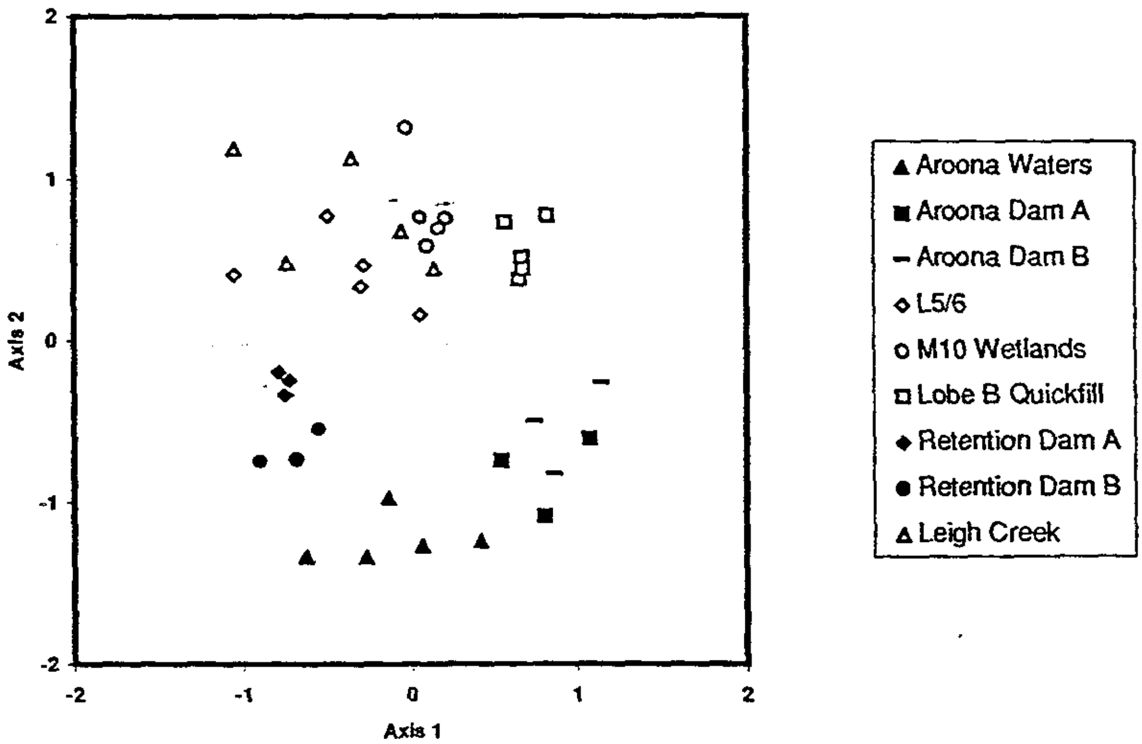


Figure 5.1 Two dimensional MDS ordination of macroinvertebrate assemblage data. Open characters are saline sites, closed characters are freshwater sites. Note the clear difference in macroinvertebrate assemblage structure between these two habitat types.

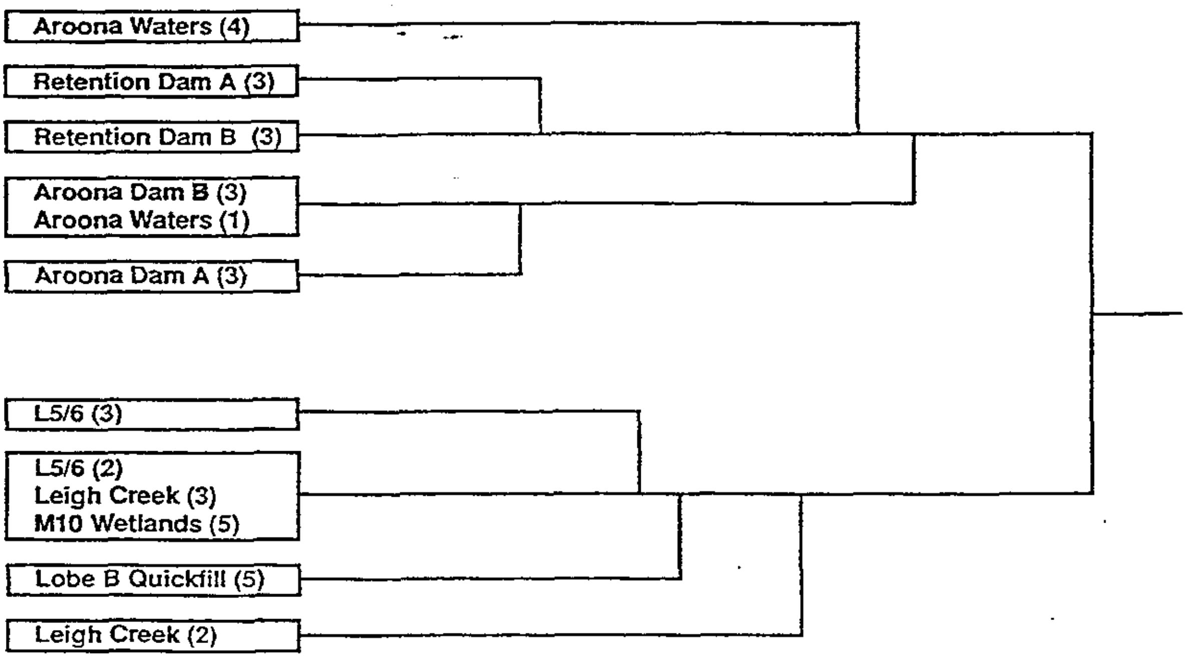


Figure 5.2 Flexible UPGMA classification of macroinvertebrate assemblage data. Note the complete separation of saline sites (bottom group) and freshwater sites (top group).

opportunity for aquatic macroinvertebrates to migrate to these sites. The sediments at the freshwater sites were heterogeneous with a large proportion of gravel, pebble and coarse organic matter such as leaf litter and woody debris. Aquatic and riparian vegetation was common at these sites. The complexity of the sediments and vegetation provide a broad range of habitats that macroinvertebrates can exploit.

With the exception of **Leigh Creek** the saline sites are not associated with natural watercourses and have been established for less than six years. This means limited time and opportunity for aquatic macroinvertebrates to migrate to these sites and establish themselves. **Leigh Creek** is a natural watercourse: this suggests that there has been adequate time and opportunity for aquatic macroinvertebrates to establish themselves at this site. Unlike the other sites **Leigh Creek** is temporary. Whenever it begins flowing after a dry period macroinvertebrates must migrate to this site, unless they have desiccation resistant stages which emerge after re-wetting. These factors suggest that macroinvertebrates have had less opportunity to migrate to and establish themselves at the saline sites.

The benthos at the saline sites was mainly soft fine sediments. Riparian and aquatic vegetation and organic debris were limited at these sites. Therefore along with limited opportunity to reach the saline sites there was a limited range of habitat for macroinvertebrates to exploit. These factors may reduce the taxonomic richness and change the community structure of saline sites when compared to the freshwater sites.

In conjunction with salinity the age of a wetland, association with natural water courses, impermanence and habitat complexity are probably important factors in determining the differences in community structure and the lower taxonomic richness of the saline sites.

5.5 Comparisons With Other Wetlands

There are four natural wetland types in the arid areas of South Australia which have some similarities with the Leigh Creek wetlands: salt lakes, acid salt lakes, freshwater upland Flinders Ranges streams and saline lowland Flinders Ranges streams. Comparisons of the macroinvertebrate fauna of these types of wetlands with the surveyed Leigh Creek sites may allow some insight into the comparative status of the Leigh Creek sites.

5.5.1 Freshwater Sites and Flinders Ranges Upland Streams

The freshwater sites, **Aroona Waters, Aroona Dam** and the **Retention Dam** can be compared with the upland streams of the Central and Northern Flinders Ranges. There are a number of differences in the fauna of these sites compared with that of Bunyeroo creek, Brachina Creek and Parachilna Creek in the Central Flinders Ranges (Wade: unpublished data).

The caddis fly (Trichoptera) fauna of the freshwater Leigh Creek sites is quite limited. Caddis flies are common in Flinders Ranges streams (especially Ecnomidae, Hydroptilidae and Hydropsychidae). These animals often prefer lotic (flowing water) habitats, while **Aroona Waters, Aroona Dam** and the **Retention Dam** are lentic (still water). Another animal which prefers lotic habitats is the filter feeding Simuliidae (blackfly) larvae. Simuliidae were also absent from the freshwater Leigh Creek sites.

The Ephemeropterans (mayflies) *Tasmanocoenis tillyardi, Baetis soror* and *Cloeon fluviatile* are also common in Flinders Ranges streams. *T. tillyardi* was present at **Aroona Waters** and *C. fluviatile* at the **Retention Dam** site 7A, but in lower densities than are usually found in Flinders Ranges streams.

The Dipteran fauna at the Leigh Creek freshwater sites is dominated by Chironomidae but the subfamily Orthocladinnae was not found. The Ceratopogonidae fauna appeared similar between the two areas whilst other dipterans were rare, which is similar to Flinders Ranges streams. Ostracods, Copepods and Oligochaetes are also common in both areas.

Odonata (dragon fly) larvae are more abundant and diverse in Flinders Ranges streams. Coleoptera (beetle) adults and larvae are diverse but generally occur in low densities in Flinders Ranges streams, and this was also the case at the freshwater sites. Hemipterans (backswimmers and waterboatmen) were rare at the Leigh Creek sites compared to Flinders Ranges streams.

These results suggest that Flinders Ranges streams have a richer benthic macroinvertebrate fauna than the freshwater sites at Leigh Creek. The absence of flowing water may exclude some taxa from these sites. Compared to the **Retention Dam** and **Aroona Dam** Flinders Ranges streams are better vegetated and afford a wider range of habitats for aquatic macroinvertebrates. **Aroona Waters** has much richer aquatic and riparian vegetation than the dam sites. This is reflected in the greater richness at these sites.

5.5.2 Leigh Creek and Flinders Ranges Lowland Streams

Leigh Creek can be compared with other lowland creeks in the Flinders Ranges area. Information on lowland saline Flinders Ranges creeks is very limited. Based on two sampling times at Willochra Creek, downstream of where the creek crosses the Quorn-Hawker road (A. Boulton: unpublished data) common taxa are Dytiscidae, Notonectidae, Chironomidae, Ostrocoda and Leptoceridae (Trichopera). **Leigh Creek** did not have Leptoceridae or Notonectidae but Cyclopoids and Ceratopogonidae were common. It is difficult to come to a strong conclusion based on this limited data set, however these two saline lowland creeks seem similar.

5.5.3 The M10 Wetlands, Lobe B Quickfill, L5/6 and Saline Lakes

The **M10 Wetlands, Lobe B Quickfill** and L5/6 can be compared with the saline lakes of the area, including Eyre Peninsula saline lakes and the larger northern salt lakes such as Lake Eyre. Extensive research has been undertaken on the zooplankton of these lakes. The results of this study are not directly comparable to the salt lake work as different habitats were sampled: the benthos in this survey and the plankton in most salt lake work.

According to Williams (1990) Anostraca (brine shrimps), Cladocera (Daphnia), Ostracoda and Coleoptera have been found in the zooplankton of Lake Eyre. Brine shrimps and Daphnia are unlikely to be found in benthic samples. Ostracoda and Copepoda were found in the Leigh Creek wetlands. In addition to the above taxa Williams (1984) found many insects (including Chironomidae, Ceratopogonidae, Tabanidae, Tipulidae and Coleoptera) in seven lakes which ranged in salinity from 4.9 - 66.5g/L on the Eyre Peninsula. Given that the benthos was sampled in this survey and the plankton by Williams (1984, 1990), the fauna of the saline Leigh Creek sites has many similarities with the fauna of Lake Eyre and the Eyre Peninsula lakes.

5.5.4 Lobe C and Acid Saline Lakes

Lobe C can be compared with permanent acidic salt lakes such as Tregalana Ponds in the northern Eyre Peninsula. Tregalana Ponds are more saline (42 - 321g/L), have a higher pH (3.2 - 7.8) and are much smaller than **Lobe C.** Hudson (1990) found numerous Notonectidae, Chironomidae, Ephyridae, Dytiscidae and Hydrophilidae in the acidic waters of Tregalana Ponds. Despite this, the establishment of many taxa in **Lobe C** appears unlikely because the pH is considerably lower than that of Tregalana Ponds.

5.6 Conclusions

There are clear differences between the macroinvertebrate community structure of the saline and fresh water wetlands at Leigh Creek and taxonomic richness is lower at saline sites. These differences are probably due to a combination of factors. Higher salinity, simple homogeneous habitat structure, short establishment time and isolation from natural watercourses ensure that saline sites have a reduced taxonomic richness. The greater taxonomic richness at freshwater sites is due to the lower salinity, more complex habitats, longer establishment time and location on natural watercourses. It is likely that these factors allow:

- greater access to freshwater sites by potentially colonising organisms;
- greater colonising success due to a wider choice of habitats within the freshwater sites; and
- a larger pool of potentially colonising organisms adapted to lower salinity.

It is also likely that these factors are the main cause of the differences in community composition between the freshwater and saline sites.

When compared with Flinders Ranges streams **Aroona Dam, Aroona Waters** and the **Retention Dam** seem to have a limited fauna, possibly due to less complex habitats and a lack of flowing water. **Leigh Creek** has similar fauna to Willochra Creek, another saline lowland Flinders Ranges stream. The **M10 Wetlands, L5/6** and **Lobe B Quickfill** support fauna which is similar to that found in Lake Eyre and salt lakes on the Eyre Peninsula. **Lobe C** has a very poor fauna, even when compared with acidic saline lakes on the Northern Eyre Peninsula.

The conclusions of faunal comparisons between Leigh Creek sites surveyed for this report and the other sites (Willochra Creek, Brachina Creek, Bunyeroo Creek, Parachilna Creek, Lake Eyre and the Eyre Peninsula salt lakes) should be treated with caution. These comparisons are qualitative and the data for the other work was collected using different sampling techniques than used for this study. Taxonomic resolution is also poor with comparisons being made at the level of order and family. In contrast, data collection for this survey was rigorous and quantitative. Certainly conclusions drawn from comparisons of sites assessed within this survey are far stronger than comparisons with outside data.

Table 5.2 Macroinvertebrate Taxa Present by Site

	Taxa	Aroona Waters	Aroona Dam site A	Aroona Dam site B	L5/6	M10 Wetlands	Lobe C	Lobe B	Retention Dam 7A	Retention Dam 7B	Leigh Creek
Phylum Platyhelminthes											
Class Tubellaria	Flatworm sp. #1	+									
Phylum Annelida											
Class Oligochaeta	Worm sp. #1	+	+	+						+	
Phylum Arthropoda											
Class Arachnida											
Order Acarina											
"Hydracarina"	Mite sp.#1	+			+					+	
	Mite sp. #2				+						
	Mite sp. #3					+					
Class Crustacea											
Order Diplostraca											
Suborder Cladocera											
	Cladoceran sp. #2	+									
	Cladoceran sp. #3								+		
Family Chydoridae	Chidorid sp. #1	+									
Subclass Copepoda											
Order Cyclopoida	Cyclopoid spp.	+	+	+	+	+		+	+	+	+
Subclass Ostracoda											
Order Podocopa	Striped Ostracod sp. #1	+									
	Green Ostracod sp. #2	+									+
	White Ostracod sp. #3	+	+								
Class Insecta											
Order Coleoptera											
Family Dytiscidae	*Eretus australis* (Adult)	+									
	Limbodessus sp. (Adult)	+	+	+		+		+			
	Antiporus sp. (Larvae)							+	+		
	Necterosoma sp. (Adult)				+	+	+				
	Necterosoma sp. (Larvae)				+	+					+
Family Hydrophilidae	*Berosus* sp. (Larvae)	+			+						
	Berosus sp. (Adult)							+			
	Hydrophilid sp. (Larvae)					+					+
Family Heteroceridae	*Heterocerus* sp. (Adult)				+						
Family Scirtidae	*Scirtidae* sp. #1 (Larvae)	+									

Table 5.2 Macroinvertebrate Taxa Present by Site (Continued)

	Taxa	Aroona Waters	Aroona Dam site A	Aroona Dam site B	L5/6	M10 Wetlands	Lobe C	Lobe B	Retention Dam 7A	Retention Dam 7B	Leigh Creek
Order Diptera											
	Unidentified Diptera sp. #1			+							
Family Ceratopogonidae											
Sub Family Ceratopogoninae	Ceratopogonidae sp. #1	+	+	+	+	+			+	+	+
	Ceratopogonidae sp. #2	+		+							
	Ceratopogonidae sp. #3	+		+	+	+		+			+
	Ceratopogonidae sp. #4			+	+						
	Ceratopogonidae sp. #5										
	Ceratopogonidae sp. #6					+					
	Ceratopogonidae sp. #7					+					
Sub Family Forcipomyiinae	Forcipomyiinae sp.	+									
Family Chironomidae											
	Unidentified Chiro sp. #1	+		+							
	Unidentified Chiro sp. #2					+					+
	Unidentified Chiro sp. #3							+			
Sub Family Chironominae											
Tribe Chironomini	*Chironomus* sp.	+	+	+	+			+			
	Cryptochironomus sp.	+									
	Harnischia sp.								+	+	
	Polypedilum sp.	+									
Tribe Tanytarsini	*Cladotanytarsus* sp.	+							+	+	+
	Tanytarsus sp.	+		+	+	+		+	+	+	+
Sub Family Tanypodinae	*Procladius* sp.		+	+	+	+		+	+	+	+
Tribe Pentaneurini	*Pentaneurini* spp.	+							+		
Family Culicidae											
Sub Family Anophelinae	*Anopheles annulipes*	+									
Family Psychodidae											
Sub Family Psychodinae	*Rotundopteryx* sp ?									+	
Family Tabanidae											
Sub Family Tabaninae	*Tabanus* sp.									+	+
Family Tipulidae											
Sub Family Limoniinae	Tipulid sp. #1							+		+	+
Family Ephydridae?	Ephydrid sp. #1					+		+			+

Table 5.2 Macroinvertebrate Taxa Present by Site (Continued)

	Taxa	Aroona Waters	Aroona Dam site A	Aroona Dam site B	L5/6	M10 Wetlands	Lobe C	Lobe B	Retention Dam 7A	Retention Dam 7B	Leigh Creek
Order Ephemeroptera											
Family Caenidae	*Tasmanocoenis tillyardi*	+								+	
Family Baetidae	*Cloeon fluviatile*								+		
Order Hemiptera											
Family Corixidae	Micronecta sp.									+	
Order Lepidoptera											
Family Pyralidae											
Sub Family Nymphulinae?	Lepidoptera sp. #1										+
Order Odonata											
Family Anisoptera	early instar spp.	+				+		+	+		
Order Trichoptera											
Family Leptoceridae?	Caddis sp. #1		+	+				+		+	
	Caddis sp. #2			+					+		

? implies some uncertainty in identification. This problem occurs when only small early instar specimens are collected.

Chapter 6 Amphibians

Craig Williams

6.1 Summary

Frogs are widespread throughout the world's freshwater environments and are only absent from the polar regions, saline environments, and areas of extreme aridity. Consequently, very few parts of Australia are without them. Specialised lifestyles and breeding habits allow frogs to inhabit Australia's deserts, alps, and temperate regions. However, their presence in such environments is contingent upon certain water characteristics being favourable. Their permeable skins and aquatic breeding habits render them sensitive to salinity, low pH, water pollution, and environmental change in general. This makes them ideal environmental monitoring organisms, as their presence is indicative of a healthy freshwater environment.

This study revealed that many of the water bodies around Leigh Creek were not suitable for frogs due to their physical nature and water chemistry. The isolation of such sites from the nearest frog populations in the Flinders Ranges may also hamper colonisation. Nonetheless, burrowing frogs, which are not dependant upon the permanent and semipermanent water bodies we studied, were found to be common on the claypans adjacent to the coalfields.

6.2 Introduction

Australia is home to a rich amphibian fauna. Although only one of the three orders are present (frogs: Order Anura) there are 208 species, 28 of which occur in South Australia. Frogs are an important part of many freshwater environments. Throughout their usually aquatic larval stage and predominantly terrestrial adult life they occupy many positions in the food web. Embryos and larvae (tadpoles) serve as prey for macroinvertebrates, fish, terrestrial animals and birds (Cohn 1994) while tadpoles are usually herbivorous aquatic grazers. Adult frogs are predators of many terrestrial and flying invertebrates while acting as prey for several larger animals including reptiles, birds, and mammals. They are often significant contributors to the biomass and biodiversity of freshwater systems (Boyer and Grue 1995). No native Australian species are known to inhabit saline environments.

Frogs are considered reliable indicators of environmental health because of their extreme sensitivity to environmental change, which may include pollution, development or climatic change (Dunson *et al.* 1992; Tyler 1983). They are the most advanced life forms to lay unprotected eggs (i.e. without a shell). Their embryonic and larval stages, which are periods of major physiological, anatomical, and histological change (Cooke 1981) are continuously exposed to the aquatic environment. This makes them vulnerable to interference with growth, leading to malformation. Similarly, adult amphibians respire through a thin skin that is permeable to many soluble substances, leaving them vulnerable to environmental contaminants of several types. It follows that the presence of a healthy amphibian population is a reflection of a healthy freshwater environment. However, their absence in a saline environment does not necessarily imply an unhealthy ecosystem.

6.3 Local amphibian fauna

The Flinders Ranges and Northern Deserts regions contain a variety of habitats that support several species. The former provides permanent and semi-permanent water bodies with an abundance of riparian vegetation, while the latter provides claypans and waterholes which become flooded by occasional heavy rains. The Leigh Creek area is at the cusp of these two regions, which is reflected in the resident frog fauna (Table 6.1).

