

Attachment 1: Ensham Progressive Certification Rehabilitation Area 2018



Cond. No.	Subject	Requirement	Due Date
G17	Terms of Reference for the Residual Void Project	Submitted to the administering authority for review and comment	15 March 2017
NoD		Lodge \$174,543,962 in FA to NRM	28 March 2017
G18	Terms of Reference for the Residual Void Project	Updated to address the comments and resubmitted to the administering authority for approval.	Within 20 business days of receiving comments from the AA. Estimated 21 April 2017
G5	Appendix: Rehabilitation Success Criteria	Populate for all domains excluding voids	28 April 2017
G12	Rehabilitation Management Plan	Submitted to the administering authority for review and comment.	31 May 2017
G13	Rehabilitation Management Plan	Updated to address the comments and resubmitted to the administering authority for approval.	Within 20 business days of receiving comments from the AA. Estimated 4 May 2017
Table G1	Low wall spoil Pit B	Topsoil, rip and seed at least 110 ha	30 June 2017
Table G1	Low wall spoil Pit D, E	Reshape at least 50 ha	30 June 2017
G9	Notification on how rehabilitation has been undertaken in accordance with Condition G8.	AA must receive notification	Within 20 business days after 30 June 2017. Makes 28 July 2017 .
G21	Progress reports must detail the status of the Residual Void Project	First report provided to the administering authority	31 July 2017
Table G1	Low wall spoil Pit D, E	Reshape at least 50 ha	19 December 2017
Table G1	Low wall spoil Pit D, E	Topsoil, rip and seed at least 100 ha	19 December 2017
G9	Notification on how rehabilitation has been undertaken in accordance with Condition G8.	AA must receive notification	Within 20 business days after 19 December 2017. Makes 5 February 2018 .
G21	Progress reports must detail the status of the Residual Void Project	Second report provided to the administering authority	31 January 2018
Table G1	Low wall spoil Pit D, E, F	Reshape at least 50 ha	29 June 2018
G9	Notification on how rehabilitation has been undertaken in accordance with Condition G8.	AA must receive notification	Within 20 business days after 29 June 2018. Makes 27 July 2018 .

G21	Progress reports must detail the status of the Residual Void Project	Third report provided to the administering authority	31 July 2018
G21	Progress reports must detail the status of the Residual Void Project	Fourth report provided to the administering authority	31 October 2018
Table G1	Low wall spoil Pit D, E, F	Reshape at least 50 ha	31 January 2019
Table G1	Low wall spoil Pit D, E, F	Topsoil, rip and seed at least 100 ha	31 January 2019
G9	Notification on how rehabilitation has been undertaken in accordance with Condition G8.	AA must receive notification	Within 20 business days after 31 January 2019. Makes 28 February 2019 .
G6	Appendix: Rehabilitation Success Criteria	Populate for all domains including voids	31 March 2019
G24	Appendix 4: Rehabilitation Success Criteria	Submit an Environmental Authority amendment application to populate Appendix 4: Rehabilitation Success Criteria with rehabilitation success criteria for voids and residual void areas and volumes.	Prior to 31 March 2019
G16	Residual Void Project	Completed and submitted to the administering authority for review and comment	31 March 2019
G10	Table G1: Rehabilitation Schedule	A final report that describes and confirms that rehabilitation in accordance with the table has been undertaken	31 March 2019
G23	Residual Void Project	Updated to address the comments and resubmitted to the administering authority for approval.	Within 20 business of receiving comments from the administering authority Estimated May 2019
G26	An annual report that describes rehabilitation status against the requirements of Condition G4	developed by a suitably qualified person and provided to the administering authority upon request	provided to the administering authority upon request

Benchmarking Report: Analysis of the regulatory requirements for rehabilitating mining voids across Australia and other coal producing countries

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Scope

This benchmarking report provides a brief analysis of the current regulatory and legislative requirements for rehabilitating mine voids within:

1. The state jurisdiction of the three main coal producing states in Australia; Queensland, New South Wales and Victoria; and
2. The federal and various state jurisdictions of the top ten coal producing countries as per Figure 1., Excluding the Ukraine, Indonesia, Colombia and Poland due to constraints with accessing available literature and websites.

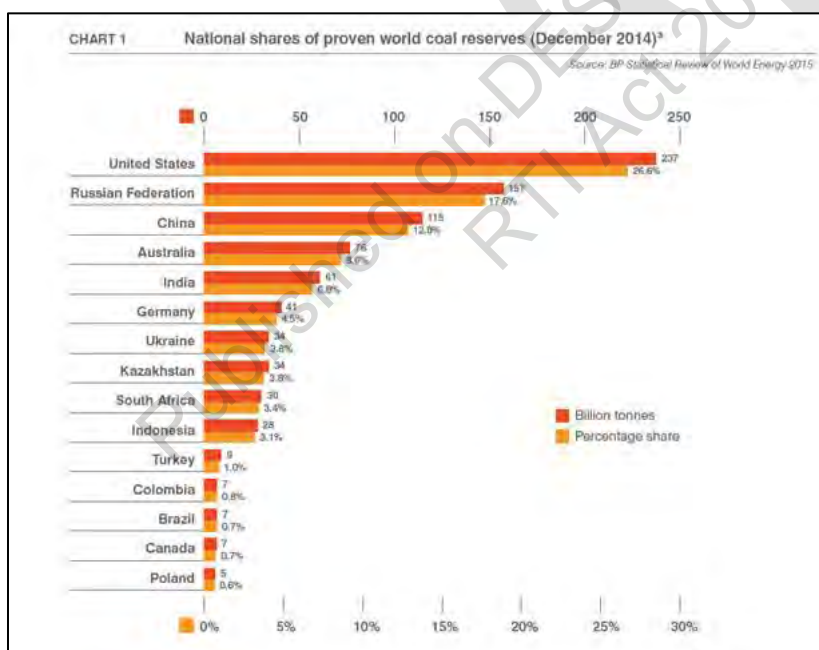


Figure 1. National shares of proven world coal reserves December 2014.

This benchmarking report aims to answer the following for each jurisdiction listed above:

1. Are mining voids required to be backfilled by legislation, either complete backfilling or partial backfilling? and
2. What is the overarching legislation that regulates the rehabilitation and reclamation of mining voids? and

3. Are there any other regulatory requirements for mining void management, rehabilitation or reclamation of mine voids.

A summary of the findings have been presented in the summary tables below. Only three countries have a specific regulatory requirement to backfill mine voids, these are the United States of America, Canada and India. Of these three countries, active enforcement of these regulations mostly occurs in the United States of America and Canada.

This benchmarking report also includes various case studies from around the world detailing how mining voids have been managed and rehabilitated.

Please note this benchmarking report does not critically evaluate the potential environmental impacts from backfilling mining voids or describe current best practice management of mining voids rehabilitation.

Summary – Australia

In addition to the top three coal producing states in Australia, South Australia and the Northern Territory have also been included in the summary table below.