Crinia riparia and *Limnodynastes tasmaniensis* are primarily inhabitants of the Flinders Ranges while *Neobatrachus centralis* and *Cyclorana platycephala* live only on claypans as in the Northern Deserts. *Litoria caerulea* and *L. rubella* live at semi-permanent water holes after flooding and are often found in human habitation. The latter is also known from several natural freshwater systems in the northern Flinders Ranges.

Table 6.1 Frogs of the Flinders Ranges and Northern Deserts that possibly occur or have been previously found in the Leigh Creek area.

Family Hylidae	
Litoria rubella	Desert Tree Frog
Litoria caerulea	Green Tree Frog
Cyclorana platycephala	Common Water Holding Frog
Family Myobatrachidae	
Crinia riparia	Flinders Ranges Toadlet
Limnodynastes tasmaniensis	Spotted Grass Frog
Neobatrachus centralis	Trilling Frog

6.4 Sampling methods

The frogs of this region are predominantly nocturnal, meaning the most productive searches are performed at night. To search for frogs in permanent and semi-permanent water bodies, sites were inspected briefly in daylight to allow searchers to become familiar with the terrain and identify possible frog habitats. In the case of *Limnodynastes tasmaniensis*, *Crinia riparia*, and *Litoria rubella*, these are usually at the fringes of pools and streams, amongst vegetation and other refugia such as rocks and pebbles. *L. rubella* may also be found under loose bark on trees adjacent to water bodies. During the breeding season their distinctive calling behaviour may also be used for location. They are spotted with torchlight and captured by hand, with identification *in situ*. Alternatively, frogs may be transported back to the laboratory in moist cloth bags for further examination.

The observation of burrowing frogs in arid environments is extremely opportunistic. Species such as *Neobatrachus pictus* and *Cyclorana platycephala* only emerge from their burrows (up to several feet deep) after substantial summer rains to breed in the pools that form on the surface of claypans. After breeding they may retreat back into the ground within a few weeks. Positive identification often relies on local residents photographing the frogs, or capturing and maintaining them for later identification.

The lifestyle and physical appearance of frogs in this region can vary considerably between species. This means that positive identifications can often be made by interviewing local residents about their sightings and experiences with frogs.

The study sites were sampled on three occasions. On the 7th and 8th of December 1994 **Aroona Waters**, **Retention Dam**, nearby Windy Creek, and several mine sites were searched. These sites were again searched between the 12th and 15th of June 1995, and on the 20th and 21st of August 1995.

6.5 Results

No frogs were found during the searches conducted at the specified sites on the dates mentioned. However, an opportunistic observation and video recording of frogs (by B. Odermatt, ETSA) took place after 34 mm of rain at Leigh Creek South on January 16th, 1995. Over the subsequent days a large number of frogs were seen at several claypan sites adjacent to the coalfields, where pools of water had formed at the side of roads, at the bottom of overburden mounds, and on flat areas. Many of these pools contained tadpoles (A. Mason and B. Odermatt, ETSA, personal communication). The location and breeding behaviour of these frogs was indicative of an arid zone burrowing species. Examination of the video tape revealed that the frogs were *Neobatrachus centralis* (Table 6.2). This is a species believed to be composed of several subtypes, with the frogs found at Leigh Creek referred to as "pale parotoids" by Tyler (M.J. Tyler, University of Adelaide, personal communication) in reference to the colouration of the glands on the back of the head. The sites where the frogs were seen in January were inspected in August 1995, long after they had retreated into their burrows. This revealed that *N. centralis* is widely distributed throughout the claypans adjacent to the coalfields. There was no evidence of this frog at the permanent or semi-permanent water bodies sampled, as this species only occupies a claypan environment.

The only other species believed to occur at any of the sites is *Litoria rubella* (Table 6.2), which is associated with human habitation adjacent to **Aroona Dam** and **Aroona Waters**. This was deduced from an interview with the residents. Evidence regarding the frog's appearance, behaviour, and habitation leave no doubt about its identity. This species was said to occur in "plague" proportions throughout the late spring and early winter of 1995 when it inhabited the plumbing system of the house and adjacent ablution blocks (A. Thomas personal communication). This is typical for *L. rubella*. There have also been occasional sightings of this species in other ablution blocks throughout the Leigh Creek area. It was not found to inhabit nearby natural water bodies.

Frogs are also known to occur at nearby locations. For example, when Windy Creek and Emu Creek (approximately 5 and 6 km south of Leigh Creek South respectively) contain water they are home to large numbers of frogs and tadpoles. Local residents described the adults as small and dark but their identity has not been confirmed.

Table 6.2 Frogs found in this survey

species	location
Neobatrachus centralis	widely distributed throughout claypan sites
†*Litoria rubella*	human habitation near **Aroona Dam**

† Presence deduced by personal communication, not by first hand sighting.

6.6 Discussion

When examining the eight designated study sights and the water chemistry data relating to each (Table 2.1), explanations for the absence of frogs can be formulated. As aquatic breeders, the frogs in this area are reliant upon suitable water quality, especially appropriate levels of salinity and pH. They also require a suitable physical habitat both in and out of the water. This includes aquatic vegetation and terrestrial refugia close to water bodies. The latter provides refuge and an appropriate habitat for the herbivorous grazing of tadpoles.

Several studies have been carried out to determine the maximum salinity that amphibian eggs, larvae, and adults can tolerate. In a review of literature, Ruibal (1959), stated that the maximum salinity tolerated by adult frogs of most species was 10 g/L, but often much lower, while for eggs the tolerance is usually between 4 and 6 g/L. In later studies, juvenile frogs of an African species were found to be tolerant to no more than 14 g/L (Munsey 1972), while Beebee (1985) found that 5.25 g/L was lethal to most eggs of a toad species within seven days. Dunson (1977) found that there can be a synergism between high water temperatures and salinity in causing the death of tadpoles. This may be relevant in the Leigh Creek area where the water temperature of shallow pools in summer may exceed 30°C.

In terms of the pH that amphibians will tolerate, Dunson and Connell (1982) found that eggs of an African species would not hatch at pH 3.9 and lower while Pierce (1985) provides a review of studies that indicate many species will suffer increased embryonic mortality below pH 4.

The frogs we might expect to find at the fringes of permanent and semi-permanent water bodies are also reliant upon the presence of suitable refugia (e.g. vegetation, rocks and stones) for survival against climatic conditions and predators. Aquatic vegetation is also essential for the successful breeding of such species as it provides a refuge for spawning, and the appropriate microhabitat for the herbivorous grazing of tadpoles.

6.6.1 Aroona Waters

The physical nature of this site is suitable for frogs, with an abundance of suitable refugia and aquatic vegetation. The pH and salinity of the water is within all documented tolerances for frog embryos and tadpoles.

A possible explanation for the absence of frogs at this site is the use of copper sulphate to treat blue green algae in **Aroona Dam**. Amphibian embryos and larvae are sensitive to very low concentrations of dissolved heavy metals, especially copper (Landé and Guttman 1973; Porter and Hakanson 1976; Jayaprakash and Madhyastha 1987; Williams 1993). However, there may be other factors involved.

6.6.2 Aroona Dam

Although the pH and salinity of this locality is within all documented tolerances, it lacks the appropriate aquatic vegetation and refugia at many parts of its periphery to support frogs. Other water chemistry factors may also be involved.

6.6.3 Retention Dam

The salinity and acidity of the water is within all documented amphibian tolerances. This water body lacks the appropriate aquatic vegetation to support frog breeding even although there is a great amount of suitable terrestrial refugia at the periphery.

6.6.4 Leigh Creek

The salinity of this water (16.3 g/L) makes the creek unsuitable for frog breeding and habitation.

6.6.5 L 5/6

The high salinity levels of both the main water body and the stream inflow (13.1 g/L and 8.8 g/L respectively) would prevent the breeding of amphibians. It is also likely that the physiological well-being of adult frogs in this water would be compromised.

6.6.7 M 10 Wetlands

High salinity levels (13.9 g/L) and a lack of suitable refugia make these water bodies unsuitable for frog breeding and habitation.

6.6.8 Lobe B Quickfill

A salinity of 5.9 g/L would adversely affect the survival of most frog embryos in this water. This would prevent efficient breeding activity.

6.6.9 Lobe C

The extremely acidic water (pH 2.52) and high salinity (25 g/L) would prevent frog breeding in this water body. This water would prove lethal to most frogs within hours.

6.7 Conclusions

In terms of an appropriate physical environment for frogs, only **Aroona Waters** is ideal. Other sites appear to lack suitable terrestrial refugia and aquatic vegetation, as well as having unsuitable pH and salinity. Additionally, the abundance of bird life in the region, combined with the lack of suitable habitats, may result in highly efficient predation on any frogs present.

However, the absence of *Limnodynastes tasmaniensis* and *Crinia riparia* in rehabilitated mine sites converted into ponds and wetlands may be partly due to the isolation of such sites. The nearest seeding populations of the two species in the northern Flinders Ranges would have little chance of reaching the mine sites, even during times of heavy rainfall.

The presence of *Litoria rubella* in human habitation at Aroona is understandable given the previous records of its presence in that vicinity (based on specimens held at the South Australian Museum). If the adjacent natural water bodies were suitable we would expect to find *L. rubella* there.

Although *Cyclorana platycephala* has not been recorded at the clay pans at Leigh Creek previously, it may nonetheless be present. Given the presence of *Neobatrachus centralis*, a species of similar habit, and the fact that *C. platycephala* is known from Farina (65 km to the north) it is possible that its discovery at Leigh Creek awaits.

While the presence of *Litoria caerulea* in South Australia is mostly limited to the North East deserts, particularly the Cooper Basin, there have been reports of it approximately 55 km north of Leigh Creek (Tyler 1977). It is possible that the species occurs in this region.

6.8 Comparisons with Flinders Ranges and adjacent areas

In relation to similar habitat types in the Northern Flinders Ranges, the sites we sampled at Leigh Creek have a poor frog fauna. If these sites were suitable, they may be expected to contain *Limnodynastes tasmaniensis* and/or *Crinia riparia*. We might also expect to find *Litoria rubella* in a natural environment rather than just confined to human habitation.

The presence of *Neobatrachus centralis* in large numbers in the claypans at several sights compares favourably with similar habitats in adjacent areas around the Northern Flinders Ranges.

Chapter 7 Synthesis

7.1 Biological comparison of Leigh Creek water bodies

The surveyed sites can be split into three groups based on their biological make-up. Each of these groups has distinctive water chemistry. The first distinction is between **Lobe C** and all other sites. **Lobe C** is almost devoid of multicellular life. This is undoubtedly due to the low pH of the water at **Lobe C**. The water in **Lobe C** is a potential danger to the surrounding rangeland, watercourses and groundwater. Discussions with several ETSA personnel suggest that the water level at **Lobe C** is stable. Steps should be taken to ensure that the water level does not rise and pollute surrounding areas.

The next major distinction is between the saline sites (**Leigh Creek, M10 Wetlands, L5/6, Lobe B Quickfill** and **Lobe C**) and the freshwater sites (**Aroona Dam, Aroona Waters** and the **Retention Dam**). The community structure of the macroinvertebrates, algae and the aquatic and riparian plants was consistently different between the saline and freshwater sites. Part of this difference was certainly due to salinity. The potential pool of colonising organisms will differ between saline and freshwater sites.

Other factors may have contributed to these differences. All the freshwater sites were located on natural watercourses while all but one of the saline sites were not. Many organisms are transported downstream during floods. This allows a greater potential pool of colonising organisms access to the freshwater sites. The saline sites have been established for a shorter time than the freshwater sites and this has allowed less time for the introduction and establishment of new organisms. The soft unstable sediments and steeply sloping banks may have limited the number of aquatic and riparian plants at saline sites. This flows on to other groups because plants provide food and shelter for many organisms. Plants also stabilise sediments and prevent erosion. The fine sediments at saline sites minimise the habitat variability for algae and invertebrates. The freshwater sites had sediments which varied in particle size and had more leaf litter and woody debris. This provides greater habitat complexity for invertebrates and algae.

The saline sites had a higher concentration of soluble nitrogen. This may have influenced the algal composition at these sites. Nitrogen is often a limiting resource for algae and blue-green algae (which can fix atmospheric nitrogen) were more common at low N sites.

Frogs cannot survive and reproduce in saline water so their absence from the saline sites is not surprising. Their absence from **Aroona Dam** and the **Retention Dam** might be explained by the lack of adequate vegetation and shelter but their absence from **Aroona Waters** is puzzling. Frog numbers may vary with season or rainfall events: further sampling is required to get a clearer picture of frog distribution at the freshwater sites.

7.2 A comment on salinity and water quality

It must be stressed that saline water does not automatically mean poor water quality. The salinity of water bodies in the drier areas of Australia varies naturally. Many native animals and plants are adapted to life in saline environments. Traditionally these water bodies have been judged on their value as drinking water for stock and humans. If these are the criteria then saline water is poor quality water. When judged biologically saline lakes are legitimate natural systems. Certainly it is important to prevent salinisation of freshwater systems due to human impact, but naturally saline water bodies should not be thought of as polluted environments.

7.3 Comparison of Leigh Creek sites and natural water bodies

The condition of **Lobe C** was appalling. Only one kind of invertebrate (an adult beetle) was found there. No algae or plants were found at this site. The flora and fauna here were very limited even when compared to naturally acidic saline lakes on Eyre Peninsula.

The saline coalfield water bodies **(L5/6, M10 Wetlands** and **Lobe B Quickfill)** have similar macroinvertebrate fauna, but limited riparian and aquatic plant flora when compared to natural saline lakes. This may be due to the unstable sediments, steeply sloping banks and isolation from natural watercourses. Overall these sites are in poor condition compared to natural salt lakes but rehabilitation is a viable option.

Aroona Dam and the **Retention Dam** are unique. Large permanent freshwater lakes do not occur naturally in the areas around Leigh Creek. The algal, plant and macroinvertebrate communities at these sites have some similarities to freshwater upland Flinders Ranges streams, however the diversity of flora and fauna is greater in the streams.

Biologically **Aroona Waters** is very similar to natural upland Flinders Ranges streams. It has extensive stands of riparian and aquatic vegetation. This site had the greatest taxonomic richness of plants, algae and invertebrates. The absence of frogs from this site is puzzling. The use of copper sulphate to control algae in **Aroona Dam** may exclude frogs from **Aroona Waters.**

Leigh Creek has a lower taxonomic richness of plants, algae and macroinvertebrates than **Aroona Waters.** This is not surprising because at the point of sampling **Leigh Creek** is a lowland arid zone stream. The salinity here is likely to vary from freshwater during floods to very saline as the stream dries out. This is typical of streams of this type. **Leigh Creek** is the most natural site we surveyed, closely followed by **Aroona Waters.**

7.4 Some comments on monitoring and rehabilitation

Biological and chemical monitoring of water bodies has the potential to play an important role in the future management of the Leigh Creek mine. Badly designed and / or poorly executed monitoring programs can provide results with little or no value and waste much time and money. A good monitoring program must fit the following criteria:

- Start with a clearly defined question.
- There are many variables which can be measured in biological and chemical surveys. Choose the measured variables wisely and make sure they are appropriate for the question.
- Design a sampling program to answer the question. It is essential to have adequate control sites and spatial and temporal replication of samples.
- Finish with carefully executed data collection and analysis.

Two reasons for aquatic monitoring at Leigh Creek stand out: firstly, to ensure that products of the mining process do not pollute the waterways that flow through the site, and secondly, monitoring to measure the success of wetland rehabilitation programs.

All mining activities cause disturbance to the topsoil and underlying sediments. This process could release materials that may be considered pollutants outside the mine. At Leigh Creek the most obvious pollutants are sediments eroded from overburden piles and acid water from **Lobe C**. Saline ground and surface water may also pollute freshwater streams and surrounding land. Watercourses such as **Leigh Creek** provide a likely conduit for pollutants to leave the mine site.

Chemical and biological monitoring can assess whether pollutants are leaving the mine site. If this is occurring preventative measures can be taken to minimise these problems. Monitoring of temporary arid zone streams such as **Leigh Creek** poses some unique problems. The vast majority of all material carried by these streams is transported by floods. In these situations opportunistic chemical sampling must be conducted during floods along with any regular program. Biological sampling should be carried out in the period between flooding and drying of sites, but the biological status of a wetland will change over time after a flood and this needs to be taken into account when sampling and analysing the data.

The Leigh Creek mine has a limited life. Some time in the future mining will cease, probably due to financial non viability or exhaustion of the coal body. There are a number of management options for the wetlands when the mine closes. Wetlands could be drained and filled in, retained as wetlands and rehabilitated or left as they are. For many of the wetlands on the mine site the final option is unsatisfactory.

If the coalfield wetlands are rehabilitated a number of things need to be done. Earthmoving is required to improve the topography of the areas surrounding the wetlands and plants must be introduced to minimise erosion and provide habitat. It would be wise to carry out pilot runs of these projects. Biological and chemical monitoring would be an essential part of the process to assess the success of rehabilitation.

Biologically, **Lobe C** may be beyond repair. A thorough geological and chemical assessment of this site needs to be done before any rehabilitation is considered. Ongoing containment and reduction of water levels may be the best option. The saline coalfield sites show potential for improvement. The invertebrate and algal communities show that these sites can support many organisms. Work to change the topography of these sites along with planting of appropriate riparian vegetation would certainly enhance the biological status of these water bodies.

Aroona Waters and **Leigh Creek** seem quite healthy. It is essential that steps are taken to ensure the amount of eroded sediment and other potential pollutants from the mine site cannot impact on **Leigh Creek**. To completely return these sites to their natural state the **Retention Dam** and **Aroona Dam** would have to be removed. This would reinstate the natural flow regime at these sites. Removal of these dams would also return **Leigh Creek** at the **Retention Dam** site and Aroona Creek at the **Aroona Dam** site to their natural state. Large permanent freshwater lakes are not natural in this area, however they may have conservation value for birds and possibly other organisms. These factors need to be weighed up before a decision is taken. These dams may still be required for water supply after mining has ceased at Leigh Creek. If this is the case it would be unwise to remove the dams.

To ensure that rehabilitation of wetlands has the greatest chance of success an integrated approach must be used. Rehabilitation of wetlands without considering surrounding areas that are degraded by mining will only solve part of the problem. The catchment of a wetland plays a major role in determining the physical, chemical and biological status of that wetland. Wetland rehabilitation cannot be considered in isolation; catchments must also be rehabilitated.

Glossary

Abiotic factors Non-biological factors in an organism's environment such as water chemistry, topography, geology etc.

Aerobic Organism capable of living in the presence of oxygen.

Anaerobic Organism capable of living in the absence of oxygen.

Assemblage A group of organisms associated with a particular environment.

Annual plants Plants which complete their life cycle in a year.

Benthic organisms Organisms which live on the sediment surface in a water body.

Benthos The sediment surface in a water body.

Bioavailable Nutrients available to biological organisms.

Biofilm Assemblage of algae, fungi and bacteria that grows attached to a wetted surface.

Bioindicator Organism or group of organisms that respond to particular environmental cues. They can be used as an indicator of the presence or absence of those cues.

Biomonitoring The use of organisms to monitor the condition of the environment.

Biota Living organisms.

Classification See chapter 3.3.3

Desiccation Dehydration or drying.

Detritivore Animal which feeds on dead material, usually of plant origin.

Diatom Common name for a member of the class Bacillariophyceae. These are a microscopic group of algae characterised by a thin double silica coating.

Drawdown Period The time period when the water level in a lake or river is below average.

Elutriated To wash a sample and pour off the water to separate a lighter fraction of a sample from a heavier fraction.

Ephemeral Wetland A wetland that holds water for only a short time after rain.

Exotic Weed A plant which is not native to a given area.

Filamentous Algae Algae that is formed from a chain of algal cells.

Flow Regime The pattern or history of water level and flow fluctuation for a water body.

Grazer An animal which feeds on plant material.

Herbivorous An animal which feeds exclusively on plants.

Hybrid A cross-bred animal or plant.

Hydrology The interactions of water and its environment.

Invertebrate Any animal without a backbone.

Intermittent wetland A wetland that is filled unpredictably and holds water some of the time.

Larval An immature stage in the life of an animal which is markedly different to the adult stage.

Lentic A still water environment.

Littoral The shallow areas around the edge of a wetland.

Lotic A flowing water environment.
Macroalgae Algae that can be seen with the naked eye.
Macroinvertebrate An animal without a backbone large enough to be seen with the naked eye.
Macrophyte A vascular plant, commonly applied to aquatic vascular plants.
Microbe A micro organism such as bacteria.
Microhabitat The immediate environment of an organism within a general habitat distinguished by its own set of environmental conditions.
Migration Corridor A defined route providing a passage for the movement of animals from one area to another.
Multivariate Analysis See chapter 3.3.3
Ordination See chapter 3.3.3
Perennial Plant which persists for more than one year.
Periphyton (see biofilm).
Planktonic Zone Area characterised by the presence of plankton, usually in the water column.
Photosynthesis The production of carbohydrates in green plants using energy from sunlight.
Phylum/ Phyla A primary grouping/division for classification of plants and animals.
Profundal The point in a deep water body at which photosynthesis ceases.
Propagule Any spore seed fruit or part of a plant capable of producing a new plant or a means of dispersal
Prostrate Grasses Grasses that trail on the ground or lie on a surface.
Quadrat Sample area enclosed within a boundary within which a plant or animal community is analysed.
Rangeland Land which produces plants suitable for grazing but is too dry for cultivation.
Refugia An area with a favourable microhabitat which affords protection from predators where an animal can shelter.
Rhizome A horizontal underground stem that bears roots and leaves and persists from season to season, a method of producing new plants.
Riparian Growing on or living on the banks of rivers, streams or other wetlands.
Substrata Base to which a plant or animal is fixed.
Succession The sequence of different communities of organisms occurring in an area over time.
Taxa/ Taxonomic group A unit of classification of organisms e.g. species, genus, family etc.
Topography The shape and surface features of the lands surface.
Turbidity The cloudiness of water caused by suspended particles.
Understorey Shrubs and small trees which make up the layer between the tree canopy and the ground cover.
Wetland General term for coastal or inland water body.
Zooplankton Animal plankton.

References

Beebee, T.J.C. (1985) Salt tolerances of natterjack toad (*Bufo calamita*) eggs and larvae from coastal and inland populations in Britain. *Herpetological Journal* **1**, 14-16.

Belbin, L. (1993) 'PATN Pattern Analysis Package'. (Division of Wildlife and Ecology, CSIRO: Australia)

Best, E.P.H. (1988) The phytosocialogical approach to the description and classification of aquatic macrophyte vegetation. In 'Vegetation of inland waters'. (Symoens, J.J., ed.) (Kluwer Academic Publishers: Dordrecht)

Black, J.M. (1980) 'Flora of South Australia'. Vols I-IV. (South Australian Government Printing Division: Adelaide)

Boyer, R. and Grue, C.E. (1995) The need for water quality criteria for frogs. *Environmental Health Perspectives*. **103**, 352-357.

Brock, M.A. (1981) The ecology of halophytes in the south-east of South Australia. *Hydrobiologia*, **81**, 23-32.

Cohn, J.P. (1994) Salamanders slip-sliding away or too surreptitious to count? *Bioscience* **44**, 219-223.

Cooke, A.S. (1981) Tadpoles as indicators of harmful levels of pollution in the field. *Environmental Pollution* **25**, 123-133.

Dawson, F.H. (1988) Water flow and the vegetation of running waters. In 'Vegetation of inland waters' (Symoens, J.J., ed.) (Kluwer Academic Publishers: Dordrecht)

De Deckker, P., Bauld, J. and Burne, R.V. (1982) Pillie Lake, Eyre Peninsula, South Australia: modern environment and biota, dolomite sedimentation and Holocene history. *Transactions of the Royal Society of South Australia*, **106**, 169-181.

Dunson, W.A. (1977) Tolerance to high temperature and salinity by tadpoles of the Philippine frog, *Rana cancrivora*. *Copeia* **1977**, 375-378.

Dunson, W.A. and Connell, J. (1982) Specific inhibition of hatching in amphibian embryos at low pH. *Journal of Herpetology* **16** (3), 314-316.

Dunson, W.A., Wyman, R.L. and Corbett, E.S. (1992) A symposium on amphibian declines and habitat acidification. *Journal of Herpetology* **26**, 349-342.

Frith, H.J, Braithwaite, L.W. and McKean, J.L. (1969) Waterfowl in an inland swamp in New South Wales. II. Food. *CSIRO Wildlife Research* **14**, 17-64.

Geddes, M.C. (1976) Seasonal fauna of some ephemeral saline waters in western Victoria with particular reference to *Parartemia zietziana* Sayce (Crustacea: Anostraca) *Australian Journal of Marine and Freshwater Research* **27**: 1-22.

Harden, G. (1994) 'Flora of New South Wales'. Vols I-III. (New South Wales University Press: Sydney)

Hudson, P. (1990) 'Acidic salt lakes of Northeastern Eyre Peninsula'. Unpublished Honours Thesis (Department of Zoology: University of Adelaide)

Jayaprakash, R.I. and Madhyastha, M.N. (1987) Toxicities of some heavy metals to the tadpoles of frog, *Microhyla ornata* (Dumeril and Bibron). *Toxicology Letters* **36**, 205-208.

Keddy, P.A. (1982) Shoreline vegetation in Axe Lake, Ontario, effects of exposure on zonation patterns. *Journal of Ecology* **64**, 331-344.

Klimesova, J. (1994) The effects of timing and duration of floods on growth of young plants of *Phalaris arundinacea* L. and *Urtica dioica* L.: an experimental study. *Aquatic Botany* **48**, 21-29.

Landé, S.P. and Guttman, S.I. (1973) The effects of copper sulfate on the growth and mortality rate of *Rana pipiens* tadpoles. *Herpetologica* **29**, 22-27.

Lock, M.A., Wallace, R.R. Costerton, J.W., Ventullo, R.M. and Charlton, S.E. (1984) River epilithon: Toward a structural functional model. *OIKOS* **42**, 10-22.

McCormick, P.V. and Cairns, J. Jr. (1994) Algae as indicators of environmental change. *Journal of Applied Phycology* **6**, 509-526.

McCosker, R.O., Blanch, S.J., Smith, R.G., Duggin, J.A. and Brock, M.A. (1993) Lower Gwydir Watercourse vegetation survey report, January 1993. (Report prepared for the NSW Department of Water Resources. Departments of Ecosystem Management and Botany, University of New England, Armidale, NSW)

Mueller-Bombois, D. and Ellenberg, H. (1974) 'Aims and methods of vegetation ecology'. (John Wiley and Sons: Sydney)

Munsey, L.D. (1972) Salinity tolerance of the African pipid frog, *Xenopus laevis*. *Copeia* **1972**, 584-586.

Norris, R.H. and Norris, K.R. (1995) The need for biological assessment of water quality: An Australian perspective. *Australian Journal of Ecology* **20**, 1-6

Pierce, B.A. (1985) Acid tolerance in amphibians. *Bioscience* **35**, 239-243.

Piller, L.M. (1994) ''Top-down' versus 'bottom-up': periphyton dynamics in springs in the Flinders Ranges streams in South Australia'. (Unpublished honours thesis: Department of Zoology, University of Adelaide)

Porter, K.R. and Hakanson, D.E. (1976) Toxicity of mine drainage to embryonic and larval boreal toads (Bufonidae: *Bufo boreas*). *Copeia* **1976**, 327-331.

Resh, V.H. Norris, R.H and Barbour, M.T: (1995) Design and implementation of rapid assessment approaches for water resource monitoring using benthic macroinvertebrates *Australian Journal of Ecology* **20**, 108-121

Rounick, J.S. and Winterbourne, M.J. (1983) The formation, structure and utilization of stone surface organic layers in two New Zealand streams. *Freshwater Biology* **13**, 57-72.

Rubial, R. (1959) The ecology of a brackish water population of *Rana pipiens*. *Copeia* **1959**, 315-322.

Sainty, G.R. and Jacobs, S.W.L. (1993) 'Waterplants in Australia'. (Sainty and Associates: Sydney)

Steinman, A.D. and McIntyre C.D. (1990) Recovery of lotic periphyton communities after disturbance. *Environmental Management* **14**, 589-604.

Tyler, M.J. (1977) 'Frogs of South Australia'. (South Australian Museum: Adelaide)

Tyler, M.J. (1983) Natural pollution monitors. *Australian Natural History* **21**, 31-33.

Wetzel, R.G. (1985) 'Limnology'. (W.B. Saunders Company: Philadelphia)

Wetzel, R.G. and Likens G.E. (1991) 'Limnological Analyses' 2nd edition. (Springer-Verlag: New York)

Williams, C.R. (1993) 'The effects of copper on the survivorship, growth and development of the spotted grass frog, *Limnodynastes tasmaniensis* Günther 1858'. (Unpublished Honours thesis: Department of Zoology, University of Adelaide)

Williams, W.D. (1980) 'Australian Freshwater Life' (McMillan: Melbourne)

Williams, W.D. (1983) 'Life In Inland Waters' (Blackwell Scientific Publications: Melbourne)

Williams, W.D. (1984) Chemical and biological features of salt lakes on the Eyre Peninsula, South Australia, and an explanation of regional differences in the fauna of Australian salt lakes: *Verh. Int. Ver. Limnol.* **22**, 1208-1215

Williams, W.D. (1985) Salt Lakes. In 'The Natural History of Eyre Peninsula'. (The Royal Society of South Australia: Adelaide)

Williams, W.D., Boulton, A.J. and Taaffe, R.G. (1990) Salinity as a determinant of salt lake fauna: a question of scale. *Hydrobiologia* **197**, 257-266.

24.32 Appendix FF - Environmental Impact Assessment of Discharge Water on Flora and Fauna

SA Museum (2011) *Environmental impact assessment of discharge water on Flora and Fauna of the Leigh Creek Waterways*. Leijs & Blaylock, 15 June 2011.

Report for Alinta Energy

Environmental impact assessment of discharge water on flora and fauna of the Leigh Creek Waterways.

Summary

• The Leigh Creek and Sunday Creek waterways were surveyed for flora and fauna. No suitable stygofauna sites were found. Seventy-nine species of plants and 34 species of birds were recorded. No rare or endangered species were found. To minimize the environmental impact it is recommended to discharge water into the creek with salinities below 15.000 µS/cm.

Introduction

Above average rainfall in the period November 2009 – April 2011 severely impacted the Leigh Creek Coal mine operations. Because all on-site water storage areas are full there is a need to discharge water in order to open up new areas. The intention is to pump water from a number of pits and discharge about 700 Ml of water with moderate to high salinity levels into Lobe C and discharge about 300 Ml of low salinity water into the Sunday Creek that feeds into the Leigh Creek just north of the main coalfield (Figure 1).

Objectives

The objectives of the study are to:

1. Assess and report on the ecology of the Leigh Creek waterway, as demarcated in the yellow sections on figure 1. The assessment to include flora and fauna, and in particular the stygofauna residing in the shallow sands and gravels of the creek beds.
2. To assess the likely impact of discharge water on the ecology of the Leigh Creek waterway. The impacts to be assessed in the following ranges:
   a. Low salinity, low nitrogen (<10,000 µS/cm salinity, <0.5mg/L oxidised nitrogen)
   b. Moderate salinity, moderate nitrogen (10,000-20,000 µS/cm salinity, 0.5 – 1.5mg/L nitrogen)
   c. High salinity, high nitrogen (>20,0000 µS/cm salinity, >1.5mg/L nitrogen)

Stygofauna

Stygofauna are considered species that have naturally small distribution areas. Individual species are often restricted to single aquifers and have restricted geographical distributions, in some cases smaller than 10 km^2 (Leys et al. 2003, Cooper et al. 2007, Guzik et al. 2008). Species with geographical distributions of less than 10.000 km^2 are categorized as Short Range Endemics (SRE) (Harvey 2000), because of a number of ecological and life-history traits that confines them to restricted geographical areas, such as: poor dispersal ability, in stygofauna dispersal is restricted by voids in the aquifer; confinement to discontinuous habitats; and low levels of fecundity. SRE-species and SRE ecological communities are therefore vulnerable to disturbance of their natural habitat. Stygofauna have been found in a range of aquifer types such as fractured rock, alluvial and limestone aquifers and additionally is often found in the underflow (hyporheic) of creeks and rivers.

The rationale for including stygofauna in this impact assessment is the recent discovery of a diverse stygofauna in the Flinders and Gammon Ranges area (Leys et al. 2009). Several new species of Amphipoda and Bathynellidae were found in the hyporheic of springs and pastoral wells within a 25 km radius of the coalfield. It was therefore considered possible for stygofauna to exist in the assessment area in the case suitable subterranean habitats, such as hyporheic environments in coarse sand or gravel beds or springs were present.

However, during the field inspection of the creeks on 7-8 June 2011 no suitable stygofauna habitats were found. Although the Sunday Creek consisted of coarse alluvial sediments just west of Telford, at the time of the visit the creekbed was dry. Going downstream the sediments in the Sunday Creek become gradually much finer and are unsuitable for stygofauna. The Leigh Creek was unsuitable for stygofauna because of the fine clay sediments in its bedding.

Vegetation and bird survey

An assessment of the vegetation of the target waterways was carried out on 7-8 June 2011. During this assessment a note of the bird species occurring in the area was also made.

The area comprises mostly low chenopod shrub land with some large flood-out areas along the drainage lines. Following the recent heavy rains there is a considerable amount of growth in these flood-out areas with dense stands of *Myoporum montanum* (Native Myrtle), some *Santalum lanceolatum* (Plumbush) and the occasional *Pittosporum angustifolium* (Native Apricot). Along the drainage lines there are scattered *Eucalyptus camaldulensis* (River Red Gum). Since the rains there has been a good germination of this species throughout the flood-out areas and are a now up to one metre high.

There are three sites within the area which have been previously assessed (1999, 2002 and 2003) for plants for the Vegetation Survey of South Australia. The list of plants noted is shown in Appendix 1. Only a few plants have previously been collected for the State Herbarium of South Australia from this area. During this survey a total of 22 species were collected. A summary of all plants seen or collected is shown in Appendix 1. This list is far from complete and additional species will be added.

The following introduced plants were noted in quantity in the flood-out areas – *Argemone ochroleuca ssp. ochroleuca* (Mexican Poppy), *Carrichtera annua* (Wards Weed), *Nicotiana glauca* (Native Tobacco), and along the drainage lines - *Nicotiana glauca* (Native Tobacco). There is also a number of *Tamarix sp.* (Athel Tree) in the drainage line adjacent to the spoil heap on the eastern side of the assessment area. This plant is considered an environmental weed in the pastoral areas of South Australia.

There is a considerable amount of erosion along some of the drainage lines.

A total of 34 species of birds were recorded during the two days (see Appendix 2). Nesting holes of the White-backed Swallow were noted along the banks of the drainage lines. A nest of a Nankeen Kestrel was seen in a River Red Gum. A single egg of an Emu was found suggesting that it could nest in the area.

Impact assessment

There appears to be no plants of significance within the proposed area where excess water will be discharged. It is most likely some plants along the drainage lines will be killed due to salt toxicity and/or drowning if the water levels remain high.

The level of impact on the local flora and fauna will depend on the salinity levels of the discharged water. Because there is insufficient data available on the salinity tolerance of the reported plant species we use the reported salinity tolerance of the *Eucalyptus camaldulensis* (River Red Gum) as a justification for the recommendations below. *Eucalyptus camaldulensis* is salt sensitive and trees are reported to show pour health at salinities greater than 15.000-22.000 µS/cm (Pepper & Craig 1986). The majority of *E. camaldulensis* seedlings are reported not to survive the first two years when soil salinities are between 4.000 and 11.600 µS/cm (Pepper & Craig 1986).

To minimize the impact on the health of the most significant trees along the creek it is suggested not to exceed salinity levels of 15.000 µS/cm when discharging excess water in the Sunday Creek.

Recommendations

To minimize environmental impact on the area it is recommended:

- to minimize the volume of discharge water into the Sunday Creek.
- to discharge excess water into the Sunday Creek that does not exceed salinity levels of 15.000 µS/cm.
- to divert excess water with salinity levels above 15.000 µS/cm to Lobe C.

References

Cooper SJB, Bradbury JH, Saint KM et al. (2007). Subterranean archipelago in the Australian arid zone: mitochondrial DNA phylogeography of amphipods from central Western Australia. Molecular Ecology **16**: 1533–1544.

Guzik MT, Cooper SJB, Humphreys WF et al. (2008) Phylogeography of the ancient Parabathynellidae (Crustacea: Bathynellacea) from the Yilgarn region of Western Australia. Invertebrate Systematics **22**:205–216.

Harvey, MS (2002). Short-range endemism in the Australian fauna: some examples from non-marine environments. Invertebrate Systematics **16**: 555-570.

Leys R, Watts CHS, Cooper SJB et al. (2003). Evolution of subterranean diving beetles (Coleoptera: Dytiscidae: Hydroporini, Bidessini) in the arid zone of Australia. Evolution **57**: 2819–2834.

Leys R & Mitchell JM. (2009) Newsletters of ARC-Linkage project. http://www.scieng.flinders.edu.au/current/biology/msl/StygoNewsletter2.pdf

Pepper RG & Craig GF (1986). Resistance of selected *Eucalyptus* species to soil salinity in Western Australia. Journal of Applied Ecology **23**: 977-987.

Figure1. Overview of the assessment area. The white dots show the positions of previous vegetation survey localities.

South Australian Museum

Report prepared by
Remko Leijs & Brian Blaylock, 15 June 2011.

APPENDIX 1 – Plants sited (X) / collected (XC) in Leigh Creek Coalfield, * introduced species.

SPECIES	COMMON-NAME	FAMILY	VEGETATION SURVEY S.A.	BLAYLOCK (2011)
Abutilon sp.	Lantern-bush	Malvaceae	X	
Acacia aneura var.	Mulga	Fabaceae	X	
Acacia oswaldii	Umbrella Wattle	Fabaceae	X	X
Acacia victoriae ssp.	Elegant Wattle	Fabaceae	X	X
**Acetosa vesicaria*	Wild Hops	Polygonaceae		X
Alternanthera nodiflora	Common Joyweed	Amaranthaceae		XC
**Argemone ochroleuca ssp. ochroleuca*	Mexican Poppy	Papaveraceae		X
Atriplex angulata	Fan Saltbush	Chenopodiaceae	X	
Atriplex cinerea	Grey Saltbush	Chenopodiaceae		XC
Atriplex holocarpa	Pop Saltbush	Chenopodiaceae	X	
Atriplex spongiosa	Pop Saltbush	Chenopodiaceae	X	
Atriplex vesicaria ssp.	Bladder Saltbush	Chenopodiaceae	X	X
**Carrichtera annua*	Wards Weed	Cruciferae		X
**Carthamus lanatus*	Saffron Thistle	Asteraceae		X
Casuarina pauper	Black Oak	Casuarinaceae	X	
Convolvulus remotus	Grassy Bindweed	Convolvulaceae		X
**Cucumis myriocarpa*	Paddy Melon	Cucurbitaceae		X
Cymbopogon ambiguus	Lemon-grass	Poaceae	X	X
Cynodon dactylon	Couch	Poaceae		XC
**Datura ferox*	Long-spine Thorn-apple	Solanaceae	X	
Datura leichhardtii	Native Thorn-apple	Solanaceae		XC
Enchylaena tomentosa var.	Ruby Saltbush	Chenopodiaceae	X	XC
Enneapogon avenaceus	Common Bottle-washers	Poaceae	X	
Eremophila alternifolia	Scented Emubush	Myoporaceae		XC
Eremophila duttonii	Harlequin Emubush	Myoporaceae		X
Eremophila freelingii	Rock Emubush	Myoporaceae	X	X
Eremophila longifolia	Weeping Emubush	Myoporaceae		X
Eucalyptus camaldulensis ssp. obtusa	River Red Gum	Myrtaceae	X	XC
Exocarpus aphyllus	Native Cherry	Santalaceae		XC
Frankenia serpyllifolia	Bristly Sea-heath	Frankeniaceae		XC
Gossypium sturtianum var. sturtianum	Sturt's Desert Rose		X	X
**Heliotropium europeaum*	Potato Weed	Boraginaceae		XC
Lotus cruentus	Red-flowered Trefoil	Fabaceae		X
Lycium australe	Australian Boxthorn	Solanaceae	X	
Lysiana exocarpi	Harlequin Mistletoe	Loranthaceae		XC
Maireana astrotricha	Low Bluebush	Chenopodiaceae	X	X
Maireana brevifolia	Short-leaf Bluebush	Chenopodiaceae	X	X
Maireana pyramidata	Black Bluebush	Chenopodiaceae	X	XC
**Malvastrum americanum*	Malvastrum	Malvaceae		X
Marrubium vulgare	Horehound	Lamiaceae	X	
Melaleuca glomerata	Desert Paperbark	Myrtaceae		X
Minuria cunninghamii	Bush Minuria	Asteraceae		XC
Mukia maderaspatana	Snake Vine	Cucurbitaceae		X
Myoporum montanum	Native Myrtle	Myoporaceae	X	XC
Nicotiana glauca	Native Tobacco	Solanaceae		X
Nitraria billardierei	Nitre-bush	Zygophyllaceae	X	X

SPECIES	COMMON-NAME	FAMILY	VEGETATION SURVEY S.A.	BLAYLOCK (2011)
Osteocarpum acropterum var.	Bonefruit	Chenopodiaceae	X	
**Parkinsonia aculeata*	Jerusalem Thorn	Caesalpiniaceae	X	
Pimelea microcephala	Shrubby Rice-flower	Thymelaeaceae		X
Pittosporum angustifolium	Native Apricot	Pittosporaceae	X	XC
Pterocaulon sphacelatum	Fruit-salad Plant	Asteraceae		X
Ptilotus obovatus var.	Silver Mulla Mulla	Amaranthaceae	X	X
Rhagodia spinescens	Spiny Saltbush	Chenopodiaceae	X	X
Salsola australis	Buckbush	Chenopodiaceae	X	X
Santalum acuminatum	Quandong	Santalaceae		X
Santalum lanceolatum	Plumbush	Santalaceae	X	XC
Scaevola spinsescens	Spiny Fanflower	Goodeniaceae		X
Sclerolaena diacantha	Grey Bindyi	Chenopodiaceae	X	X
Sclerolaena limbata	Pearl Bindyi	Chenopodiaceae	X	
Sclerolaena longicuspis	Spear-fruit Bindyi	Chenopodiaceae	X	X
Sclerolaena obliquicuspis	Oblique-spined Bindyi	Chenopodiaceae	X	
Sclerolaena patenticuspis	Spear-fruit Bindyi	Chenopodiaceae	X	
Sclerolaena ventricosa	Salt Bindyi	Chenopodiaceae	X	
Sclerostegia sp.	Samphire	Chenopodiaceae	X	
Senecio cunninghamii var. serratus	Bushy Groundsel	Asteraceae		XC
Senecio magnificus	Showy Groundsel	Asteraceae	X	XC
Senna artemisioides ssp. artemisioides	Silver Senna	Caesalpiniaceae		X
Senna artemisioides ssp. x coriacea	Broad-leaf Desert Senna	Caesalpiniaceae		X
Sida ammophila	Sand Sida	Malvaceae		X
**Sisymbrium irio*	London Rocket	Cruciferae		XC
Solanum ellipticum	Velvet Potato-bush	Solanaceae		X
**Solanum nigrum*	Black Nightshade	Solanaceae		XC
Solanum quadriloculatum	Wild Tomato	Solanaceae		X
**Sonchus oleraceus*	Milk Thistle	Asteraceae		XC
**Tamarix sp.*	Athel Tree	Tamaricaceae		XC
Tecticornia sp.	Samphire	Chenopodiaceae		XC
Tetragonia amplexicoma	Native Spinach	Aizoaceae		X
Zygophyllum ammophilum	Twinleaf	Zygophyllaceae		XC
Zygophyllum sp.	Twinleaf	Zygophyllaceae	X	