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
Australia	Queensland	<i>Environmental Protection Act 1994</i>	No specific requirement to backfill voids.	<p>The rehabilitation objectives under the <i>Environmental Protection Act 1994</i> framework is for rehabilitation to be 'safe, stable, non-polluting and sustain an appropriate suitable land use'.</p> <p>The actual conditions imposed on an environmental authority for each mine site may vary per site and mining type.</p>	Plan of Operations
Australia	New South Wales	<p>Development Consent under the <i>Environmental Planning & Assessment Act 1979</i></p> <p>Mining lease under the <i>Mining Act 1992</i>, section 239</p> <p>Exploration Code of Practice: Rehabilitation¹</p>	No specific requirement to backfill voids.	<p>Requirements for voids to be rehabilitated to a safe, stable and non-polluting sustainable condition²</p> <p>Options for backfilling, partial backfilling, reshaping and void configuration (shape) are included in the mining operations plan, but is not strictly required.</p> <p>Mining operators often develop innovative solutions to rehabilitate final voids, and ex-mines have been adapted for tourism, agricultural and ecological uses.³</p>	Mining Operations Plan
Australia	Victoria	Mining licence under the <i>Mineral Resources</i>	No specific requirement to backfill voids.	The <i>Victorian Mineral Resources (Sustainable Development) Act (1990)</i> requires that a rehabilitation plan must have as its goal the ability to return mined	Rehabilitation Plan

¹ http://www.resourcesandenergy.nsw.gov.au/_data/assets/pdf_file/0008/565955/Exploration-Code-of-Practice-Rehabilitation.pdf

² <http://www.nswmining.com.au/environment/rehabilitation-mine-closure>

³ <http://www.nswmining.com.au/getmedia/db5d728f-86d0-402f-83e3-cc408bf89092/PUB16-177-Exploration-and-mining-rehabilitation-fact-sheet-FINAL>

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		<i>(Sustainable Development) Act 1990</i>		lands to a state as close as possible to that, which existed prior to mining. Rehabilitation criteria requires that the site should be visually appealing once mining has ceased, and requires that landscaping take into account a 'critical view' of the final form of the mine site. The legislation recommends that mine pit slopes in the rehabilitated sites be neither too steep nor too long (Department of Primary Industries 2002).	
Australia	Western Australia	<i>Mining Act 1978</i> Guidelines for Preparing Mine Closure Plans May 2015 - under section 700 of the <i>Mining Act 1978</i> <i>Environmental Protection Act 1986</i> .	Risk based approached as described in the guideline, with the preference of backfilling where appropriate.	All existing mining operations must contain a mine closer plan prepared in accordance with the Guidelines for Preparing Mine Closure Plans 2011. Objectives in the guideline must be safe to humans and animals, stable, non-polluting/non-contaminating and capable to sustaining an agreed post-mining land use.	Mine Closure plans
Australia	South Australia	Mining lease under the <i>Mining Act 1971</i>	No specific requirements for backfilling voids.	The content of the PEPR must: <ul style="list-style-type: none"> demonstrate that mining operations that have (or potentially have) adverse environmental impacts are properly managed to reduce those impacts as far as reasonably practicable and eliminate, as far as reasonably practicable, risk of significant long term environmental harm Ensure that land adversely affected by mining operations is properly rehabilitated.	Program for Environment Protection and Rehabilitation (PEPR)
Australia	Northern Territory	Authorisation under the <i>Mining</i>	No specific requirements for backfilling voids.	Minimum requirements for rehabilitation and closure include: walls of shallow pits and excavations battered,	Mining Management Plan

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		<i>Management Act</i> Rehabilitation and Closure Requirements for the Extractive Industry		and walls of deep pits stabilised. All water discharges from a mine site require Waste Discharge Licences (WDL) under the Water Act.	

Summary – United States of America

The U.S Energy Information Administration provides independent statistics and analysis, and reported that the five largest coal-producing states with production in million short tons and share of total U.S coal production in 2014⁴ were:

- Wyoming: 395.7 (40%)
- West Virginia: 112.2 (11%)
- Kentucky: 77.3 (8%)
- Pennsylvania: 60.9 (6%)
- Illinois: 58.0 (6%)

The above mentioned states have also been reviewed in the summary table below, in addition to federal legislation around mining voids.

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
USA	USA Environmental Protection Agency (USA EPA)	<i>Surface Mining Control and Reclamation Act 1977 (SMCRA).</i>	Surface Mining Control and Reclamation Act of 1977 requires that surface coal mine operations “ <i>backfill, compact (where advisable to insure stability or to prevent leaching of toxic materials), and grade in order to restore the approximate original contour of the land with all highwalls, spoil piles, and depressions eliminated</i> ”	Under the federal framework, the States are also able to enact their own legislation if the Office of Surface Mining Reclamation and Enforcement approves it. The State legislation must exceed the requirements of the Federal legislation. The <i>Surface Mining Control and Reclamation Act 1977</i> requires surface mine operators to	Reclamation plan and performance bond

⁴ <https://www.eia.gov/tools/faqs/faq.cfm?id=69&t=2>

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			Generally open cut coal mines have been required to backfill since the 1970s. ⁵	<p>restore the land to a condition capable of supporting the uses it could support prior to mining, or to 'higher or better uses'. In order to achieve this, the operator is required to:</p> <ul style="list-style-type: none"> • restore the approximate original contour of the land • avoid acid mine drainage and prevent erosion to minimise impacts to nearby waters • reclaim the land in a timely manner • Establish appropriate vegetation that will cover the previously disturbed area. 	
USA	Wyoming	<i>Surface Mining Control and Reclamation Act 1977</i> Wyoming Environmental Quality Act and LQD Coal Rules and Regulations	LQD Coal Rules and Regulations require all affected land to be returned to their approximate original contour, except as authorised.	Nil found.	Reclamation plan and performance bond
USA	West Virginia	<i>Surface Mining Control and Reclamation Act 1977</i>	As per the <i>Surface Mining Control and Reclamation Act 1977</i> .	<p>Injection of coal slurry into underground mine voids has been undertaken in the past, however a moratorium on the practice has been imposed since 2009⁶</p> <p>Generally the State requires strict ground cover performance standards in the Appalachian coal region to ensure reforestation occurs.</p>	Reclamation plan and performance bond

⁵ U.S. Code (1977) Surface Mining Control and Reclamation Act of 1977, U.S. Code (Title 30, Chapter 25), Available at: <https://www.gpo.gov/fdsys/pkg/USCODE-2011-title30/pdf/USCODE-2011-title30-chap25.pdf>

⁶ <http://www.dep.wv.gov/dmr/studies%20and%20investigations/Documents/Slurry%20UIC%20Investigation.pdf>