APPENDIX 2 – Birds recorded in Leigh Creek Coalfield (7-8 June 2011)

Casuariidae	Emu	*Dromaius novaehollandiae*
Phasianidae	Brown Quail	*Coturnix ypsilophora*
Podicipedidae	Australasian Grebe	*Tachybaptus novaehollandiae*
Columbidae	Crested Pigeon	*Ocyphaps lophotes*
Columbidae	Diamond Dove	*Geopelia cuneata*
Falconidae	Nankeen Kestrel	*Falco cenchroides*
Falconidae	Brown Falcon	*Falco berigora*
Rallidae	Black-tailed Native-hen	*Tribonyx ventralis*
Charadriidae	Black-fronted Dotterel	*Elseyornis melanops*
Cacatudiae	Galah	*Eolophus roseicapillus*
Cacatudiae	Little Corella	*Cacatua sanguinea*
Psittacidae	Australian Ringneck	*Barnardius zonarius*
Psittacidae	Mulga Parrot	*Psephotus varius*
Psittacidae	Elegant Parrot	*Neophema elegans*
Cuculidae	Horsfield's Bronze-Cuckoo	*Chalcites basalis*
Tytonidae	Eastern Barn Owl	*Tyto javanica*
Halcyonidae	Red-backed Kingfisher	*Todiramphus pyrrhopygius*
Maluridae	White-winged Fairy-wren	*Malurus leucopterus*
Meliphagidae	Singing Honeyeater	*Lichenostomus virescens*
Meliphagidae	White-plumed Honeyeater	*Lichenostomus penicillatus*
Meliphagidae	Yellow-throated Miner	*Manorina flavigula*
Meliphagidae	Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*
Pomatostomidae	White-browed Babbler	*Pomatostomus superciliosa*
Psophodidae	Chirruping Wedgebill	*Psophodes cristatus*
Campephagidae	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*
Artamidae	Black-faced Woodswallow	*Artamus cinereus*
Rhipiduridae	Willie Wagtail	*Rhipidura leucophrys*
Corvidae	Australian Raven	*Corvus coronoides*
Petroicidae	Red-capped Robin	*Petroica goodenovii*
Hirundinidae	White-backed Swallow	*Cheramoeca leucosterna*
Hirundinidae	Welcome Swallow	*Hirundo neoxena*
Hirundinidae	Tree Martin	*Petrochelidon nigricans*
Estrildidae	Zebra Finch	*Taeniopygia guttata*
Motacillidae	Australasian Pipit	*Anthus novaehollandiae*

24.33 Appendix GG - Lobe C & D Internal Memo (Lucas, 2000)

Internal Memo – Lobe C & D (D.Lucas, 2000)

FLINDERS POWER

Internal Memorandum

Date	28 February 2000
To	GMMC, MOHS&E
From	HREMLC
CC	File
Re	Lobe C&D

Flinders Power Pty Ltd
Leigh Creek Coalfield

1. PROPOSAL

1.1 This report proposes to obtain an in principle agreement for Lobes C & D from PIRSA and the EPA to:

- retain the area in it's current state, and
- gain formal registration as a disused tyre dump for the scrapped tyres in Lobe D and that the tyres be buried.

1.2 This proposal is subject to the following actions :

- assessment of stability of the existing dumps regarding fires - to be completed by the 10th March,
- Continued monitoring of effectiveness of security measures,
- continued monitoring of water run-off and the development of local on site strategies if mine contaminants are detected,
- in pit water management procedures to ensure aquifers are not contaminated, and
- assessment of the suitability of the dumps for use as a covering for the disused tyres - available by the 10th of March.

2. BACKGROUND

2.1 Mining operations commenced in Lobes C&D in the mid to late 1950's and was completed in 1978. The area consists of two open cut pits surrounded by dragline dumps and is located approximately 5km from the existing operation.

2.2 A fence with locked gates and "unauthorised entry" signs secures the area from public access. There have been no problems with unauthorised entry to this area.

2.3 Levee banks and raised haul roads, built when the mine was operational, limit water flow into the pits and also act to control flow from the area impacting on the surrounding environment.

2.4 In the mid 1980's the government at that time authorised the dumping of a large quantity of tyres into the Lobe D pit.

3. DISCUSSION

In support of this proposal an assessment of the issues related to the area has been made and strategies identified to manage these issues.

3.1 Security:

- The perimeter of the area is fenced with "No Unauthorised Entry" signs prominently displayed along the fence line.
- Access gates, located at the North West corner and South East corner of the perimeter, are secured with locks. Keys to these locks have limited access by employees and are controlled by Production Branch.
- A regular monthly inspection of the security of the area is carried out by Town & Services Branch.

3.2 Dump Stability

- The area consists of two open cut pits, with Lobe C the southern pit and Lobe D the northern pit, surrounded by dragline dumps.
- In recent history there has been little evidence of fires or heating within these dumps.
- A thermal imaging survey of the area is planned for the 2nd of March with a report available on the 10th of March. This survey will give confidence in relation to dump thermal stability.

3.3 Water Management

A report by David Lucas, Engineering Geologist-Leigh Creek identifies the following key issues in relation to water management at Lobes C&D

- Levee banks and raised haul roads, designed during the operation of the mine , limit water flow into the pits and largely control water flow from the area into the surrounding environment. Recent assessments of these levees and haul roads indicate that they are in good condition and are achieving the desired water management standards.
- Minor floods, that are contained by the levee banks, pond around the base of the dumps and support the growth of healthy vegetation which would suggest that the amount of dissolved contaminates might be low.
- Small amounts of water that flow from the dumps during major floods appear to be insignificant in comparison to the creek flows that occur at these times. Water samples taken "down stream" of the area during rain do not indicate any degree of contamination. It is proposed to maintain the water testing program that is currently in place.
- Mine waters located in the pits are below the aquifers and therefore there is no risk of these aquifers being contaminated unless pit water levels rise significantly. Storm water entry into Lobe D is currently controlled by the levee system. A channel that has the potential to divert storm water into Lobe C will be closed off by the end of March 2000.

3.4 Waste Tyres

During the mid 1980's the then State Government approved the dumping of a significant number of tyres within the southern side of Lobe D pit. These tyres are not buried and provide a potential environmental risk and in particular with regard to the risk of fires.

The location and method of dumping these tyres makes their recovery hazardous and potentially very expensive. The best option would appear to be to gain approval from the EPA to bury these tyres and register the area as a disused tyre dump.

If approval is given then an assessment needs to be made of the suitability of the dumps surrounding the area to be used as fill material. The major concern will be the potential for dump material to catch fire and the thermal image survey planned for the 2nd of March will provide information to assist with the decision. A report will be available by the 10th of March.

4. RECOMMENDATION

It is recommended that:

4.1 PIRSA be approached to approve the current status of Lobe C&D as the environmental standard for this area of the operation, and

4.2 the EPA to be asked to approve the Lobe D tyre dump as a disused waste tyre dump and that the tyres be buried.

Wayne Hooper

Human Resource & Environmental Manager
LEIGH CREEK

FLINDERS POWER

Internal Memorandum

Date	24 February 2000
To	PRMLC, HRMLC
From	David Lucas
Re	**LOBES C & D – POTENTIAL FOR WATER CONTAMINATION**

Flinders Power Pty Ltd
Leigh Creek Coalfield

Outline

The possibility of water contamination from the North Field (Lobes C and D) is a matter of environmental concern. It is understood that the environmental impact to the surrounding region is to be minimised by

1. Enabling natural creeks to flow through or around the mined area with minimal contamination due to runoff from dump surfaces;
2. Preventing the inflow of contaminated mine water into the surrounding groundwater.

This memo, with more detail in the accompanying Appendix, outlines the technical issues associated with surface water and groundwater in the area and suggests possible remedies.

Summary and Recommendations

Lobes C and D are largely surrounded by a comprehensive system of levee banks and raised haulroads, constructed during mining to keep surface water out of the pit. Most of the water runoff from outward-facing dumps, is contained within this levee system and ponds on the surface. A small amount of water is directed back into the pits.

Some of the outward-facing dumps can contribute to surface water contamination in the surrounding creeks, although the areas of the dumps are very small, relative to the sizes of the creek catchments. Of the dump slopes facing outwards around each lobe, some 45–65% of them, or a total face length of 5700m, can lead to runoff into creeks. This figure includes some Lobe D dumps whose runoff would be contained in small floods but would spill over a low haulroad in larger floods.

Containment of the runoff water would require major earthworks, probably involving haulage of material from elsewhere at great cost. Disturbance of the existing dumps is not recommended due to spontaneous combustion risk. Excavation of trenches, rather than construction of levee banks, would in some cases risk destabilisation of dumps, also leading to fire risk.

Another option is to allow some or all of the runoff to occur, and monitor water contamination at and downstream (west) of the lobes. A favoured option may be a combination of some earthworks and monitoring.

Groundwater contamination is very dependent on pit water levels. Contamination is not possible at the existing water levels, or at any foreseeable future water levels, unless water is introduced into the pits from outside. If creek flow into the pits is allowed to occur, small floods can lead to groundwater contamination.

David Lucas
Engineering Geologist – Leigh Creek

C&D

1943 – dragline ministerials
1977
→ 1996 → heritage listing
mid 1980s
1977 draglines

APPENDIX

Surface Water

Past Water Control Systems

Lobes C and D lie within the natural flow channels of creek systems. During mining of the lobes, water inflow to the pits was controlled by a comprehensive system of levee banks and raised haulroads that effectively diverted the natural flow away from the pits.

The standard of construction of this flood control system was high, and continues to operate today to keep creek flow from entering the pits. However, the focus during mining was primarily to keep water out, rather than to prevent runoff from dump surfaces from escaping to the creek system (ie. the water was already outside the pit, so it did not present a problem to mining operations).

As a result, most of the outward-facing dump faces surrounding Lobes C and D run off to the inside of the levee bank system, where water is contained. Because of the way the levee bank system was constructed, most of the contained water ponds outside the pit void but inside the levee banks (ie. it cannot escape to the surrounding creek system).

Potential Runoff from Dumps

There are some areas where water can run off the dump faces and potentially escape to the creek system. The following table gives a comparison (in plan surface area, and dump face length) of the outward facing dumps that can have an impact on the creek system.

	all outward facing dumps		dumps that drain to creeks	
	length	plan area	length	plan area
LOBE C	6675 m	0.189 km^2	2775 m	0.089 km^2
LOBE D	7050 m	0.191 km^2	2910 m	0.129 km^2

The Lobe D figures are a conservative estimate because they include runoff areas that are contained in smaller floods, but spill over a low haulroad into the creek system in larger floods.

During a flood, the creek catchment areas contribute most of the flow to the creek system. The catchment areas of the creeks are listed in the following table, along with their relative size compared to the outward-facing dumps.

Creek	catchment	size relative to dumps draining to creek
Sunday Creek and Telford Channel to Lobe C	49 km^2	430 times the size of Lobe C dumps
Leigh Creek floodplain north of Northern Dumps	22 km^2	250 times the size of Lobe C dumps
Unnamed creek east of Lobe D	38 km^2	290 times the size of Lobe D dumps

Runoff calculations show that the relative amount of runoff from the dump surfaces is insignificant compared to the runoff from the creek catchments, for large storms with uniform rainfall over a wide area. However, the runoff could be more concentrated if a smaller storm event occurred only over the dumps, but then the total runoff would also be considerably less.

The following table gives estimates of the relative amounts of runoff to be expected from various storm events. The numbers in the two right columns are the percentages of water coming from the dump faces, compared to the total creek flow.

storm event	duration	probability in 20 year mine life	Lobe C runoff from dumps	Lobe D runoff from dumps
1 in 10	2 hours	88 %	0.34 %	0.64 %
1 in 100	2 hours	18 %	0.16 %	0.30 %
1 in 1000	2 hours	2 %	0.12 %	0.22 %
1 in 10	24 hours	88 %	0.73 %	1.37%
1 in 100	24 hours	18 %	0.25 %	0.46 %
1 in 1000	24 hours	2 %	0.16 %	0.31 %

Conclusion

The amount of water flowing from the dumps appears to be insignificant compared to the creek flows, in the more major floods. Smaller floods that have left water ponding around the base of the dumps are supporting healthy native vegetation, suggesting that the amount of dissolved contaminants may be low.

The linear distance of the potential problem dumps gives an indication of the extent of major earthworks required to build levee banks and/or drainage channels. There are two concerns with this approach:

1. Excavation of channels along the toes of dumps could destabilise the dumps, leading to spontaneous combustion problems;
2. Construction of levee banks would require either the use of existing dump material, with its associated problems, or the haulage of material from Lobe B at considerable expense (the use of topsoil from near the dumps is assumed to not be an option).

The two options for control of contaminated runoff water are:

1. Construct a system of levee banks and channels to either contain water or channel it back into the pits (the latter will not always be possible because of the lay of the land, and some ponding is inevitable);
2. Allow runoff to occur and monitor contaminants near and downstream of the dumps. In view of the small amount of runoff water, this may be a preferred option.

Groundwater

General Description

Lobes C and D pits contain contaminated mine water. Lobe C contains a larger quantity of waste water that was pumped there from Lobe B many years ago.

There is the potential for contamination of the following regional groundwater aquifers:

1. The Leigh Creek channel is a gravel bed that intersects the western margin of Lobe C. If pit water levels rose to the level of the gravel bed, groundwater contamination would occur. Flow through these gravels would be rapid.
2. The bedrock in the area contains groundwater stored in rock fractures, which might be contaminated through the pit floor by the storage of mine waste water in the pit.

It is known from regional monitoring that the groundwater in the fractured bedrock is very near the surface (between 4 and 12m). Water in the pits is at a much deeper level than this, and is hydraulically unable to flow out of the pits into the bedrock. The pressure difference acts to enforce the opposite effect — water should flow into the pit from the bedrock. However it doesn't appear to do so, because of the very low permeability, and hence low flow rate, of the aquifer (although very slow seepage might be occurring that is offset by evaporation).

The controlling factor for both the bedrock and creek channel aquifers, therefore, is the pit water level. If the level is allowed to rise near the natural ground surface, flow would occur through the gravels, and seepage into the bedrock would occur as the pressure exceeded the bedrock groundwater pressure.

Pit Volumes and Potential for Filling

Storage curves have been calculated for the Lobe C and D pits which give a contained volume of water for a known water elevation. Rainfall/runoff estimates have been determined for the pit voids and the creek catchments. From these, the potential risk for pit flooding can be derived.

The following two tables are for Lobes C and D, presented separately. They give flood volumes in megalitres, and water level changes, for rainfall over the pit itself, and in the worst case scenario: assuming the entire creek catchment is channelled into the pit.

storm		probability in	rain falling on pit void		creek flow channelled into pit	
event	duration	20 yr mine life	flood volume	change of level	flood volume	change of level
1:10	2 hrs	88%	43 Ml	+ 0.19m	964 Ml	+ 4.11m
1:100	2 hrs	18%	82 Ml	+ 0.36m	2688 Ml	+ 10.27m
1:1000	2 hrs	2%	166 Ml	+ 0.73m	6408 Ml	+ 19.62m
1:10	24 hrs	88%	84 Ml	+ 0.37m	1513 Ml	+ 6.28m
1:100	24 hrs	18%	158 Ml	+ 0.70m	4370 Ml	+ 14.90m
1:1000	24 hrs	2%	274 Ml	+ 1.21m	8910 Ml	>21.32m (spills)

Lobe C Flooding Scenarios — current water level EL144.68 (21.32m below surface)

storm		probability in	rain falling on pit void		creek flow channelled into pit	
event	duration	20 yr mine life	flood volume	change of level	flood volume	change of level
1:10	2 hrs	88%	61 Ml	+ 1.09m	751 Ml	+ 8.08m
1:100	2 hrs	18%	118 Ml	+ 1.93m	2093 Ml	+ 16.16m
1:1000	2 hrs	2%	238 Ml	+ 3.61m	4989 Ml	+ 26.86m
1:10	24 hrs	88%	121 Ml	+ 1.97m	1178 Ml	+ 11.09m
1:100	24 hrs	18%	226 Ml	+ 3.53m	3403 Ml	+ 21.61m
1:1000	24 hrs	2%	392 Ml	+ 4.96m	6938 Ml	+ 31.30m

Lobe D Flooding Scenarios — current water level ~EL112 (47m below surface)

The two tables show that rain falling onto the pit void will raise the pit water level only slightly, even for very large, very rare storm events. However, if either of the creeks flowing east to west past Lobes C and D are allowed to enter the pit, large storm events can fill them to levels that could allow groundwater contamination, particularly in Lobe C. In fact, even a 1:100 storm event, allowed to flow into Lobe C, could raise the water level to between 6.4 and 11.1m beneath the surface.

It is therefore critically important that creek inflow is not allowed to occur. The following remarks can be made about the two pits.

1. Lobe C has a channel cut to divert Lobe B water, which could potentially take Sunday Creek flood water into the pit (although because it is a confined channel, restricting flow, some of the water would actually continue along to the creek channel and bypass the pit). This channel is already planned to be blocked off.

2. Lobe D is already protected by a comprehensive system of levee banks on the eastern margin, preventing inflow from the unnamed creek flowing from east to west. No further work needs to be done to protect groundwater contamination around Lobe D.

Conclusion

The main concern for groundwater contamination, in Lobe C, is to be addressed in the near future, when a channel into the pit is blocked off. The Lobe C water level is at an all-time minimum since pumping ceased, at EL 144.68, and has been as high as EL 156, 11.3m higher.

If the water level exceeds EL 156 in the future, monitoring wells may be required to sample groundwater for contaminants. Wells would be required in both the basement rock aquifer, and the creek gravels.

24.34 Appendix HH – Notification of Mining Operations September 2016

Notification of Mining Operations – Leigh Creek Coalfields – MT15 & MT21 September 2016

Government
of South Australia
Department of
State Development

Ref: MO6536.001
ID NO: 2016D009625

9 September 2016

Peter Kelly
Manager Leigh Creek Coalfields
Flinders Power
PO Box 21, Leigh Creek SA 5731

Dear Mr Kelly

RE: Notification of Mining Operations for Leigh Creek Coalfields (MT 15 and MT 21)

Thank you for submitting your notification dated September 2016, advising of your intention to place inert material over re-profiled slopes in MT 15 and MT 21 in the Main Series at the Leigh Creek Coalfields.

DSD acknowledges the placement of 1 metre of inert material on the re-profiled slopes of MT 15 and MT 21 and the QA/QC processes described for these areas only, to manage the immediate risk to worker safety in these areas.

DSD is yet to form an opinion on whether the approach applied to MT 15 and MT 21 is an acceptable rehabilitation strategy for managing the long term risks to public safety and the environment in these areas.

DSD therefore expects that the final rehabilitation strategy for MT15 and MT21 is undertaken in accordance with the requirements of the approved Development Program (currently under development).

I advise that DSD has been provided with a copy of the Safe Work SA mine record entry and supporting notices from their compliance inspection dated 16/17 August 2016.

Please contact Paul De Ionno on 08 8463 3183 or paul.deionno2@sa.gov.au should you have any further enquiries.

Yours sincerely

Greg Marshall
CHIEF INSPECTOR OF MINES

cc. Graeme Sauer, Safe Work SA

Mining Regulation
GPO Box 320 Adelaide SA 5001
Tel (+61) 08 8463 3484| Fax (+61) 08 8463 3268 | www.statedevelopment.sa.gov.au | ABN 83 524 915 929

NOTIFICATION OF MINING OPERATIONS – LEIGH CREEK COALFIELDS

SEPTEMBER 2016

Peter Kelly
Manager Leigh Creek Coalfields

Contents

Tables

Figures

Appendixes

1. Background / Scope

Flinders Power (FP) has maintained open and collaborative communications with the regulators throughout the closure planning process for the Leigh Creek Coalfields. FP are committed to continuing this approach, as it strives to achieve a vision of completing all closure obligations with zero harm and applying best practice.

A key objective of delivering the closure program in the most efficient and effective manner will see the best value outcome for all stakeholders, with risks associated with the closure of the mine identified, prioritised and mitigated to as low as reasonably practicable.

The decision to close the coalfields ahead of the operational mine plan prevented the completion of works in areas MT15 and MT21 to the plan. Consequently, some areas of high spontaneous combustion risk exist, and the design options for rehabilitation of these are operationally challenging. The rehabilitation designs for these two areas have been key to discussions with the Regulators, and independent consultants throughout the development of the Mine Closure Plan (MCP).

Site safety and hazard assessments have prompted a review of the earlier designs for these areas, with the timing of action for these two areas now immediate, while the remainder of the MCP is plan is finalised.

In the interim period between mine operations ceasing, and the rehabilitation program commencing, FP submitted a draft of the MCP April 2016, as well as notifications of changes to operations (December 2015, June 2016).

As agreed at the meeting with the Department of State Development (DSD) 4th August 2016 (and confirmed by G Marshall 9th August 2016), FP will provide a notification letter advising of the priority rehabilitation works occurring in Main Series Terrace 15 (MT15), and Terrace 21 (MT21).

These works include coverage of at risk spontaneous combustion areas with inert material as soon as reasonably practicable, as directed by Graeme Sauer, Inspector of Mines (SafeWork SA), during his site inspection 15th August (ref WHSIN 303067). Cover thickness of 1m (loose) of inert material for these areas was further authorised by DSD 25th August 2016.

This notification letter complements the most recently submitted notification letter (June 2016) that advised the primary project areas and activities are consistent with the draft MCP.

In addition to those areas and activities mentioned in the previous letter, FP can confirm that re-profiling of the MT21 design area is complete and FP are now undertaking the following priority activities:

MT21 (Domain 6, Main Series Terrace 21, spanning Mine Areas M12/13)

- Surface water controls
- Inert material coverage
- Compaction by dozing

MT15 (Domain 6, Main Series Terrace 15, spanning Mine Areas M10/11)

- Re-profiling of existing surfaces
- Surface water controls
- Inert material coverage
- Compaction by dozing

2. Safe operations

FP has and will continue to maintain the mine in a safe condition, under the existing Leigh Creek Coalfields Safety Management System, and in compliance with Statutory Obligations.

FP operates principally under the terms of the Work Health and Safety Act (2012), Mines and Works Inspection Act (1920), the Perpetual Leases and EPA Licence 13009, as well as those provisions of the Mining Act (1971) from which it is not otherwise exempt.

Following the review of the site JHA's and Risk assessment, the plans for the rehabilitation works in both MT15 and MT21 have had to be changed. Effectively, particularly in MT15, the presence of very hot areas and a higher water level at base than expected has made the original plans untenable in terms of safety management. As such the design of both pits has been altered to minimise risks to operational personnel.

3. Timeline

The rehabilitation and monitoring schedule is provided as Appendix A, detailing the current timing for the key activities of

- Operations
- Inspection Test Plan
- Monitoring
- Mine Closure Plan Development and Submission

FP are delivering to schedule for the re-profiling works in MT21 (complete) and MT15 (nearing completion), and will now commence inert material coverage in MT21 mid-September, followed by MT15 in October.

The rehabilitation works in these two areas are controlled by the Inspection Test Plan (Section 7, below), and the relevant monitoring components of the schedule.

Learnings from the monitoring and field trials undertaken during the rehabilitation program will be incorporated into remaining rehabilitation activities and designs.

4. Risk

Due to the location, topography, isolation from surface and ground water, assessed characteristics of cover materials and experience incorporated into the rehabilitation designs, proceeding with the rehabilitation works as designed for areas MT15 and MT21 is recognised as low risk to offsite receptors.

Covering areas with inert material to prevent oxygen ingress is an established and proven method for controlling spontaneous combustion (and a fundamental tenet of the MCP). Once areas have been re-profiled, it is essential that cover is applied as early as possible to control and prevent further spontaneous combustion via oxygen ingress or damage by surface water runoff. This approach has been confirmed by the Inspector of Mines (Section 1, above), and endorsed by MWH.

The design cover thickness of 1m (loose, ie prior to compaction by dozing) offers advantages of reducing the time to apply (and thus limits the exposure of operators to this environment to no longer than necessary), and also allows monitoring to commence immediately to assess effectiveness. This assessment will provide information fundamental to the continuous improvement approach of the mine rehabilitation works.

Consistent with the draft Mine Closure Plan, thermal monitoring will be a key component in identifying areas at risk of spontaneous combustion, that could need additional inert material cover applied, up to 3m total (loose, ie prior to compaction by dozing, and as detailed in Section 8 below).

Material characteristics in conjunction with surface water controls, on-going thermal monitoring, site experience managing spontaneous combustion and technical expert recommendations (CB3 Mining, MWH) support the design coverage thickness.

The terminal sink nature of the in pit voids of areas MT15 and MT21, as detailed in the *Leigh Creek Coal Mine Closure – Groundwater Aspects* report (MWH, 2016) eliminates concerns regarding any receptor exposure to potential acid forming (PAF) materials that could present in the cover materials (available sample characterisation has been incorporated into the selection of planned cover material).

As the risk of impact to surrounding receptors in pit is low, FP can proceed confidently using existing material characterisation in conjunction with field testing (see Sections 6 and 7 below).

The original schedule contemplated stockpiling all inert coverage materials in-pit, before commencing spreading any of the stockpiled materials in March 2017. Due to the risk of increased spontaneous combustion resulting from leaving an area uncovered following re-profiling, the schedule has since been revised to bring forward the spreading of inert cover material on areas MT15 and MT21 to commence in September 2016 (as per Section 3 above).

Recent experience following re-profiling provides additional confidence that a reduction in batter angle and compaction by dozer significantly decreases the incidence of spontaneous combustion on waste rock dump slopes.

Risk Assessments for the mine closure were developed in conjunction with DSD (as included in the draft MCP). These assessments identified key risks relating to the mine closure for each domain, and included the Inherent Risk Rating, Proposed Mitigating Actions, and Residual Risk Rating.

The following table summarises some of the relevant risks for the rehabilitation works in MT15 and MT21, and their Inherent Risk Ratings from the Risk Assessments for Domain 6, and the site Job Hazard Analysis.

Category	Risk Ranking	Assessment	Comments
Public safety	High	MCP- D6 PS01	Completing works reduces the risks in these areas, and brings forward construction of the abandonment bund
Operational safety	High	JHA – PROD 070 JHA – PROD 071	Operating in a high risk area due to heat, and in pit adjacent to water
Surface water	Medium	MCP – D6 SW01	Surface water runoff from perimeter dump faces with suspended solids impacting on downstream receptors unlikely in these areas due to inward draining terminal sink
Surface water - AMD	Low	MCP – D6 SW02	Acidic surface water runoff from perimeter dump faces impacting on downstream receptors unlikely in these areas due to inward draining terminal sink
Groundwater	Low	MCP – D6 GW01	Pit water seeping to ground water in these areas due to contained basin and terminal sink not possible

Table 1 - Summary of relevant inherent risks for rehabilitation works in MT15 and MT21

5. Designs

Detailed designs for the re-profiling, inert coverage and surface water rehabilitation works in areas MT15 and MT21 are provided as Appendix B, summarised in Table 2 below, and according to the following principles:

- Batters will be constructed, within acceptable safety standard requirements, to a 1:3 re-profiled grade
- High risk spontaneous combustion areas will be rehabilitated (as per Section 8) where practicable
- Material will be re-profiled to contact point with base water level only.

Surface water control is integral to spontaneous combustion management for closure, and accordingly comprehensive designs for surface water control have been developed (incorporating site knowledge of flow paths) to mitigate the risk of erosion of applied cover material in pit.

The surface water control plans (Appendix B) have been developed using as a base the following design parameters:

- Limit inflow from natural surface ground level inpit, through the use of bunding and cut – off drainage systems
- Limit of inflow to re-profiled areas from adjacent mined out / internal dump areas through a system of bunding, cut-off drains and large settling pond arrangements
- All inflows that reach the re-profiled areas are directed to the base water level through a series of cut-off drains, bunds and lined overflow channels.

	MT15			MT21
Design name	D6_M11_20	D6_M11_21	D6_M11_22	D6_M13_3
Design re-profiled grade	1:3 above EL104 Natural repose below EL104	1:3	1:3	1:3
Constructed re-profiled grade	TBA	TBA	TBA	1:3
Doze / cut volume (lcm)	410,328	49,000	208,728	587,685
Inert material true thickness (m, loose)	1	1	1	1
Surface area m^2	113,710	54,092	82,316	144,400
Inert material volume (lcm)	113,710	54,092	82,316	144,400

Table 2 - MT15 and MT21 designs summary

6. Cover Material properties and inventories

The inert material to be used as cover for the MT15 and MT21 designs will be sourced from the surface waste dumps located along the Main Series low wall, as displayed in the Soil Movement plot (Appendix C).

The material will be sourced from the stockpiles designated D6_M10_1_Insk and D6_M11_1_Insk.

The combined volume of these stockpiles is 3.5 million LCM. The required volume for all of Domain 6 in-pit inert cover designs, including MT15 and MT21, is 1.0 million LCM, allowing flexibility in selection of materials, as may be required from the results of the on-site field testing program.

Inert material dumps have been selected for use as cover material on the basis of the soils and waste material characterisation completed by MWH early in 2016 and site's operational understanding of dump material.

The Inert Material plot, presented in Appendix C, utilises the material characteristics from the laboratory testing of chemical and physical properties of the samples collected as part of the *Leigh Creek Coalfield - Soil and Mine Waste Characterisation* (MWH, 2016), to illustrate sample locations and preferred stockpiles. It can be seen from this plot that:

- the stockpiles planned for the coverage in areas MT15 and MT21 (D6_M10_1_Insk and D6_M11_1_Insk) are suitable for this purpose (ie preferred stockpiles)
- the following samples relate to materials sourced from these stockpiles
    - samples LC044, 044 from D6_M11_1_Insk
    - samples LC017, 018, 019, and LC052 from D6_M10_1_Insk.

The Soil Movement plot (presented in Appendix C) provides an inventory of material available as inert cover, identifies stockpile locations, volumes, and destinations when used as inert material coverage.

The material to be used as cover for areas MT15 and MT21 is shaded a solid pink, with destinations identified using hashed fill of the same colour, with the volumes listed below :

	Volume (lcm)
Stockpile D6_M11_Insk	1,419,393
Stockpile D6_M10_Insk	2,016,724
Inert cover design MT15 (D6_M11_20)	113,710
Inert cover design MT15 (D6_M11_21)	54,092
Inert cover design MT15 (D6_M11_22)	82,316
Inert cover design MT21 (D6_M13_3)	144,400

Table 3 - Inert material stockpile and cover design volumes

Despite the absence of any risk to receptors due to AMD (Section 4, above), soil erosion characteristics have also been considered to ensure that appropriate materials are used as cover to control spontaneous combustion for closure.

Existing material characterisation work shows:

- None of the materials characterised by the Emerson Aggregate test as either partially dispersive (4 samples with Emerson Class ranking of 2), or highly dispersive (1 sample with EC ranking of 1) will be used for this coverage
- Samples (6 of) from the two stockpiles (D6_M11_1Insk, D6_M10_1Insk) to be used as coverage in MT21 and MT15 areas were classed as either EC 4 or 6.
- Relatively high clay contents (26% and 35%) were determined for samples from the two stockpiles to be used as cover in the areas, indicating good suitability as cover material for spontaneous combustion control.

7. QA/QC

FP will utilise a quality system approach to ensure the rehabilitation works are to the design specifications and standard. This includes the following key components of the rehabilitation works:

- An Inspection Test Plan (ITP) process for authorising rehabilitation designs, and activities, with stage gates dependent upon verification of individual activities prior to progressing to the next stage. These will be done by mine area, an example of which is the ITP for Domain 6, Area 13 (that encompasses MT21), presented as Appendix D.
- An example of one of the ITP steps, End of Design Survey, is provided for the re-profiling of the low wall in MT21 (see design D6_M13_3_S1_R, Appendix B). Nine cross sections were surveyed to determine the mean final re-profiled grade of 1:3.1 was achieved against the design grade of 1:3.0.
- Logging inert material sources and destinations, and confirmation that correct material is placed in design locations.
- Material characteristics will be further defined by on site field testing program (as defined in Section 8, below).
- Learnings from monitoring and field trials will be incorporated into rehabilitation designs and activities.

8. Inert Material – Cover Process

The on-site field test process for progressive inert material characterisation in MT15 & MT21 is captured in the flow chart *MT15 & MT 21 Inert Material Coverage*, provided as Appendix E.

Cover material stockpiles will be divided into nominal 20,000 loose cubic metre blocks for onsite field testing. At the forecast rate of application of cover material, this represents approximately 2 days of cover material. The 20,000LCM blocks will be surveyed, and clearly signposted.

The blocks will be initially site tested at a rate of one test per 10,000LCM as a minimum.

One in ten initial samples will be sent for laboratory correlation with the on-site field analysis, as well as to build a greater depth of information. Material that does not meet specification will not be scheduled for use, and reviewed as required.

During excavation and loading the material will be constantly visually reviewed by the trained excavator operator and supervisor. The on-site training program will ensure that relevant personnel can visually recognise a significant change in material characteristics, and take appropriate action, such as exclusion of that block, or additional testing.

Midway through the operational shift an additional confirmation field test will be carried out.

Prior to coverage with inert material, an as constructed survey will be completed, as well as a heat monitoring survey.

The inert cover material's travel to its final destination will be via a mid-haulage dump, to manage safety concerns related to downhill haulage.

Inert material will be dumped from a higher elevation mid journey during one crew roster (7days) and loaded from the lower elevation for placement during the following crew roster (7 days).

The mid haulage dump will contain 70-100,000LCM of cover material at the end of roster, and will be validated by the 7 days of in field testing conducted during construction of the dump.

The inert material cover areas will be divided into practicable zones. The material will be laid down at a volume of 1 LCM per m^2, and compacted by dozer to give a minimum 700mm true thickness of cover. The material's final coverage location will be logged as part of the QC process (as per Section 7, above).

It is planned to complete the inert coverage material laying by dozing along the contours of this material, where after completed safety assessments this is deemed practicable.

An as constructed survey will be completed, and a 3 month monitoring review commenced. This will consist of surface heat monitoring and visual inspections of batters and surface water landforms.

Field sampling and analysis protocol

Under the technical direction of MWH, a field sampling and analysis protocol has been developed. Initial field sampling results will be correlated to laboratory testing by sending 10% off site for further laboratory characterisation, with the information gained incorporated into the site based testing procedure.

The onsite testing procedure is detailed in the MWH Technical Memorandum LCRK-SS 16001, Appendix F. This will be formalised in an onsite Standard Work Instruction and included in the MCP.

The onsite testing procedure is made up of six key elements:

- Initial testing of inert stockpile blocks
- Scheduled mid-block testing
- Testing in response to a noticeable change in material mid-block
- Training of onsite staff in the testing procedure
- Training of key operators in material recognition
- Cover material source and destination tracking

Initial testing of inert material

Initial field testing will be performed at a rate of one test per 10,000LCM. Initial testing will be as per LCC-REHAB-SWI-001, approximately 10 days in advance of material being required, providing some operational flexibility. Initial field test results will be correlated by sending one in ten off for laboratory confirmation with information gained incorporated into the testing procedure.

Mid-block testing

Halfway through the shift (nominally when operational crews break for lunch) additional field sampling will be carried out to confirm the ongoing suitability of the material. This, in combination with initial field testing, will mean testing is conducted at an average of each 5,000LCM.

Noticeable change testing

Should the trained excavator operator loading inert material from the designated stockpile notice any significant change in the composition of the block, they are instructed to stop work. The operator will then move to another already pre sampled block to continue loading, and would call up to have additional testing performed on the first block to confirm the on-going suitability or otherwise.

Test procedure training

All personnel required to perform onsite testing will be required to have completed the onsite training program, and be assessed by a suitably qualified person as competent.

Material recognition training

Excavator operators loading inert material from the pre sampled stockpiles will be required to have completed Material Recognition training, and be assessed by a suitably qualified person as competent. This training package will be based on colouration and physical consistency recognition of cover material.

Material source and destination tracking

The source and field sampling results of the inert material in the mid haulage dump will be recorded and its coverage area tracked as part of the Quality control process.

A risk matrix will be used to assess if the initial coverage has met requirements. The Spontaneous Combustion Risk Analysis Matrix is presented as *Figure 1*, and explained below.

A determination of additional inert material cover and/or further monitoring requirements will be made progressively based on the risk rating.

Spontaneous combustion risk analysis matrix

This quantitative risk analysis matrix will be utilised to assess if the initial 1 metre cover material applied at MT15 and MT21 has met requirements.

An overall risk score is developed by addition of the risk values from the following inputs:

- Surface temperature monitoring
- Visible smoke
- Presence of loose material
- The height of slope at angle of repose
- Presence of water

Spontaneous Combustion Risk Analysis Matrix

Risk Value	Temperature (IR monitoring)	Visible Smoke	Presence of loose material	Height of steep slope (angle of repose)	Presence of water
1	Ambient Temperature	No history of smoke sightings	Material is compacted	<3m	No water
2	<50°C	Rare (few times per year)	Minimal (<5%)	>3m & <20m	Small patches of wetness
3	>50°C & <80°C	Often (at least once per month)	Some (>5% & <50%)	>20m & <40m	Wet
4	>80°C	Always Smoking (at least once per week)	Majority (>50%)	>40m	Ponding, or in pit lake

Low 11	Medium 15	High 18	High 20
Low 7	Medium 12	Medium 16	High 19
Very Low 4	Low 8	Medium 13	Medium 17
Very Low 2	Very Low 5	Low 9	Medium 14
Very Low 1	Very Low 3	Very Low 6	Low 10

Figure 1 - Spontaneous Combustion Risk Matrix

A risk rating of Very Low, Low, Medium or High will be the output. This risk rating will drive the decision on the need for additional cover progressively.

A Spontaneous Combustion Risk Rating of Very Low or Low will result in no further profiling of the area or cover with inert material, however the area will continue to be monitored as part of the 3 monthly thermal imaging surveys.

A Spontaneous Combustion Risk Rating of Medium or High will indicate the need to rehabilitate an area for spontaneous combustion for closure, including possible re-profiling and sealing with 1m of inert material.

The effectiveness of the rehabilitation will be assessed using the spontaneous combustion risk matrix, and an additional 1m of cover applied for areas that remain as High risk. The effectiveness of the additional cover in controlling spontaneous combustion for closure will be assessed and, if required, another 1m of cover applied. Accordingly, up to 3m (loose) of inert cover could be applied to High risk spontaneous combustion areas.

The Leigh Creek Coalfields Safety Management System will apply to spontaneous combustion rehabilitation works, and any safety risk assessment (for activities such as dumping into water) will override the recommended actions from the spontaneous combustion risk assessment.

9. Monitoring

The effectiveness of spontaneous combustion control will be assessed using the Spontaneous Combustion Risk Analysis Matrix (above), with monitoring undertaken at a minimum frequency of three monthly, as per the *MT15 and MT21 Inert Material Coverage Flowchart* (Appendix E).

The effectiveness of surface water control measures and retention of cover material will be assessed by inspections undertaken at a minimum frequency of three monthly, as per the *MT15 and MT21 Inert Material Coverage Flowchart*.

10. Reporting and Notification Processes

As detailed in the draft MCP, a monthly progress report will be prepared for FP internal purposes.

Quarterly progress reports will be prepared and submitted to the DSD, EPA and SafeWork SA.

The Change Notification Process, adopted from the Minerals Regulatory Guidelines MG2b (as presented in the draft MCP), will be used to notify DSD of significant changes in mine closure and rehabilitation activities, including those in areas MT21 and MT15.

The following steps will apply for Closure Plan variations and the notification of significant changes in mine closure and rehabilitation activities (operations):

1. A self-assessment process is undertaken by FP; incorporating:
    - a description of the proposed change; and
    - a risk assessment of relevant social or environmental impacts and those criteria associated with the proposed change to demonstrate that control strategies are adequate and residual risks (& liability) are acceptable

2. A Change Notification letter from FP providing sufficient information and details of the proposed change to operations is required to be submitted to DSD – email and PDF letter

3. DSD confirmation in writing as to whether the Change Notification is sufficient and within the scope of the current Approved Development Program (ADP) or that an ADP review is required – email and PDF letter.