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
USA	Kentucky	<i>Surface Mining Control and Reclamation Act of 1977</i>	As per the <i>Surface Mining Control and Reclamation Act 1977</i> .	Compaction is used to eliminate dangers of steep slopes and drops following high walls. Compaction after strip mining has caused difficulties with revegetation and reforestation. ⁷ Issues with coal refuse fires and abatement methods include complete excavation, quenching with water, foaming cements.	
USA	Pennsylvania	<i>Surface Mining Control and Reclamation Act of 1977</i> <i>Pennsylvania's Anthracite and Bituminous Coal Mine Safety Act(s)</i> <i>The Clean Streams Law, the Bituminous Mine Subsidence and Land Conservation Act</i>	As per the <i>Surface Mining Control and Reclamation Act 1977</i> . Significant backfilling of voids has been undertaken in Pennsylvania.	The reuse of mine waste particular coal ash has been used in mine reclamation since 1988 and ash from FBC power plants have also been used. ⁸ Pennsylvania has its own coal mine waste regulation for the reuse of coal waste in mine reclamation.	Reclamation plan and performance bond
USA	Illinois	<i>Surface Mining Control and Reclamation Act of 1977</i> <i>Resource Conservation and Recovery Act (USA EPA)</i> <i>Surface Coal Mining Land Conservation and</i>	<i>Surface Coal Mining Land Conservation and Reclamation Act (225 ILCS720)</i> requires backfilling, compaction and graded to restore original contour of the land (where advisable).	Impoundment of coal waste and coal slurry. Backfilling of voids are undertaken using coal slurry, also known as slurry backfilling.	Reclamation plan and performance bond

⁷ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

⁸ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
		<i>Reclamation Act (225 ILCS720)</i>			

Summary – Other Countries

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
Russia	Russia	<i>Federal law on Environmental Protection</i> <i>Federal law on Subsoil use Russian-gosudarstvennyy standart – “GOST”s</i>	No specific requirement to backfill mining voids.	Rehabilitation technical standards include levelling, re-profiling, scraping, storage and placement of fertile soil and growth media, construction of diversion channels, and disposal of toxic wastes. ⁹	Post closure mine plans and schedule to be included within a mining licence.
China	China	<i>Environmental Protection Law of the People's Republic of China</i> <i>Regulations on Land Reclamation 1988</i>	No specific requirement to backfill mining voids.	Assumed that enforcement of the environmental protection laws does not occur and large companies do not pay environmental protection fees. ¹⁰ Preference to reclaim mines into agricultural areas due to shortages in farmlands. ¹¹	Site Decommissioning and Closure Report
India	India	Mineral Concession Rules 1960 Mineral Conservation and Development Rules 1988	Mineral Concession Rules requires the permit holder to fill holes or excavations to the extent required by the Deputy Commissioner. Mineral Conservation and Development	Due to water security issues, coal mines are filled in with mine water for groundwater recharge and seasonal rainfall is also diverted in pits. ¹² Backfilling and other remedial actions are	Progressive Mine Closure Plan and Final Mines Closure Plan

⁹ <http://www.srk.com.au/en/publication/au-comparative-study-regulatory-approaches-mine-closure-special-emphasis-current>

¹⁰ <http://www.srk.com.au/en/newsletter/focus-facility-closure/mine-closure-planning-chinese-mining-industry>

¹¹ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

¹² <http://www.cim.org/en/Publications-and-Technical-Resources/Publications/Proceedings/2013/8/23rd-World-Mining-Congress/WMCO-2013-08-471>

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
			Rules 1988 requires that waste rock and overburden shall be backfilled into the mine excavations with a view to restoring the land to its original use as far as possible. Where backfilling is not feasible, terracing should be used.	generally not realised due to lack of finances.	
Germany	Germany	<i>Federal Mining Act 1980 (Bundesberggesetz)</i>	No specific requirement to backfill mining voids.	Reclamation into lakes used for swimming. Has various regulations relating to mining reclamation including forest laws, water rights, regional planning laws and waste laws.	Operations plan, including the mine closure operations plan
Kazakhstan	Kazakhstan	<i>Law on Subsoil and Subsoil Use 2010</i> <i>Land Code</i>	No specific requirement to backfill mining voids.	Prevention of collapse, subsidence, landslide or flooding ¹³	President approves mine closure plan.
South Africa	South Africa	<i>Constitution of the Republic of South Africa 1996</i> <i>National Water Act 1998</i> <i>Water Services Act 1997</i> <i>National Environmental Management: Waste Act 2008</i>	No specific requirement to backfill mining voids.	Constitutional objectives are sustainable development, from which stems various statutes which regulates mine and water and waste. ¹⁴ Generally focuses on pumping and treating acid mine drainage, and discharging treated water into river systems. Water pricing strategy under the National Water Act aims to promote sustainable development and efficient use of water resources and create financial incentives for mining companies to discharge treated water.	Nil found.

¹³ <http://www.srk.com.au/en/publication/au-comparative-study-regulatory-approaches-mine-closure-special-emphasis-current>

¹⁴ <http://www.scielo.org.za/pdf/pelj/v17n5/08.pdf>

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
Turkey	Turkey	<i>Regulation on Reclamation of Lands Disturbed by Mining Activities 2007</i>	No specific requirement to backfill mining voids.	Mining Laws require that land be returned to the user in a 'usable condition'. ¹⁵ Lack of interest in post-mining land use due to limit of value that can be added to post-industrial landscapes. ¹⁶	Reclamation plans
Brazil	Brazil	<i>Brazilian Constitution 1988</i> <i>Brazilian Mining Code (Decree-Law No. 227/1967) and, alternatively, the Regulation of the Mining Code (Decree-Law No. 62934/1968).</i>	No specific requirement to backfill mining voids. Constitution article 225, §2, "the person exploiting mineral resources must recover the degraded environment, in accordance to the technical solution required by the competent public authority, as set forth by law".	Brazilian Constitution requires mining companies to 'reclaim the degraded environment in accordance with the technical solution demanded by the competent public organisation'	Mining closure plan – Report of Recovery Plan of the Degraded Area
Canada	Ontario	Part VII of the Ontario <i>Mining Act</i> and Ontario Regulation 240/00 – Mine Development and Closure	Regulation specifies that open pits shall be rehabilitated by backfilling, however further subsections prescribed that this is not required where it is impracticable and flooding the pit, sloping the pit, using boulder fencing or berming may be used instead.	In Canada, the Provinces have full jurisdiction over the restoration requirements. The Federal government only becomes involved over issues of air and water pollution, particularly where issues may arise in more than one Province. The Code includes requirements to ensure the following minimum rehabilitation standards are met (these are specific to pits): <ul style="list-style-type: none"> ensuring that inadvertent access to mine openings from the surface is prevented limiting potential hazards and maintaining public safety around open 	Certified closure plan

¹⁵ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

¹⁶ <http://www.srk.com.au/en/newsletter/focus-facility-closure/mine-closure-regulation-turkey>