The following variation categories and levels of significance will be utilised:

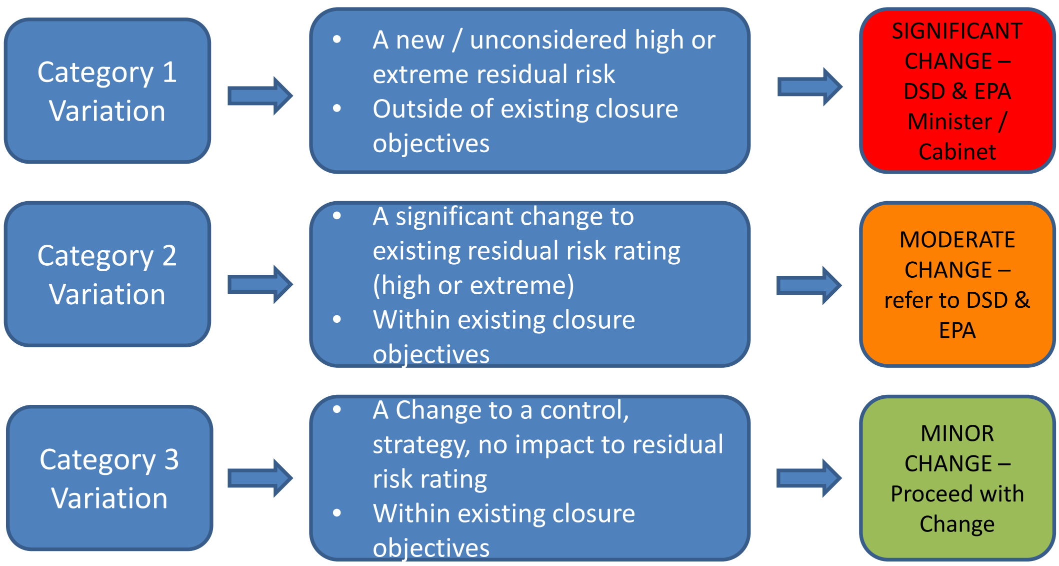


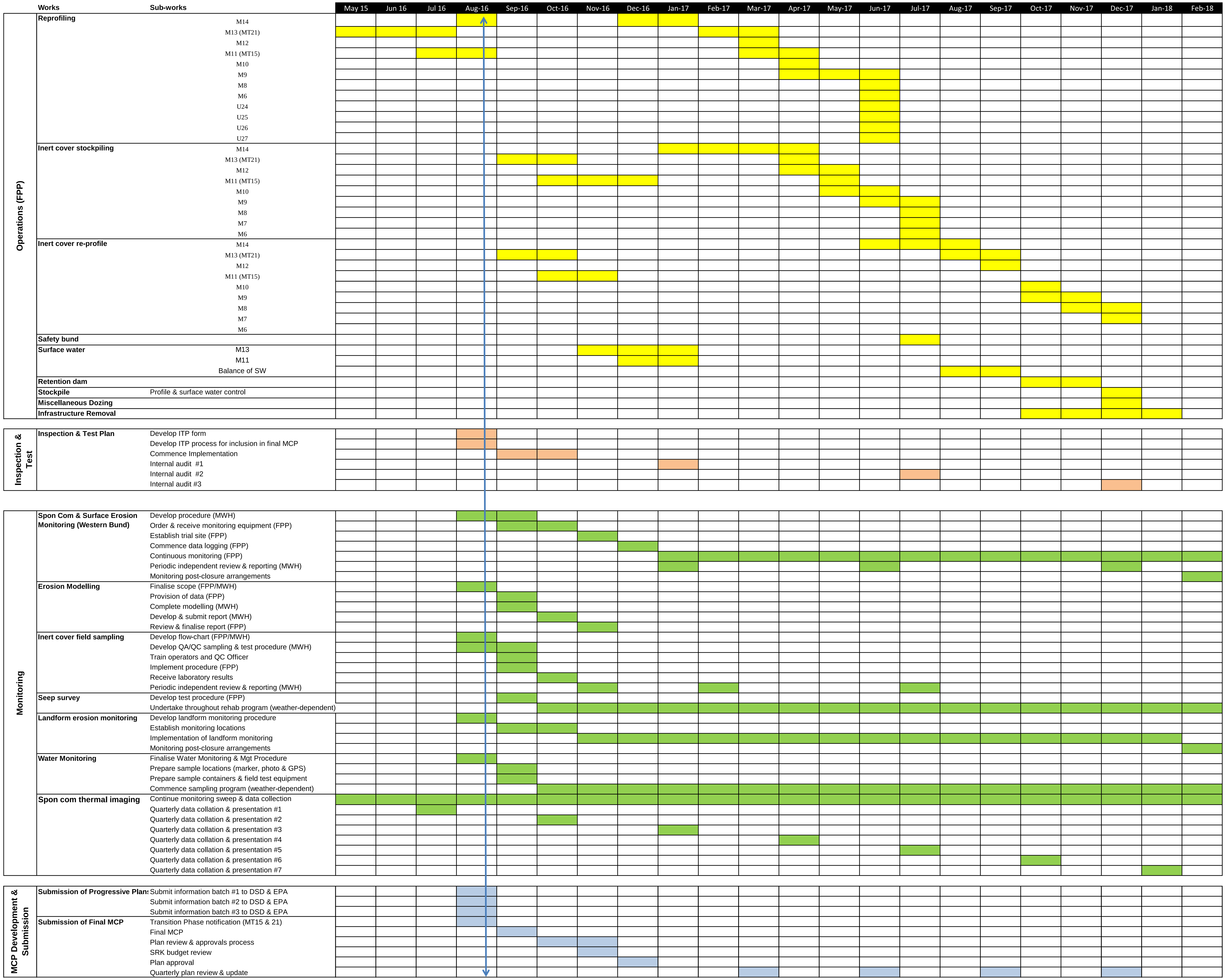
Figure 2 - Variation categories and levels of significance

Appendix A - Leigh Creek Mine Rehabilitation and Monitoring Schedule

Leigh Creek Mine - Rehabilitation & Monitoring Schedule

Last Updated:- 24/08/2016

NOTE: This schedule is based on the holistic mine plan and will be reviewed and updated on a monthly basis.



Appendix B - Rehabilitation Designs – MT15 and MT 21

D6_M11_20

D6_M11_21

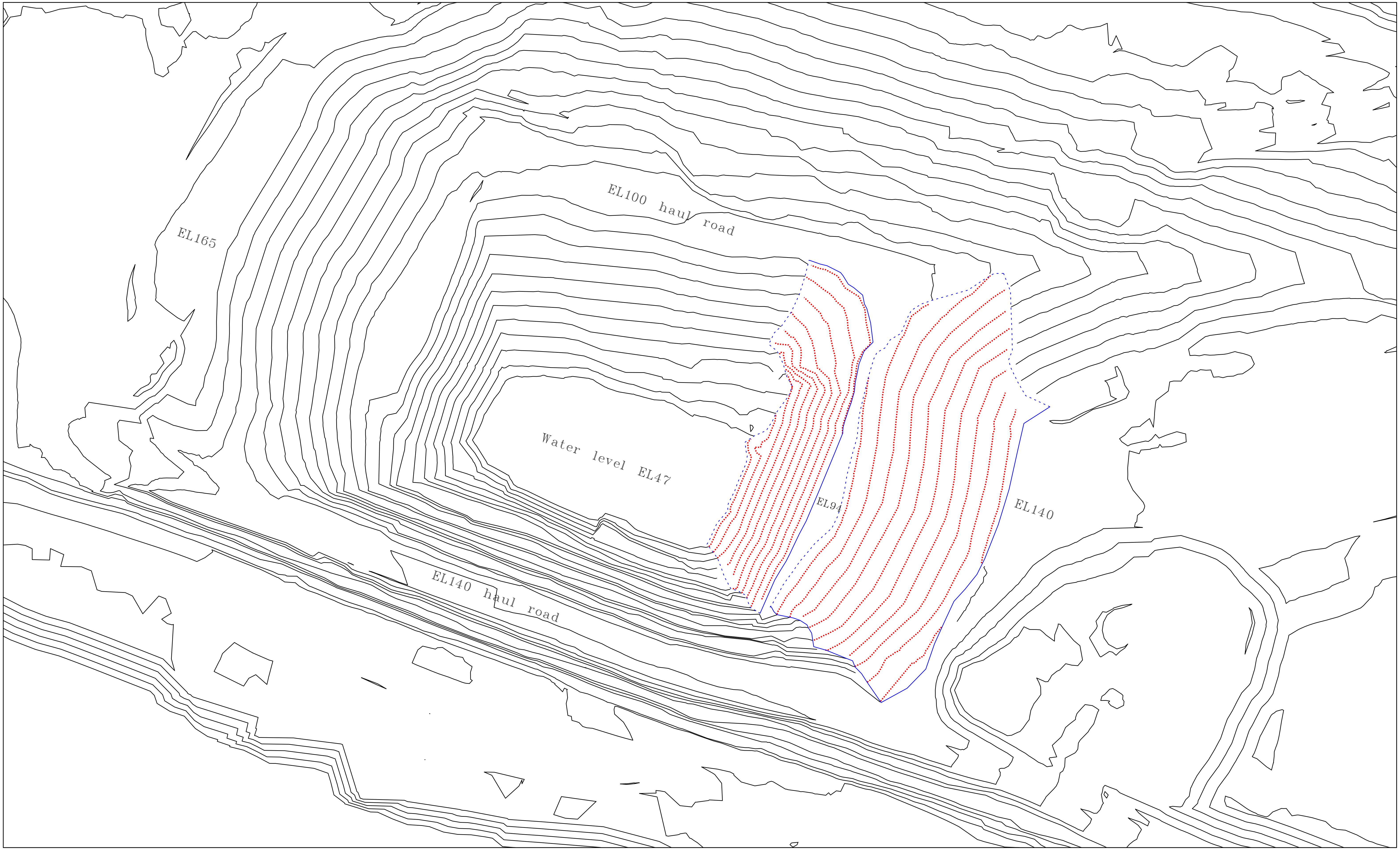
D6_M11_22

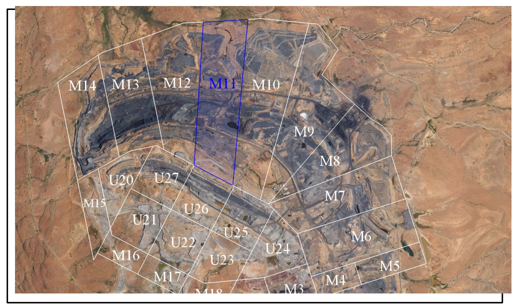
D6_M13_3_V2

D6_M13_3_S1_R

D6_M11/M10_SW

D6_M13/M14_SW





Name: D6_M11_22_V2
Activity: Re-profile
Grade: 1:3
Doze cut volume: 208,728 LCM
Inert material true thickness: 1m (Loose)
Surface area: 82,316 m2
Inert material volume : 82,316 LCM

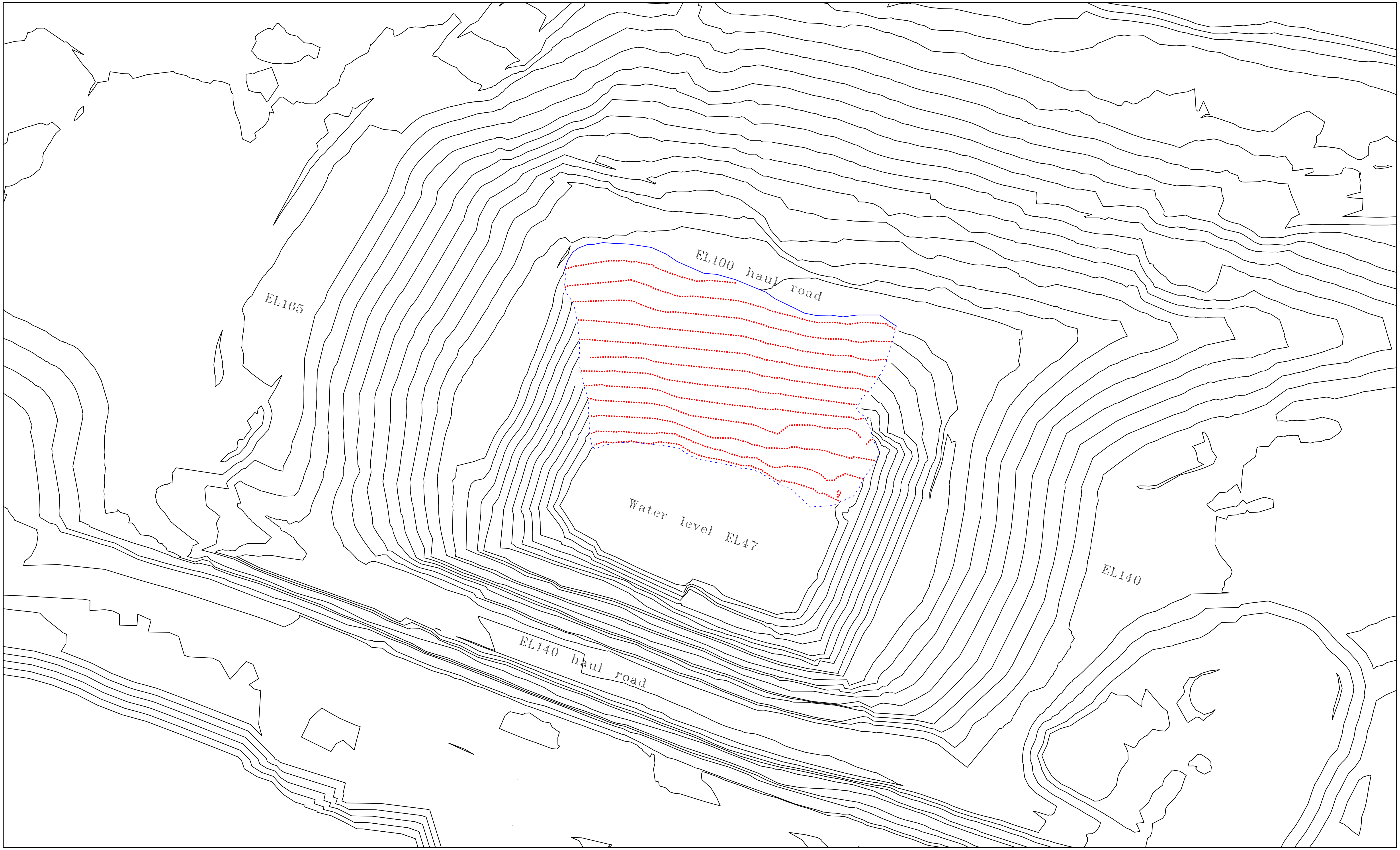
Re-profiled doze crest
Re-profiled doze toe
Re-profiled contour

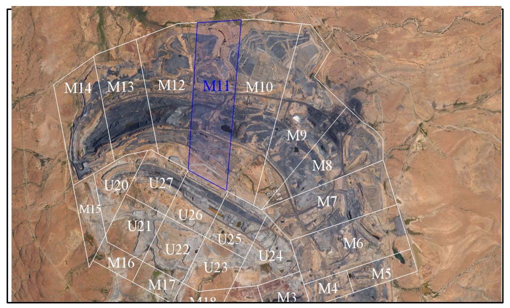
100 0 50 100 150 200 250
Metres

N

CLD Mining Pty Ltd

Design Name: D6_M11_22_V2
Drawn By: CF
Check By: PK
Draw Date: 1/9/16
Topography: Dec 15
Risk Rating: High





Name: D6_M11_21_V2
Activity: Re-profile
Grade: 1:3
Doze cut volume: 49,000 LCM
Inert material true thickness: 1m (Loose)
Surface area: 54,092 m2
Inert material volume : 54,092 LCM

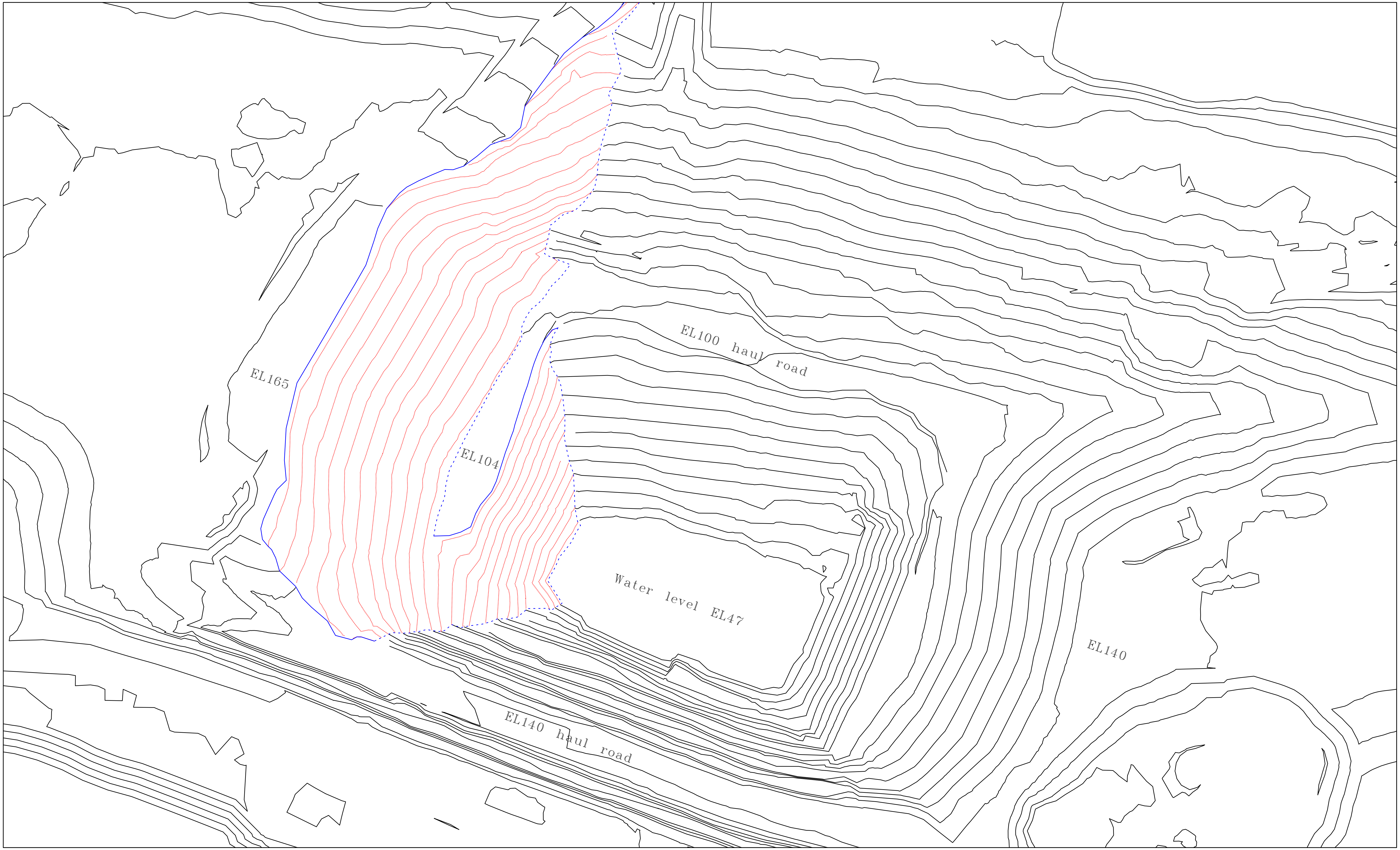
Re-profiled doze crest
Re-profiled doze toe
Re-profiled contour

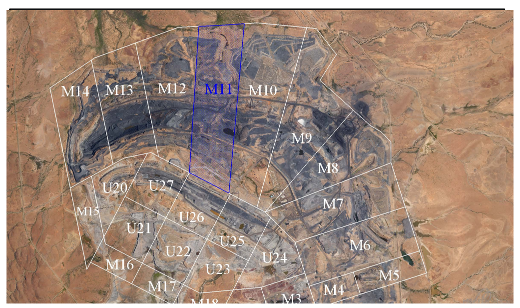
100 0 50 100 150 200 250
Metres

N

CLD Mining Pty Ltd

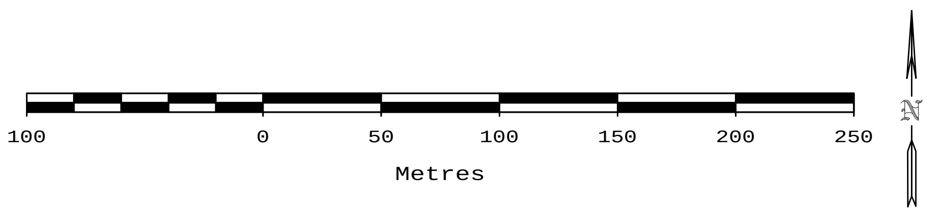
Design Name: D6_M11_21_V2
Drawn By: CF
Check By: PK
Draw Date: 1/9/16
Topography: Dec 15
Risk Rating: High





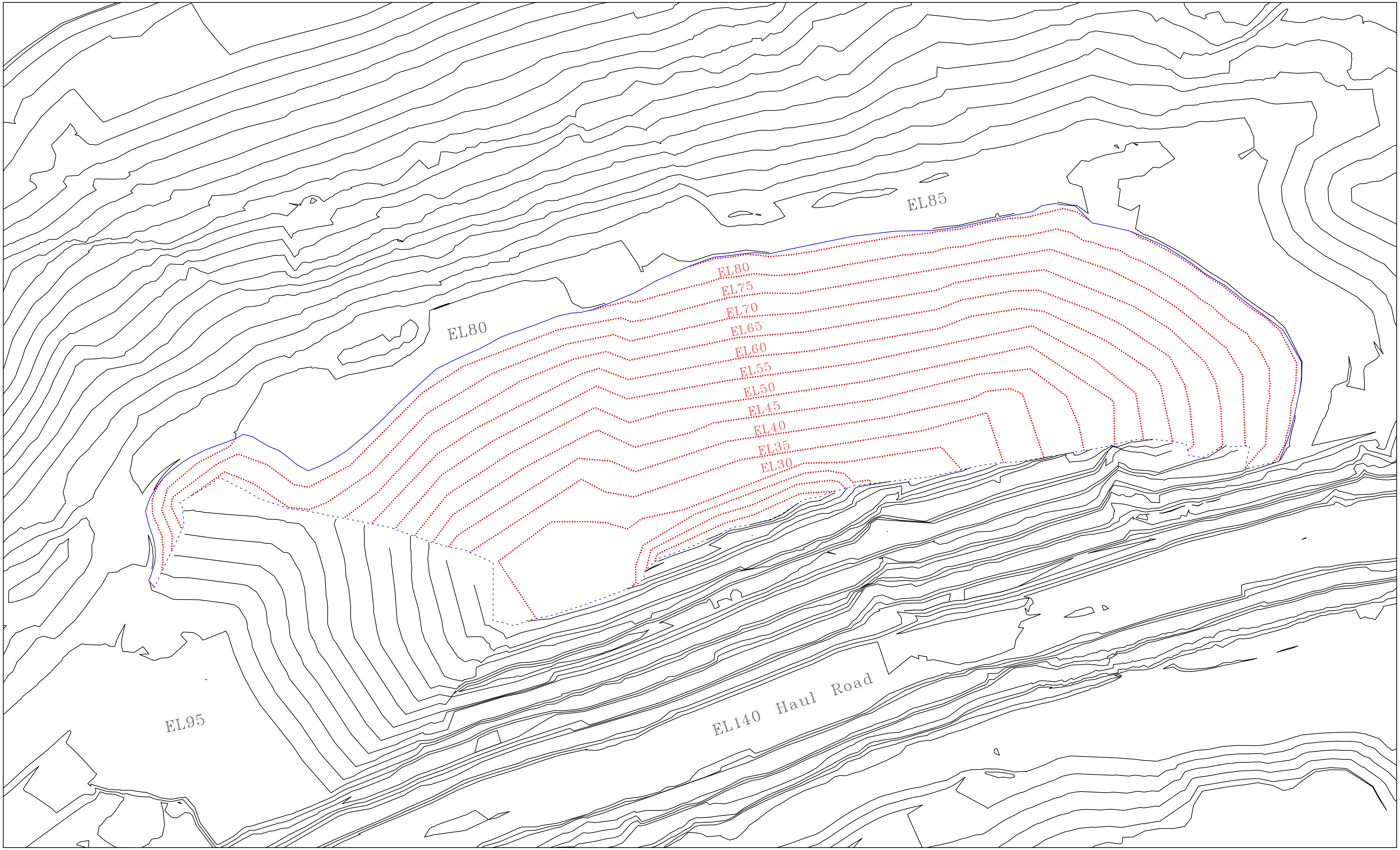
Name: D6_M11_20_V2
Activity: Re-profile
Grade: 1:3 above EL104, natural repose below EL104
Doze cut volume: 410,328 LCM
Inert material true thickness: 1m (Loose)
Surface area: 113,710 m2
Inert material volume : 113,710 LCM