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				pits	
Canada	British Columbia	<i>Mines Act 1996</i> Health, Safety and Reclamation Code for Mines in British Columbia 2008	<p>The Code requires that voids from mining exploration are backfilled. However these pits and trenches from exploration do not need to be backfilled if the sides are sloped to a stable and safe angle determined by a suitably qualified person or it is fenced to prevent access or there is a means of egress.</p> <p>The Code requires various standards for the reclamation and closure of open pits based on if the pit contains water and if overburden has been used in. However backfilling is not specifically required.</p>	<p>In Canada, the Provinces have full jurisdiction over the restoration requirements. The Federal government only becomes involved over issues of air and water pollution, particularly where issues may arise in more than one Province.</p> <p>The Code outlines various reclamation standards for closure of open pits, dumps openings and impoundments.</p>	Decommissioning and reclamation plan for all mining projects with an environmental assessment

Case studies – Rehabilitation of mine voids across the world

Name of Mine or Project	Jurisdiction	Post-closure outcome / final land use
New Acland	Queensland, Australia	55ha of final voids have been authorised, final rehabilitation of these voids will be determined in the future through a mine closure plan.
Sand and gravel quarries Penrith	New South Wales, Australia	Recreational lakes and wetland areas.
Cadia Hill	New South Wales, Australia	Backfilling and returning to pasture for grazing and native forest.
Wesfarmers Premier Coal	Western Australia, Australia	Reclaimed into a recreational lake.
Jarrahdale mine	Western Australia, Australia	Recreational area, lakes and native eucalypt forest.
Ranger Uranium Mine ¹⁷	Northern Territory, Australia	Rehabilitation work included backfilling pits and dredging tailing dams to establish a similar environmental to the adjacent areas of Kakadu National Park. Approximately 100 million tonnes of rock is expected to be used as backfill.
Witwatersrand basin (gold fields) ¹⁸	South Africa	Discharge of contaminated water into nearby streams and rivers and the creation of a system of wetlands which serve as a water purification system.
El Terronal Mercury Mine ¹⁹	Asturias, Spain	Mine waste encapsulation and road construction over encapsulated mine.
Aitik copper mine ²⁰	Sweden	Use of industrial waste such as sewage sludge, fly ash and green liquor dregs to treat acid mine drainage and act as a sealing layer.
Injection coal slurry into mine voids, in Virginia 1983 -1999	West Virginia, USA	Injection of coal slurry into abandoned underground coal mines.
Big Bend Area ²¹	Texas, USA	Backfilling has been used at the Big Bend Area where dangerous highwalls, openings and pits were left abandoned. Closure includes backfilling, grate closures, bat friendly gates on openings, mortared walls, cable nets, and concreted caps.
Western Pennsylvania ²²	Pennsylvania, USA	1 Mt of amended fill using coal combustion by-

¹⁷ <http://www.abc.net.au/news/2016-04-29/traditional-owners-welcome-deal-over-ranger-uranium-mine/7372554>

¹⁸ <http://www.scielo.org.za/pdf/pelj/v17n5/08.pdf>

¹⁹ <http://www.wolkersdorfer.info/publication/pdf/0269-Jarvis.pdf>

²⁰ <http://www.wolkersdorfer.info/publication/pdf/0269-Jarvis.pdf>

²¹ <http://www.slideshare.net/JEBrandt/historical-mining-in-texas-and-the-abandoned-mine-land-program>

Name of Mine or Project	Jurisdiction	Post-closure outcome / final land use
		products was used to return a double high wall along 3353 m of hillside.
Zwenku Lake,	Zwenkau, Germany	Flooding old mines to create a network of lakes in Lusatia
Southern area of Leipzig	Leipzig, Germany	Flooding 8 mining lakes, using pipelines to move water.
Bergheim lignite mine ²³	Rhenish , Germany	In this region several mines are locate in close proximity, and backfill waste material from the mines are transported to a central location (Bergheim lignite mine) and reused at to optimise the speed of backfilling, while reducing storage requirements. This mine has been reclaimed into forest.
Germano Mine ²⁴	Brazil	Backfilling iron ore open pit with coarse sand tailing from Germano Plant. This option was chosen due to the many landslide occurrences.
Riacho dos Machados ²⁵	Brazil	Pit was filled with water and reclaimed into a lake.
Suncun Coal Mine ²⁶	Shangdong, China	Crushed mining wastes were mixed with cement to backfill mined cavities as a way to lessen subsidence.

²² https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

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²⁴ http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0370-44672011000200012

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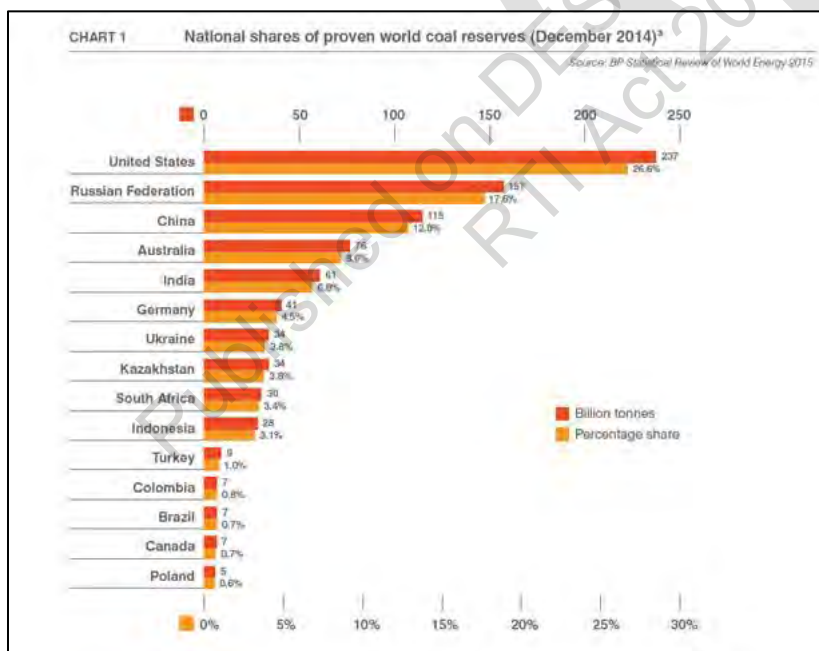


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¹ http://www.resourcesandenergy.nsw.gov.au/_data/assets/pdf_file/0008/565955/Exploration-Code-of-Practice-Rehabilitation.pdf

² <http://www.nswmining.com.au/environment/rehabilitation-mine-closure>

³ <http://www.nswmining.com.au/getmedia/db5d728f-86d0-402f-83e3-cc408bf89092/PUB16-177-Exploration-and-mining-rehabilitation-fact-sheet-FINAL>

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		<i>(Sustainable Development) Act 1990</i>		lands to a state as close as possible to that, which existed prior to mining. Rehabilitation criteria requires that the site should be visually appealing once mining has ceased, and requires that landscaping take into account a 'critical view' of the final form of the mine site. The legislation recommends that mine pit slopes in the rehabilitated sites be neither too steep nor too long (Department of Primary Industries 2002).	
Australia	Western Australia	<i>Mining Act 1978</i> Guidelines for Preparing Mine Closure Plans May 2015 - under section 700 of the <i>Mining Act 1978</i> <i>Environmental Protection Act 1986</i> .	Risk based approached as described in the guideline, with the preference of backfilling where appropriate.	All existing mining operations must contain a mine closer plan prepared in accordance with the Guidelines for Preparing Mine Closure Plans 2011. Objectives in the guideline must be safe to humans and animals, stable, non-polluting/non-contaminating and capable to sustaining an agreed post-mining land use.	Mine Closure plans
Australia	South Australia	Mining lease under the <i>Mining Act 1971</i>	No specific requirements for backfilling voids.	The content of the PEPR must: <ul style="list-style-type: none"> demonstrate that mining operations that have (or potentially have) adverse environmental impacts are properly managed to reduce those impacts as far as reasonably practicable and eliminate, as far as reasonably practicable, risk of significant long term environmental harm <p>Ensure that land adversely affected by mining operations is properly rehabilitated.</p>	Program for Environment Protection and Rehabilitation (PEPR)
Australia	Northern Territory	Authorisation under the <i>Mining</i>	No specific requirements for backfilling voids.	Minimum requirements for rehabilitation and closure include: walls of shallow pits and excavations battered,	Mining Management Plan

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
		<i>Management Act</i> Rehabilitation and Closure Requirements for the Extractive Industry		and walls of deep pits stabilised. All water discharges from a mine site require Waste Discharge Licences (WDL) under the Water Act.	

Summary – United States of America

The U.S Energy Information Administration provides independent statistics and analysis, and reported that the five largest coal-producing states with production in million short tons and share of total U.S coal production in 2014⁴ were:

- Wyoming: 395.7 (40%)
- West Virginia: 112.2 (11%)
- Kentucky: 77.3 (8%)
- Pennsylvania: 60.9 (6%)
- Illinois: 58.0 (6%)

The above mentioned states have also been reviewed in the summary table below, in addition to federal legislation around mining voids.

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
USA	USA Environmental Protection Agency (USA EPA)	<i>Surface Mining Control and Reclamation Act 1977 (SMCRA).</i>	Surface Mining Control and Reclamation Act of 1977 requires that surface coal mine operations “ <i>backfill, compact (where advisable to insure stability or to prevent leaching of toxic materials), and grade in order to restore the approximate original contour of the land with all highwalls, spoil piles, and depressions eliminated</i> ”	Under the federal framework, the States are also able to enact their own legislation if the Office of Surface Mining Reclamation and Enforcement approves it. The State legislation must exceed the requirements of the Federal legislation. The <i>Surface Mining Control and Reclamation Act 1977</i> requires surface mine operators to	Reclamation plan and performance bond

⁴ <https://www.eia.gov/tools/faqs/faq.cfm?id=69&t=2>

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
			Generally open cut coal mines have been required to backfill since the 1970s. ⁵	<p>restore the land to a condition capable of supporting the uses it could support prior to mining, or to 'higher or better uses'. In order to achieve this, the operator is required to:</p> <ul style="list-style-type: none"> • restore the approximate original contour of the land • avoid acid mine drainage and prevent erosion to minimise impacts to nearby waters • reclaim the land in a timely manner • Establish appropriate vegetation that will cover the previously disturbed area. 	
USA	Wyoming	<p><i>Surface Mining Control and Reclamation Act 1977</i></p> <p>Wyoming Environmental Quality Act and LQD Coal Rules and Regulations</p>	LQD Coal Rules and Regulations require all affected land to be returned to their approximate original contour, except as authorised.	Nil found.	Reclamation plan and performance bond
USA	West Virginia	<i>Surface Mining Control and Reclamation Act 1977</i>	As per the <i>Surface Mining Control and Reclamation Act 1977</i> .	<p>Injection of coal slurry into underground mine voids has been undertaken in the past, however a moratorium on the practice has been imposed since 2009⁶</p> <p>Generally the State requires strict ground cover performance standards in the Appalachian coal region to ensure reforestation occurs.</p>	Reclamation plan and performance bond

⁵ U.S. Code (1977) Surface Mining Control and Reclamation Act of 1977, U.S. Code (Title 30, Chapter 25), Available at: <https://www.gpo.gov/fdsys/pkg/USCODE-2011-title30/pdf/USCODE-2011-title30-chap25.pdf>

⁶ <http://www.dep.wv.gov/dmr/studies%20and%20investigations/Documents/Slurry%20UIC%20Investigation.pdf>

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
USA	Kentucky	<i>Surface Mining Control and Reclamation Act of 1977</i>	As per the <i>Surface Mining Control and Reclamation Act 1977</i> .	Compaction is used to eliminate dangers of steep slopes and drops following high walls. Compaction after strip mining has caused difficulties with revegetation and reforestation. ⁷ Issues with coal refuse fires and abatement methods include complete excavation, quenching with water, foaming cements.	
USA	Pennsylvania	<i>Surface Mining Control and Reclamation Act of 1977</i> <i>Pennsylvania's Anthracite and Bituminous Coal Mine Safety Act(s)</i> <i>The Clean Streams Law, the Bituminous Mine Subsidence and Land Conservation Act</i>	As per the <i>Surface Mining Control and Reclamation Act 1977</i> . Significant backfilling of voids has been undertaken in Pennsylvania.	The reuse of mine waste particular coal ash has been used in mine reclamation since 1988 and ash from FBC power plants have also been used. ⁸ Pennsylvania has its own coal mine waste regulation for the reuse of coal waste in mine reclamation.	Reclamation plan and performance bond
USA	Illinois	<i>Surface Mining Control and Reclamation Act of 1977</i> <i>Resource Conservation and Recovery Act (USA EPA)</i> <i>Surface Coal Mining Land Conservation and</i>	<i>Surface Coal Mining Land Conservation and Reclamation Act (225 ILCS720)</i> requires backfilling, compaction and graded to restore original contour of the land (where advisable).	Impoundment of coal waste and coal slurry. Backfilling of voids are undertaken using coal slurry, also known as slurry backfilling.	Reclamation plan and performance bond

⁷ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

⁸ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
		<i>Reclamation Act (225 ILCS720)</i>			

Summary – Other Countries

Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
Russia	Russia	<i>Federal law on Environmental Protection</i> <i>Federal law on Subsoil use Russian-gosudarstvennyy standart – “GOST”s</i>	No specific requirement to backfill mining voids.	Rehabilitation technical standards include levelling, re-profiling, scraping, storage and placement of fertile soil and growth media, construction of diversion channels, and disposal of toxic wastes. ⁹	Post closure mine plans and schedule to be included within a mining licence.
China	China	<i>Environmental Protection Law of the People's Republic of China</i> <i>Regulations on Land Reclamation 1988</i>	No specific requirement to backfill mining voids.	Assumed that enforcement of the environmental protection laws does not occur and large companies do not pay environmental protection fees. ¹⁰ Preference to reclaim mines into agricultural areas due to shortages in farmlands. ¹¹	Site Decommissioning and Closure Report
India	India	Mineral Concession Rules 1960 Mineral Conservation and Development Rules 1988	Mineral Concession Rules requires the permit holder to fill holes or excavations to the extent required by the Deputy Commissioner. Mineral Conservation and Development	Due to water security issues, coal mines are filled in with mine water for groundwater recharge and seasonal rainfall is also diverted in pits. ¹² Backfilling and other remedial actions are	Progressive Mine Closure Plan and Final Mines Closure Plan