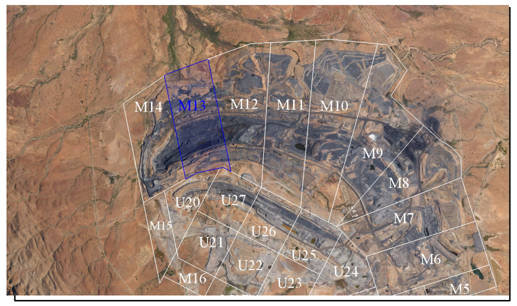
Re-profiled doze crest
Re-profiled doze toe
Re-profiled contour



CLD Mining Pty Ltd

Design Name: D6_M11_20_V2
Drawn By: CF
Check By: PK
Draw Date: 1/9/16
Topography: Dec 15
Risk Rating: High





Inert cover contour
Inert cover crest
Inert cover toe

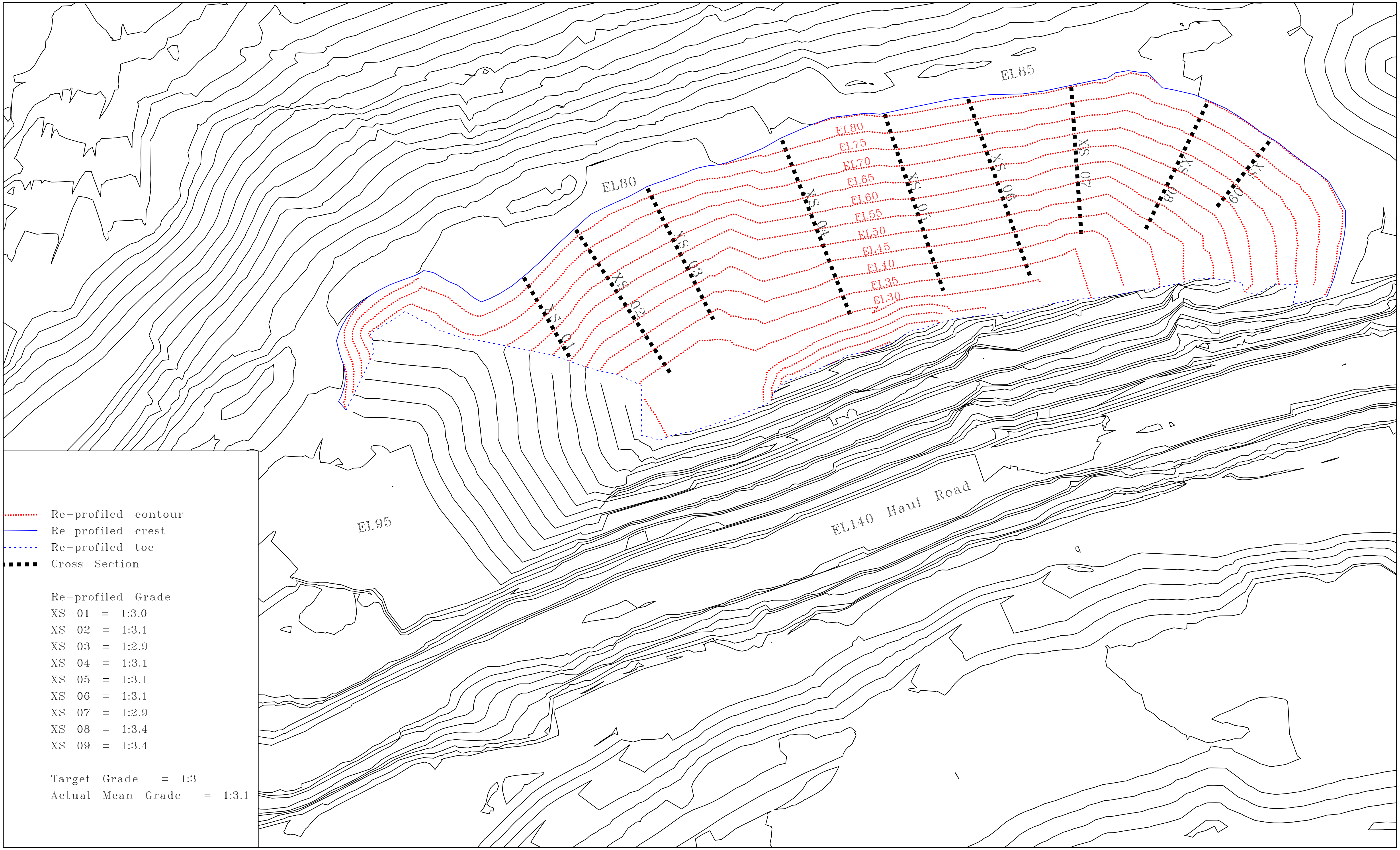
Surface area = 144,400 m2
True thickness = 1m (Loose)
Horizontal thickness = 3.17m (Loose)
Inert material volume = 144,400 lcm

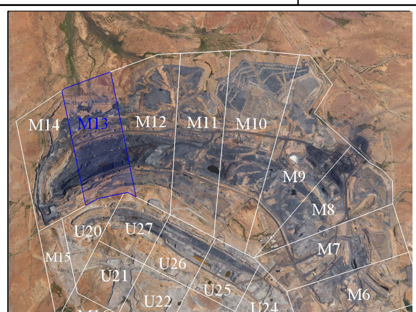
40 0 20 40 60 80 100
Metres

N

CLD Mining Pty Ltd

Design Name: D6_M13_3_V2
Drawn By: CF
Check By: PK
Draw Date: 27/7/16
Topography: 26/7/16
Risk Rating: High





CLD Mining Pty Ltd

Design Name: D6_M13_3_S1_R
Drawn By: CF
Check By: PK
Survey :26/07/16

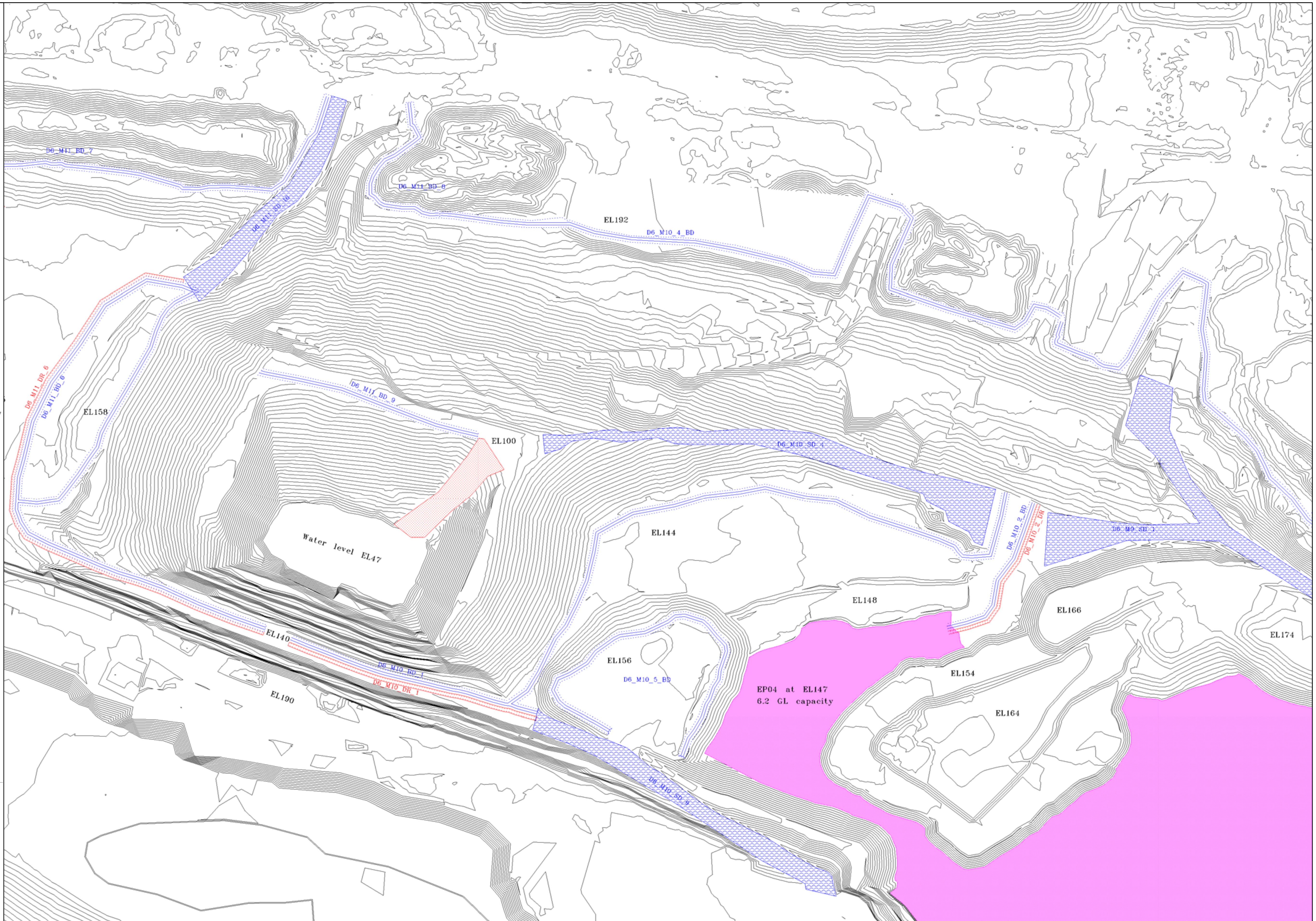
Bund crest
Bund toe
Spot dump
Conglomerate channel
Evaporation pond
Drain crest
Drain toe

Spot dumps
D6_M11_SD_16 = 16,867 lcm
D6_M10_SD_4 = 19,575 lcm
D6_M10_SD_9 = 15,324 lcm
D6_M9_SD_1 = 18,364 lcm

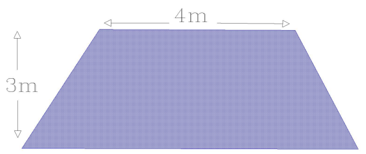
Type A Bund
D6_M11_BD_6 = 23,675 lcm
D6_M11_BD_7 = 17,050 lcm
D6_M11_BD_8 = 7,302 lcm
D6_M11_BD_9 = 9,515 lcm
D6_M10_BD_1 = 25,567 lcm
D6_M10_BD_2 = 7,827 lcm
D6_M10_BD_4 = 29,346 lcm
D6_M10_BD_5 = 22,011 lcm
D6_M9_BD_6 = 29,234 lcm

Drain
D6_M11_DR_6 =14,810 lcm
D6_M10_DR_1 = 4,693 lcm
D6_M10_DR_2 = 4,233 lcm

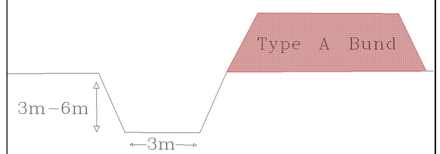
EP04 capacity 6.2 GL @ EL147

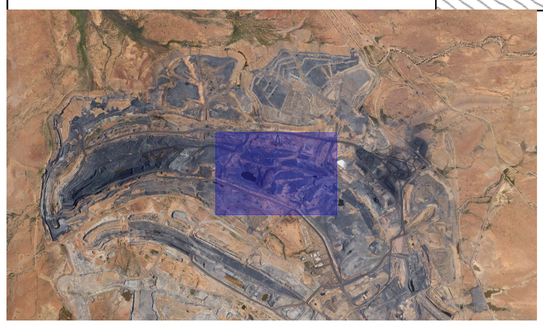


Type A Bund



Channel





100 0 50 100 150 200 250
Metres

N

CLD Mining Pty Ltd

Design Name: D6_M11/M10_SW
Drawn By: CF
Check By: PK
Survey : 24/08/16

Bund crest
Bund toe
Spot dump
Conglomerate channel
Evaporation pond
Drain crest
Drain toe

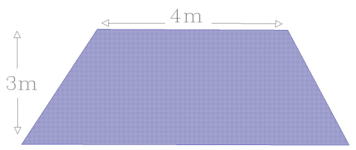
Spot dumps
D6_M14_SD_12 = 26,342 lcm
D6_M14_SD_1 = 21,157 lcm
D6_M14_SD_2 = 13,112 lcm
D6_M12_SD_2 = 18,004 lcm
D6_M11_SD_15 = 5,425 lcm
D6_M11_SD_8 = 8,980 lcm

Type A Bund
D6_M14_BD_1 = 4,388 lcm
D6_M14_BD_2 = 7,062 lcm
D6_M14_BD_3 = 7,812 lcm
D6_M14_BD_6 = 32,798 lcm
D6_M14_BD_5 = 2,006 lcm
D6_M13_BD_1 = 26,412 lcm
D6_M13_BD_2 = 24,838 lcm
D6_M13_BD_3 = 11,140 lcm
D6_M13_BD_4 = 5,893 lcm
D6_M13_BD_5 = 24,650 lcm
D6_M12_BD_1 = 27,502 lcm
D6_M12_BD_3 = 4,427 lcm
D6_M12_BD_4 = 4,147 lcm
D6_M12_BD_5 = 16,781 lcm
D6_M12_BD_6 = 10,814 lcm
D6_M12_BD_16 = 17,259 lcm
D6_M11_BD_1 = 6,224 lcm
D6_M11_BD_3 = 6,440 lcm
D6_M11_BD_5 = 14,625 lcm
D6_M11_BD_7 = 17,050 lcm

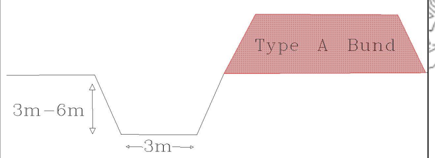
Drain
D6_M14_DR_1 = 6,079 lcm
D6_M14_DR_2 = 3,563 lcm
D6_M13_DR_1 = 1,075 lcm
D6_M13_DR_2 = 13,347 lcm
D6_M13_DR_3 = 8,229 lcm
D6_M12_DR_6 = 6,253 lcm
D6_M11_DR_5 = 11,810 lcm

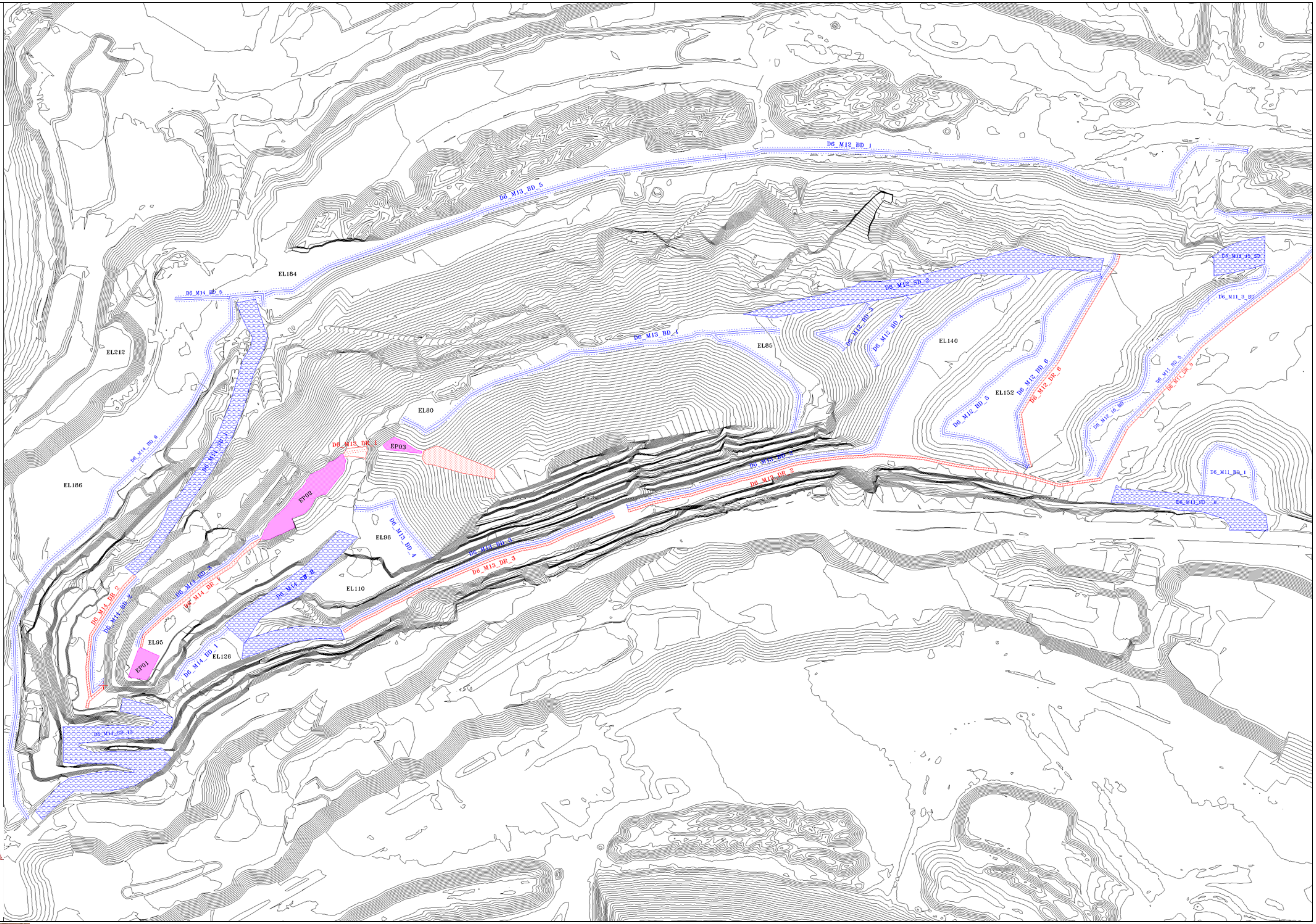
EP01 – Settling pond
EP02 capacity = 28.3 ML
EP03 – Settling pond