⁹ <http://www.srk.com.au/en/publication/au-comparative-study-regulatory-approaches-mine-closure-special-emphasis-current>

¹⁰ <http://www.srk.com.au/en/newsletter/focus-facility-closure/mine-closure-planning-chinese-mining-industry>

¹¹ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

¹² <http://www.cim.org/en/Publications-and-Technical-Resources/Publications/Proceedings/2013/8/23rd-World-Mining-Congress/WMCO-2013-08-471>

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
			Rules 1988 requires that waste rock and overburden shall be backfilled into the mine excavations with a view to restoring the land to its original use as far as possible. Where backfilling is not feasible, terracing should be used.	generally not realised due to lack of finances.	
Germany	Germany	<i>Federal Mining Act 1980 (Bundesberggesetz)</i>	No specific requirement to backfill mining voids.	Reclamation into lakes used for swimming. Has various regulations relating to mining reclamation including forest laws, water rights, regional planning laws and waste laws.	Operations plan, including the mine closure operations plan
Kazakhstan	Kazakhstan	<i>Law on Subsoil and Subsoil Use 2010</i> <i>Land Code</i>	No specific requirement to backfill mining voids.	Prevention of collapse, subsidence, landslide or flooding ¹³	President approves mine closure plan.
South Africa	South Africa	<i>Constitution of the Republic of South Africa 1996</i> <i>National Water Act 1998</i> <i>Water Services Act 1997</i> <i>National Environmental Management: Waste Act 2008</i>	No specific requirement to backfill mining voids.	Constitutional objectives are sustainable development, from which stems various statutes which regulates mine and water and waste. ¹⁴ Generally focuses on pumping and treating acid mine drainage, and discharging treated water into river systems. Water pricing strategy under the National Water Act aims to promote sustainable development and efficient use of water resources and create financial incentives for mining companies to discharge treated water.	Nil found.

¹³ <http://www.srk.com.au/en/publication/au-comparative-study-regulatory-approaches-mine-closure-special-emphasis-current>

¹⁴ <http://www.scielo.org.za/pdf/peli/v17n5/08.pdf>

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
Turkey	Turkey	<i>Regulation on Reclamation of Lands Disturbed by Mining Activities 2007</i>	No specific requirement to backfill mining voids.	Mining Laws require that land be returned to the user in a 'usable condition'. ¹⁵ Lack of interest in post-mining land use due to limit of value that can be added to post-industrial landscapes. ¹⁶	Reclamation plans
Brazil	Brazil	<i>Brazilian Constitution 1988</i> <i>Brazilian Mining Code (Decree-Law No. 227/1967) and, alternatively, the Regulation of the Mining Code (Decree-Law No. 62934/1968).</i>	No specific requirement to backfill mining voids. Constitution article 225, §2, "the person exploiting mineral resources must recover the degraded environment, in accordance to the technical solution required by the competent public authority, as set forth by law".	Brazilian Constitution requires mining companies to 'reclaim the degraded environment in accordance with the technical solution demanded by the competent public organisation'	Mining closure plan – Report of Recovery Plan of the Degraded Area
Canada	Ontario	Part VII of the Ontario <i>Mining Act</i> and Ontario Regulation 240/00 – Mine Development and Closure	Regulation specifies that open pits shall be rehabilitated by backfilling, however further subsections prescribed that this is not required where it is impracticable and flooding the pit, sloping the pit, using boulder fencing or berming may be used instead.	In Canada, the Provinces have full jurisdiction over the restoration requirements. The Federal government only becomes involved over issues of air and water pollution, particularly where issues may arise in more than one Province. The Code includes requirements to ensure the following minimum rehabilitation standards are met (these are specific to pits): <ul style="list-style-type: none"> ensuring that inadvertent access to mine openings from the surface is prevented limiting potential hazards and maintaining public safety around open 	Certified closure plan

¹⁵ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

¹⁶ <http://www.srk.com.au/en/newsletter/focus-facility-closure/mine-closure-regulation-turkey>

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Area	Jurisdiction	Relevant legislation	Regulatory requirement for backfilling mining voids	Other rehabilitation and mining void management	Planning document
				pits	
Canada	British Columbia	<i>Mines Act 1996</i> Health, Safety and Reclamation Code for Mines in British Columbia 2008	<p>The Code requires that voids from mining exploration are backfilled. However these pits and trenches from exploration do not need to be backfilled if the sides are sloped to a stable and safe angle determined by a suitably qualified person or it is fenced to prevent access or there is a means of egress.</p> <p>The Code requires various standards for the reclamation and closure of open pits based on if the pit contains water and if overburden has been used in. However backfilling is not specifically required.</p>	<p>In Canada, the Provinces have full jurisdiction over the restoration requirements. The Federal government only becomes involved over issues of air and water pollution, particularly where issues may arise in more than one Province.</p> <p>The Code outlines various reclamation standards for closure of open pits, dumps openings and impoundments.</p>	Decommissioning and reclamation plan for all mining projects with an environmental assessment

Case studies – Rehabilitation of mine voids across the world

Name of Mine or Project	Jurisdiction	Post-closure outcome / final land use
New Acland	Queensland, Australia	55ha of final voids have been authorised, final rehabilitation of these voids will be determined in the future through a mine closure plan.
Sand and gravel quarries Penrith	New South Wales, Australia	Recreational lakes and wetland areas.
Cadia Hill	New South Wales, Australia	Backfilling and returning to pasture for grazing and native forest.
Wesfarmers Premier Coal	Western Australia, Australia	Reclaimed into a recreational lake.
Jarrahdale mine	Western Australia, Australia	Recreational area, lakes and native eucalypt forest.
Ranger Uranium Mine ¹⁷	Northern Territory, Australia	Rehabilitation work included backfilling pits and dredging tailing dams to establish a similar environmental to the adjacent areas of Kakadu National Park. Approximately 100 million tonnes of rock is expected to be used as backfill.
Witwatersrand basin (gold fields) ¹⁸	South Africa	Discharge of contaminated water into nearby streams and rivers and the creation of a system of wetlands which serve as a water purification system.
El Terronal Mercury Mine ¹⁹	Asturias, Spain	Mine waste encapsulation and road construction over encapsulated mine.
Aitik copper mine ²⁰	Sweden	Use of industrial waste such as sewage sludge, fly ash and green liquor dregs to treat acid mine drainage and act as a sealing layer.
Injection coal slurry into mine voids, in Virginia 1983 -1999	West Virginia, USA	Injection of coal slurry into abandoned underground coal mines.
Big Bend Area ²¹	Texas, USA	Backfilling has been used at the Big Bend Area where dangerous highwalls, openings and pits were left abandoned. Closure includes backfilling, grate closures, bat friendly gates on openings, mortared walls, cable nets, and concreted caps.
Western Pennsylvania ²²	Pennsylvania, USA	1 Mt of amended fill using coal combustion by-

¹⁷ <http://www.abc.net.au/news/2016-04-29/traditional-owners-welcome-deal-over-ranger-uranium-mine/7372554>

¹⁸ <http://www.scielo.org.za/pdf/pelj/v17n5/08.pdf>

¹⁹ <http://www.wolkersdorfer.info/publication/pdf/0269-Jarvis.pdf>

²⁰ <http://www.wolkersdorfer.info/publication/pdf/0269-Jarvis.pdf>

²¹ <http://www.slideshare.net/JEBrandt/historical-mining-in-texas-and-the-abandoned-mine-land-program>

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Name of Mine or Project	Jurisdiction	Post-closure outcome / final land use
		products was used to return a double high wall along 3353 m of hillside.
Zwenku Lake,	Zwenkau, Germany	Flooding old mines to create a network of lakes in Lusatia
Southern area of Leipzig	Leipzig, Germany	Flooding 8 mining lakes, using pipelines to move water.
Bergheim lignite mine ²³	Rhenish , Germany	In this region several mines are locate in close proximity, and backfill waste material from the mines are transported to a central location (Bergheim lignite mine) and reused at to optimise the speed of backfilling, while reducing storage requirements. This mine has been reclaimed into forest.
Germano Mine ²⁴	Brazil	Backfilling iron ore open pit with coarse sand tailing from Germano Plant. This option was chosen due to the many landslide occurrences.
Riacho dos Machados ²⁵	Brazil	Pit was filled with water and reclaimed into a lake.
Suncun Coal Mine ²⁶	Shangdong, China	Crushed mining wastes were mixed with cement to backfill mined cavities as a way to lessen subsidence.

²² https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

²³ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf

²⁴ http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0370-44672011000200012

²⁵ http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0370-44672011000200012

²⁶ https://www.usea.org/sites/default/files/022013_Coal%20mine%20site%20reclamation_ccc216.pdf



THE MINE REHABILITATION SPECIALISTS
highlandsenvironmental.com.au

FINAL REPORT

**SOIL AND LAND RESOURCE SUITABILITY ASSESSMENT
FOR SUSTAINABLE CATTLE GRAZING OF
REHABILITATION AT ENSHAM MINE**

16 December 2017

Prepared for Ensham Resources

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EXECUTIVE SUMMARY

Rehabilitation that is suitable for sustainable cattle grazing is a statutory objective for most rehabilitation at Ensham mine, central Queensland. This document reports an evaluation of soil and land resources across approximately 1,000 hectares of rehabilitation and determines the suitability of that rehabilitation for sustainable cattle grazing using standard government-defined criteria. It also provides some recommendations for land and grazing management.

Of the 20 discrete areas of rehabilitation assessed, 17 of these are land suitability class 4 and three of these are land suitability class 5. Land suitability class 4 rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. Land suitability class 5 rehabilitation has extreme limitations that preclude grazing of the land for most of the year.

Primary limitations to sustainable grazing in rehabilitation are: erosion risk; strong to very strong alkalinity in topsoils and mine overburdens (now subsoils in rehabilitation); poor soil water retention capacity; and, low soil fertility. Most of these limitations are inherent to the constructed post-mining landscape and are enduring characteristics of the rehabilitation. However, limitations like these are not unique to mine rehabilitation and are common limitations in unmined grazing lands across central Queensland.

Recommendations are provided for the mitigation of particular limitations, e.g. strong alkalinity in soils, in existing and future rehabilitation, and also for future grazing systems in rehabilitation. The appropriate grazing production model for rehabilitation is a *store weaner production* model. In this system the main products are store weaners for sale or growing on better country, which is not rehabilitation.

1 INTRODUCTION

A post-mining land use of sustainable cattle grazing is an important objective for most rehabilitation at Ensham mine. In 2017 this objective was formalised in Environmental Authority (EA) EPML00732813 and applies to most rehabilitation domains at the mine (see EA condition G5 and Appendix 4). Rehabilitation that comprises soil and land resources that are suitable for sustainable cattle grazing is a critical measure of rehabilitation success at Ensham.

This document reports an evaluation of soil and land resources in rehabilitation and determines the suitability of that rehabilitation for sustainable cattle grazing using standard government-defined criteria. Highlands Environmental Pty Limited completed this work in September - November 2017.

1.1 Study area

This study evaluated soil and land resources across approximately 1,000 hectares (ha) of rehabilitation at Ensham mine. In 2017 existing rehabilitation had been stratified into 21 'rehabilitation polygons' for monitoring and mapping. Polygons were based on core rehabilitation attributes, e.g. age, spoil type, topsoil and vegetation. Each polygon represents an area of rehabilitation that is more-or-less homogeneous. None of the existing rehabilitation pre-dates 2004.

1.2 Previous land resource studies

Several studies have assessed land resources in the pre-mining landscape at Ensham mine. Some of these studies have also proposed possible post-mining outcomes, however none have actually assessed land resources following open-cut mining and rehabilitation. These studies form a record of pre-mining conditions, and also a benchmark against which post-mining outcomes can be gauged.

1.2.1 Regional assessments

The Queensland Government and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have undertaken regional-scale mapping of land resources and soils throughout much of Queensland, including the study area. Relevant studies, which assessed pre-mining land resources, are summarised as follows.

Lands of the Nogoa-Belyando Area, Queensland (Galloway *et al.* 1967 for CSIRO).

This early study mapped soils across most of the Central Highlands region comprising the former shires of Bauhinia, Emerald, Peak Downs and part of Jericho, an area of 9 million hectares (ha). The landscape was assessed using the reconnaissance survey method that mapped and described the area in terms of 43 land systems, and arranged soils into seven major groups with 34 families (all via a now superseded classification scheme). Although this work excluded the study area (the boundary was Crinum Creek), because of its close proximity it does provide a preliminary indication of soil types that can be expected.

Land Units of the Fitzroy Region, Queensland (Nix and Gunn, 1977 for CSIRO)

This was the last report of its type by CSIRO and reflects considerable methodology changes compared to earlier reports, though these too are now superseded. This report consolidates and restructures information from three earlier reports covering the same area, almost 20 million ha and including the study area. It identified 142 simple land units with associated lithology, soils and vegetation, and also land capability.

Soils in the study area are mapped as alluvial clay soils near to the Nogoa River (land units 39-53 and 123-142), and skeletal soils to the north and adjacent to Boggy Creek (land units 54-56). Probable specific land units within these mapping groups have been interpreted from mapping (Table 1-1).