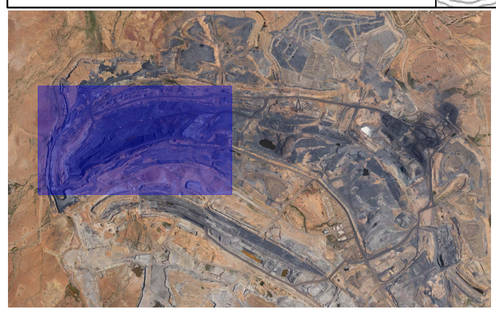
Type A Bund



Drain







200 0 100 200 300 400 500
Metres

N

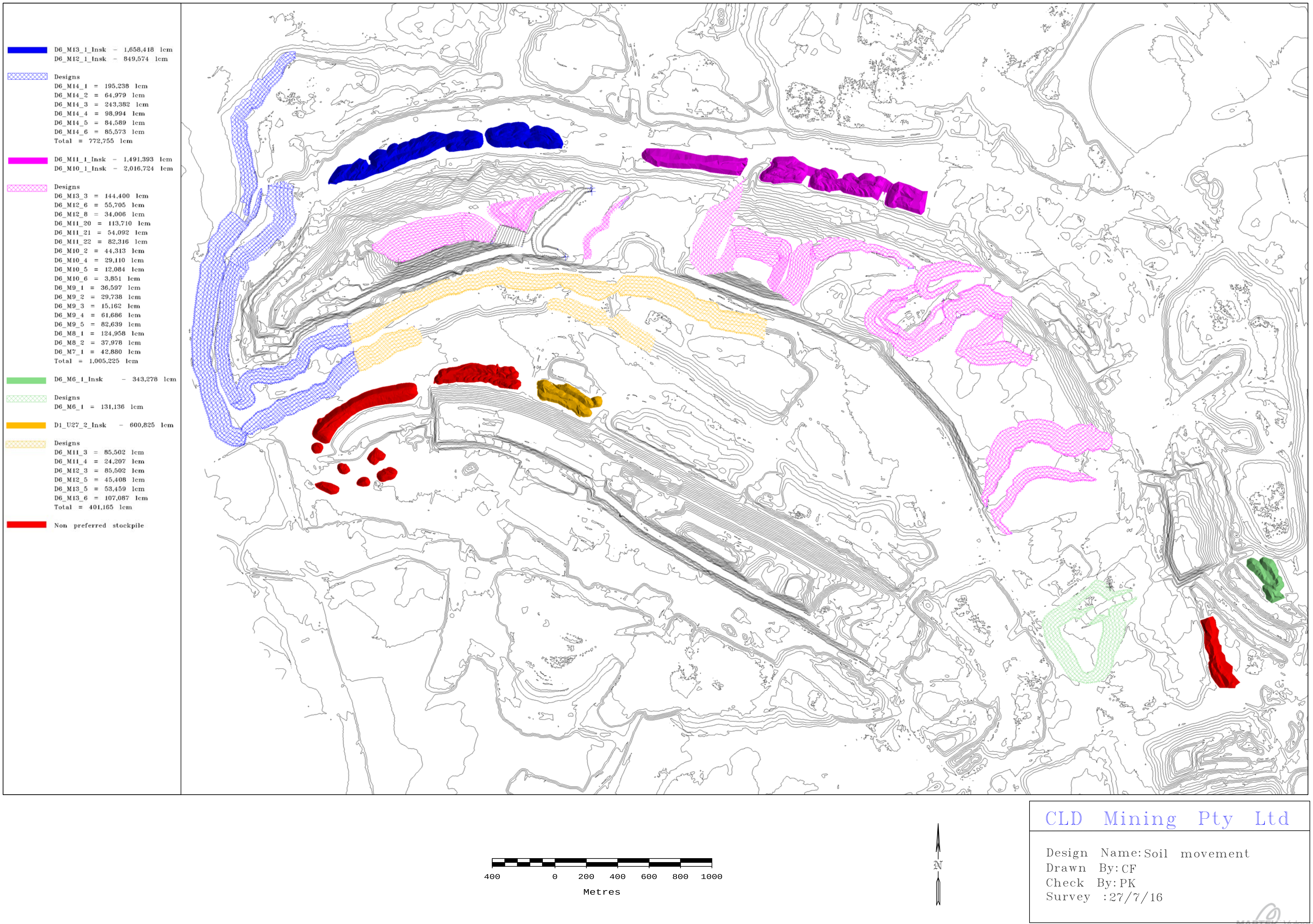
CLD Mining Pty Ltd

Design Name: D6_M13/M14_SW
Drawn By: CF
Check By: PK
Survey : 24/08/16

Appendix C - Materials Inventory and Soil Characterisation

Soil Movement plot

Inert Material plot



D6_M13_1_Insk – 1,658,418 lcm
D6_M12_1_Insk – 849,574 lcm
Designs
D6_M14_1 = 195,238 lcm
D6_M14_2 = 64,979 lcm
D6_M14_3 = 243,382 lcm
D6_M14_4 = 98,994 lcm
D6_M14_5 = 84,589 lcm
D6_M14_6 = 85,573 lcm
Total = 772,755 lcm
D6_M11_1_Insk – 1,491,393 lcm
D6_M10_1_Insk – 2,016,724 lcm
Designs
D6_M13_3 = 144,400 lcm
D6_M12_6 = 55,705 lcm
D6_M12_8 = 34,006 lcm
D6_M11_20 = 113,710 lcm
D6_M11_21 = 54,092 lcm
D6_M11_22 = 82,316 lcm
D6_M10_2 = 44,313 lcm
D6_M10_4 = 29,110 lcm
D6_M10_5 = 12,084 lcm
D6_M10_6 = 3,851 lcm
D6_M9_1 = 36,597 lcm
D6_M9_2 = 29,738 lcm
D6_M9_3 = 15,162 lcm
D6_M9_4 = 61,686 lcm
D6_M9_5 = 82,639 lcm
D6_M8_1 = 124,958 lcm
D6_M8_2 = 37,978 lcm
D6_M7_1 = 42,880 lcm
Total = 1,005,225 lcm
D6_M6_1_Insk – 343,278 lcm
Designs
D6_M6_1 = 131,136 lcm
D1_U27_2_Insk – 600,825 lcm
Designs
D6_M11_3 = 85,502 lcm
D6_M11_4 = 24,207 lcm
D6_M12_3 = 85,502 lcm
D6_M12_5 = 45,408 lcm
D6_M13_5 = 53,459 lcm
D6_M13_6 = 107,087 lcm
Total = 401,165 lcm
Non preferred stockpile
400 0 200 400 600 800 1000
Metres
N
CLD Mining Pty Ltd
Design Name: Soil movement
Drawn By: CF
Check By: PK
Survey :27/7/16

Preferred Stockpile
D6_M13_1_Insk – Sample 10,11,12,13,14
D6_M12_1_Insk – Sample 15,16
D6_M11_1_Insk – Sample 44,43
D6_M10_1_Insk – Sample 18,19,52,
D6_M6_1_Insk – Sample 51, 50
D1_U27_2_Insk – Sample 22, 23
Available volume – 6,960,212 lcm

Non-preferred Stockpile
D1_U20_1_Insk – Sample 27,28,29
D1_U20_2_Insk – Sample 31
D1_U20_6_Insk – Sample 30
D1_U27_1_Insk – Sample 24,25,26
D6_M6_2_Insk – Sample 41,42
Available volume – 2,450,816 lcm

Stock not sampled
D1_U20_3_Insk
D1_U20_4_Insk
D1_U20_5_Insk
D1_U20_7_Insk
Available volume – 211,525 lcm

PAF-LC
Sample No.
LC007
LC008
LC017
LC027
LC028
LC029
LC030
LC031
LC033

Partially Dispersive
LC034
LC015
LC029
LC024
LC034
LC029
LC024

Highly Dispersive
LC025
LC031
LC033

High remnant coal
LC039
LC040
LC047
LC041
LC042

400 0 200 400 600 800 1000
Metres

N

CLD Mining Pty Ltd

Design Name: Inert material
Drawn By: CF
Check By: PK
Draw Date: 11/6/16

Appendix D - Example ITP – Bulk Earthworks Domain 6 Area 13

Project Information:

Project:

Leigh Creek Coalfield Remediation

ITP– Bulk Earthworks

Domain 6
Area 13

Revision History						
Rev.	**Rev. Date**	**Prepared by**	**Checked by**	**Approved by**	**Description**	**Status**

Client: Department of State Development

Responsible dept	Prepared by	Checked by	Approved by	Format
LCK	**Matt Sloan**	**Ken Donaldson**	**Paul Jones**	**A4**

Originator	Document Type	Status			
	Inspection and Test Plan	**Approved**			
	Civil and Bulk Earthworks **Leigh Creek Coalfield Remediation**	FPP Document Number			
		Rev.	Date		Page **1 of 4**

INSPECTION AND TEST PLAN

Originator	FPP Document Number **QA001**		Rev. **01**	**Civil and bulk earth works** **Leigh Creek Remediation Project**
FlindersPower	Drawing/Part Numbers:			
	Inspection & Test Plan Type **Earth Works**			

No.	Operation	Document Name	Standard, Spec. or Drawing	Verifying Document/ Report	Inspection Intervention				Remarks
					Responsibility	FPP	3rd Party CLD	DSD	
1.0	***Approvals***								
1.1	*Review and Approve ITP*		N/A	This ITP	PE/QC	R	R		
2.0	***Preliminaries***								
2.1	*Approved for Construction Drawings*		N/A	Document Register	PM	H, R	R		
2.2	Survey complete for baseline		N/A	As built survey	SU	R	M		
3.0	***Re-profiling***								
3.1	Set survey pegs		D6_M13_3_S1_V1 D6_M13_4_S1_V1 D6_M13_lw_V1		SU	V	M		
3.2	Progressive check to design per shift				SU/SF	D			
3.3	End of Month survey against design			EOM Survey results	SU	D	R		
3.4	End of design survey		D6_M13_3_S1_R	Completion survey	SU	H	R		
4.0	***Inert Cover Stockpiling***								
4.1	Complete initial soil testing and define suitable source locations in line with design	Inert material coverage flow chart		Dump test results	QC	D			
4.2	Design destination inert stockpile				PE				

Inspection Codes

Key	H	Hold Point	V	Visual Inspection
	W	Witness	D	Dimension Inspection
	M	Monitor	R	Review & Approve Documentation

Responsibility

PM	Project Manager	SF	Supervisor/Foreman
SU	Surveyor	PE	Project Engineer
QC	Quality Control		

INSPECTION AND TEST PLAN

Originator	FPP Document Number **QA001**	Rev. **01**	**Civil and bulk earth works** **Leigh Creek Remediation Project**
FlindersPower	Drawing/Part Numbers:		
	Inspection & Test Plan Type **Earth Works**		

No.	Operation	Document Name	Standard, Spec. or Drawing	Verifying Document/ Report	Inspection Intervention				Remarks
					Responsibility	FPP	3rd Party CLD	DSD	
4.3	Set survey pegs		D6_M13_3_S1_V1 D6_M13_4_S1_V1		SU				
4.4	Complete daily soil movement log	Inert material coverage flow chart			QC	D			
4.5	Progressive check to design per shift	Inert material coverage flow chart			SU/SF				
4.6	Complete weekly soil inventory distribution chart	Inert material coverage flow chart			QC	D			
4.7	On-going visual inspection of soil quality by excavator operator	Inert material coverage flow chart		Visual Inspection	SF	V			
4.8	Progressive reconciliation of volumes moved against plan	Inert material coverage flow chart			SU	D			
4.9	End of design survey	Inert material coverage flow chart		As built survey	SU				
5.0	***Inert Cover Re-profile***								
5.1	Set survey pegs		D6_M13_3_S2_V2						
5.2	Conduct thermal imaging prior to inert material cover put in position			Thermal imaging report	QC	V	M		
5.3	Progressive check to design per shift				QA/PE	D	M		
5.4	Survey			As built survey	SU	D			
5.5	Surface water management completed to design		D6_M13/M14_SW	As built survey	SU	H	R		

Inspection Codes

Key				
	H	Hold Point	V	Visual Inspection
	W	Witness	D	Dimension Inspection
	M	Monitor	R	Review & Approve Documentation

Responsibility

PM	Project Manager	SF	Supervisor/Foreman
SU	Surveyor	PE	Project Engineer
QC	Quality Control		

INSPECTION AND TEST PLAN

Originator	FPP Document Number **QA001**	Rev. **01**	**Civil and bulk earth works** **Leigh Creek Remediation Project**
FlindersPower	Drawing/Part Numbers:		
	Inspection & Test Plan Type **Earth Works**		

No.	Operation	Document Name	Standard, Spec. or Drawing	Verifying Document/ Report	Inspection Intervention				Remarks
					Responsibility	FPP	3rd Party CLD	DSD	
6.0	***Spon-Com Management – Post inert cover***								
6.1	Weekly thermal imaging								
6.2	Spon Comb Risk Assessment to determine further works								
6.3	Implements learning's from test dump								
6.4									
6.5									

7.0	***Completion***								
7.1	Final Survey				SU	W	M	M	
7.2	Complete MDR								
7.3	DSD Site Visit				PM	M	M	M	
7.4	Sign of construction handover certificate				QA	R	M	M	

Inspection Codes

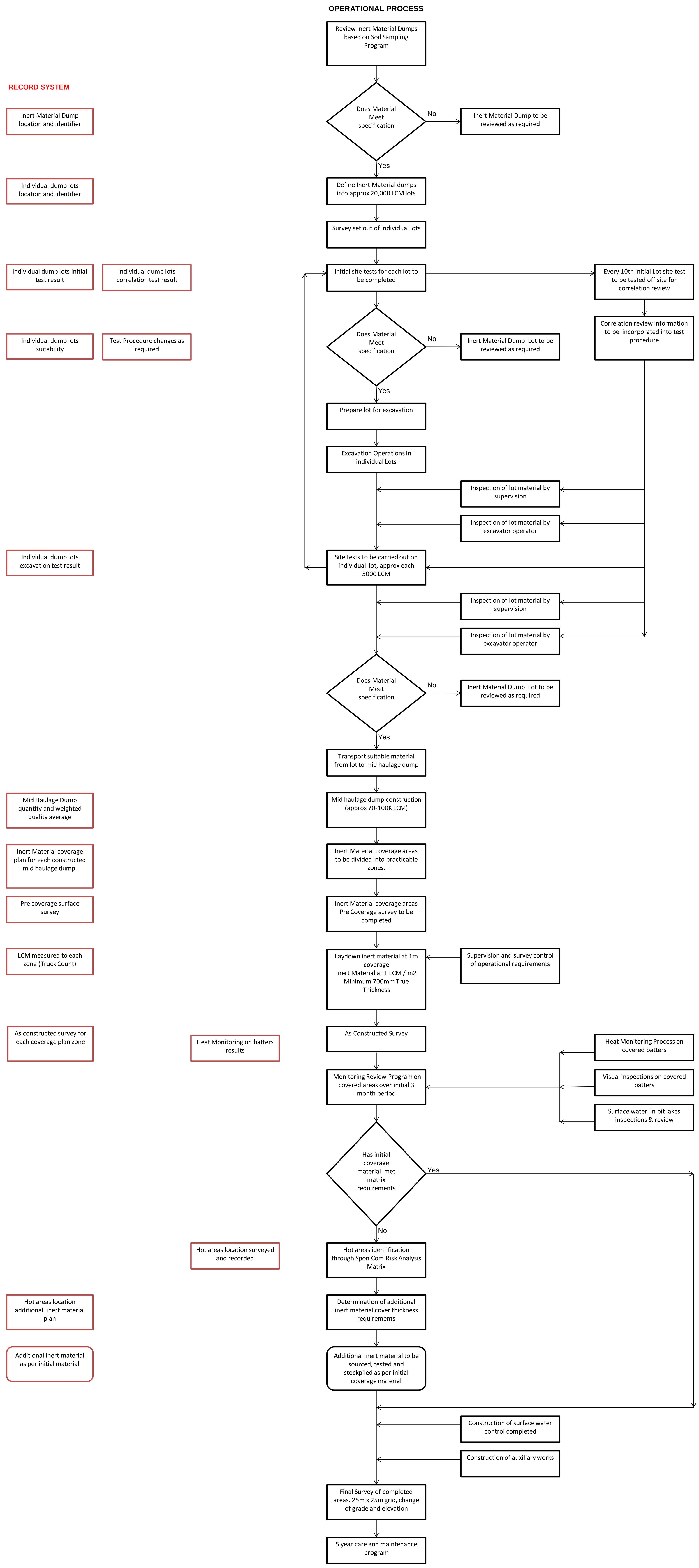
Key				
	H	Hold Point	V	Visual Inspection
	W	Witness	D	Dimension Inspection
	M	Monitor	R	Review & Approve Documentation

Responsibility

PM	Project Manager	SF	Supervisor/Foreman
SU	Surveyor	PE	Project Engineer
QC	Quality Control		

Appendix E - MT15 and MT21 Inert Material Coverage Flowchart

MT15 & MT21 Inert Material Coverage



Appendix F - Field Sampling and Analysis Protocol

MWH

BUILDING A BETTER WORLD

TECHNICAL MEMORANDUM

TO: Paul Jones

CC: Ken Donaldson

FROM: Matt Braimbridge

SUBJECT: Leigh Creek - Field Sampling Protocol

DATE: 28 August 2016

REF: LCRK-SS-16001

MWH Australia Pty Ltd

Dear Paul,

This technical memo details the draft field sampling and analysis protocol for mine waste materials at the Leigh Creek site. It is intended that the overall protocol for ongoing assessment of mine waste materials on site be refined and finalised following the site visit scheduled for early September 2016.

Detailed within this technical memo are:

- Background information;
- Field sampling protocol;
- Details of proposed field based analyses;
- Field assessment instructions;
- Laboratory analysis suite for assessment of collected samples;
- Equipment list; and
- Draft field assessment / record sheet.

It is proposed that sampling locations be identified during the site visit to cover a wide range of the potential waste materials to be used as cover / rehabilitation materials. This will enable a range of materials to be assessed on site and via further laboratory analysis, be visually identified by site personnel.

1. Background

It is understood that consultation with the South Australian Department of State Development (DSD) has outlined a requirement for further information pertaining to the characteristics of mine waste materials, particularly the potential for Acid Metalliferous Drainage (AMD) at the Leigh Creek site.

It is proposed that additional sampling of mine waste materials be undertaken to supplement the existing knowledge base on mine waste chemical and geochemical characteristics. The additional sampling program will comprise an initial sampling and analysis program in combination with an ongoing field based / laboratory confirmation assessment protocol. A key aspect to this work will be to train site personnel in field testing of key mine waste parameters for ongoing sampling and calibration of field sampling tests with laboratory results. This will allow for additional sampling and assessment and identification of potentially hostile waste materials during earthworks / rehabilitation activities.

A site visit by MWH is scheduled for early September to train site personnel in the field sampling and analysis procedure. As part of the site training program, an additional 30 samples of mine waste material will be collected and sent to ALS laboratory for analysis of target chemical and geochemical characteristics.

A report will be provided once lab results are received to confirm the approach and calibration of field / laboratory assessment, and associated finalisation of field sampling, QA/QC procedures and AMD management procedures.

2. Field Sampling Protocol

It is proposed that sampling locations and waste materials be identified during the site visit to provide a wide range of the potential mine waste to be used as cover / rehabilitation materials. Representative samples will be collected with site personnel and assessed on site (see Section 3), prior to being sent to an analytical laboratory for further assessment (Section 4).

The field training and sampling program to be conducted in early September will comprise:

- Identification of the various mine waste types to be used as cover / rehabilitation material;
- Collection of representative samples (approximately 30 samples) and photography of typical materials;
- Instruction on field testing of pH, electrical conductivity and clay dispersion;
- Completion of field sampling / record sheets; and
- Procedures for forwarding of selected samples to analytical laboratory for further analysis.

The following field sampling protocol is proposed as a means of continual sampling / analysis and confirmation of material suitability to be conducted by site personnel. It is intended that the protocol be revised as required following the initial site visit, sampling and training program.

- Stockpiles of mine waste designated as potential cover materials will be divided into 20,000 m^3 blocks for onsite testing. This represents approx. 2 days of movement of waste material.
- Each 20,000 m^3 blocks will be surveyed, marked out, and named.
- An initial field test (soil pH, electrical conductivity and clay dispersion) will be performed on a minimum of 3 samples collected from each block approximately 10 days in advance of being used, to allow operational flexibility.
- If the operator notices any change in waste material change at any time, additional samples will be tested / collected. Three additional samples will be tested halfway through the block (lunch time) to confirm the characteristics of the mine waste materials.

- Each block will have a minimum of 6 field based tests. A representative sample of the mine waste from each block will be sent to an analytical laboratory for further analysis and confirmation of suitability.
- For operational safety reasons, cover material will be placed in a mid-haulage dump and rehandled at a lower level the next shift block.
- Working in 7 day shift blocks (stockpile mine waste for 7 days / rehandle and cover for 7 days)
- The Mid haulage dump will contain 7 days of cover (70,000 m^3) with a minimum of 21 field tests confirming suitability.
- Each mid haulage dump block shall be tracked to its final location (an area the size of 7 days cover placement).

  Initial field test results will be correlated with laboratory analysis for confirmation of characteristics and suitability of use as cover material.

3. Field Based Analyses

The field based analysis to be conducted on the initial samples collected (n=30) and then on an ongoing basis during earthworks (n=6 for each 20,000 m^3 block) are detailed as follows.

pH (1:1 saturated paste)

The field pH of a soil or mine waste material is designed to provide a reasonable prediction of the existing acidity levels in the material. This test does not give any quantitative measure of the amount of acid that could be produced through the oxidation of potentially acid forming (PAF) waste material, but will give an indication of any PAF waste that has started to oxidise and produce acid.

Specific instructions on how to perform the analysis and use the pH / EC meter will be included

Electrical conductivity (1:1 saturated paste)

Soil salinity is measured via an assessment of electrical conductivity (EC). Soil water that contains salt is able to conduct electricity. The more salt there is in a solution, the easier it is for an electric current to flow.

Specific instructions on how to perform the analysis and use the pH / EC meter will be included

Clay dispersion

Dispersion (the separation of soil into single particles) is governed by soil texture, clay type, soil organic matter, soil salinity and exchangeable cations.

Specific instructions on how to perform the clay dispersion test will be included

Visual assessment of mine waste materials

Photos of representative samples of the various waste materials identified will be collated and included in the revised version of the field sampling plan to assist with the identification of the various mine waste materials present.

4. Laboratory analysis suite for assessment of collected samples

The samples collected during the initial site visit, sampling and training program, and the additional samples collected during the earthworks will be sent to an analytical laboratory in Adelaide (ALS) for the following analyses:

- pH and electrical conductivity;
- exchangeable cations;
- total and sulfate sulfur;
- Inorganic C and Acid Neutralisation Capacity (ANC);
- Net Acid Generation (NAG);
- Net Acid Production Potential (NAPP); and
- total and water soluble metal concentrations.

A Chain of Custody (CoC) for the ALS Laboratory in Adelaide, detailing the required laboratory analyses will be provided prior to the site visit and completed on site to be sent with the samples. A CoC template for subsequent analyses of collected samples will also be provided.

5. Equipment list

The following equipment will be required for the field sampling and analysis:

- pH / EC meter
- DI water
- Squirter bottle
- Plastic sample containers
- Petri dishes
- Sample bags / permanent marker
- Sample record sheets, pens, clipboard
- Shovel / trowel
- Camera

6. Field assessment sheet

To be completed

Matt Braimbridge
Discipline Lead – Soils, Mine Waste, Landforms and Tailings