Table 1-1 Land unit descriptions within the study area (after Nix and Gunn, 1977)

Study area	Land unit	Lithology	Terrain	Soil	Vegetation	Land capability
South-side of Nogoia River	127	Alluvium, medium to fine texture	Level to very gently sloping	Deep texture contrast soils	Brigalow open forest	V
North-side of Nogoia River	41	Tertiary clay	Level to gently undulating	Deep cracking clay soils	Brigalow open forest	III
Along northern part of Boggy Creek	55	Quartz sandstone	Mountainous to hilly	Skeletal, shallow	Sandstone open forest	VII-VIII

Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources. Although detail of the assessment conducted in this study is not known, contemporary general definitions used in land and soil capability assessment provide a sound guide and approximation to the outcomes of this study, viz.

Land and soil capability classes (LSCC) I, II and III – Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation) with few to moderate limitations.

LSCC IV and V – Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation) but Class V land should not be cultivated.

LSCC VI – Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture) with moderate limitations.

LSCC VII and VIII – Land generally incapable of agricultural land use (selective forestry and nature conservation) (from State of NSW and Office of Environment and Heritage, 2012 and Queensland Government, 2017a)

Lands Resource Survey and Evaluation of the Kilcummin Area, central Queensland (Shields and Williams, 1991).

This report provides a practical application of land resource assessment techniques. These techniques have been used to supplement contemporaneous guidance materials issued by Government.

Understanding and Managing Soils of the Central Highlands (Bourne and Tuck, 1993).

This landmark report underpins most modern land resource assessments in central Queensland. This study identified six broad land resource areas (LRAs) that cover the central Highlands and within these, 18 agricultural management units (AMUs) (Table 1-2). Mapping units within the study area have been interpreted and reveal five LRAs could have been present pre-mining (Table 1-3).

Table 1-2 Relationship of LRAs to AMUs (from Bourne and Tuck, 1993)

LRA	AMUs	
	Major occurrence	Minor occurrence
Alluvial plains	Adelong, Moramana, College	Dooruna, Isaac, Lascelles, Lonsome, Rolleston, Turkey Creek
Undulating scrub plains	Rolleston, Picardy, Springton, Turkey Creek, Glengallan, Glen Idol	Adelong, Lonsome
Eucalypt duplex plains	Lascelles, Duckponds	Glengallan, Turkey Creek, Glen Idol
Undulating downs	Orion, Jimbaroo	Kia-Ora, Glen Idol, Moramana

LRA	AMUs	
	Major occurrence	Minor occurrence
Plateaus	Duckponds	Glen Idol, Highlands, Lascelles
Ranges	Highlands	Lascelles, Glen Idol

Table 1-3 LRA descriptions within the study area (after Bourne and Tuck, 1993)

LRA	Landform	Soils	Vegetation	Land use
Alluvial plains	Level plains on Quaternary alluvium	Alluvial clays	Eucalypt woodland	Rainfed and irrigated cropping, grazing
Undulating scrub plains	Undulating plains on sedimentary rocks, Tertiary basalt and unconsolidated sediments	Cracking clays	Brigalow	Rainfed cropping, grazing
Eucalypt duplex plains	Gentle plains to low hills	Mainly solodic soils	Poplar box woodlands	Grazing
Undulating downs	Gentle plains on Tertiary basalt	Cracking clays	Dense grasslands	Rainfed cropping and grazing
Ranges	Hills to very steep hills	Stony lithosols, minor earths	Ironbark, bendee, Acacia spp.	Grazing native pastures

1.2.2 Local assessments

Ensham Central Project EIS, Terrain, Soil and Land Capability Assessment Study (Hansen Bailey, 2006)

Hollingsworth, Dames and Moore (1991) mapped soils for the Ensham mine in the late 1980s, identifying six major soil units. Later, Hansen Bailey (2006) supplemented this work with further field investigation for a subsequent mining approval. Although the latter study focussed only on land immediately adjacent to the Nogoa River, much of the information is relevant to the study area. For example the geological regime, which is summarised as follows.

- Quaternary Alluvium; River and Floodplain Deposits – clay, silt, sand, gravel.
- Cainozoic Soil Cover including Older Alluvial and Colluvial Deposits – soil, sand, siliceous and ferruginous gravel and reworked laterite.
- Tertiary Emerald Formation – argillaceous sandstone, lateritised sediments, laterite, claystone, siltstone, sandstone and pebbly sandstone.
- Permian Undifferentiated Blackwater Group which includes the Rangal Coal Measures, Burngrove Formation and Fairhill Formation which comprise carbonaceous mudstone, thinly interbedded mudstone and fine sandstone, siliceous siltstone, lithic calcareous and feldspathic sandstone, tuff and coal seams.

Each of these materials is readily identifiable in rehabilitation at Ensham where it may or may not be covered with soil.

Hansen Bailey (2006) adopted the major soil groups identified by Hollingsworth, Dames and Moore (1991). These groups were:

1. Shallow rocky (skeletal) soils - Rudosols
2. Moderately shallow gravelly sands, loams and clay soils – Rudosols and Tenosols
3. Gradational red and yellow earths – Tenosols, Kandosols and Ferrosols
4. Duplex soils - Sodosols
5. Uniform, fine textured, non-cracking clays - Dermosols
6. Cracking clay soils - Vertosols

In terms of land suitability for sustainable cattle grazing, Hansen Bailey (2006), using QDME (1995), found that pre-mining the land was a mix of Class 1 to Class 5 land, and forecast that post-mining the rehabilitation would be a mix of Class 2, 4 and 5 land for grazing land use.

1.3 Cattle grazing trials in coal mine rehabilitation

Cattle grazing productivity metrics are not a component of soil and land resource suitability assessment for sustainable grazing in Queensland. However, 'grazing trials' do provide good and useful supplementary information about what happens to soil and land condition, and also pasture and cattle condition, when cattle graze rehabilitation.

1.3.1 Industry trials

Land Use – Liddell Grazing Trial (GCAA, undated)

This paper summarises a recent cattle grazing trial at Liddell coal mine in the Hunter Valley, NSW. The trial consisted of 70 ha each of rehabilitation (3 to 10 years old) and unmined land, and Charbray steers at a stocking rate of one beast per 2.4 ha. Cattle were grazed for 18 months and key results for soil, pasture and cattle are summarised as:

- Soil – soils in rehabilitation had elevated salinity and sodicity;
- Pasture – groundcover was maintained above 70% throughout the trial;
- Cattle – cattle in rehabilitation gained more weight over the period, though testing showed blood copper deficiency.

Sustainable Grazing on Rehabilitated Lands in the Bowen Basin – Stages 1 and 2 (Grigg *et al.* 2006)

This Australian Coal Association Research Program (ACARP) sponsored research by The University of Queensland considered several grazing regimes in small areas at Goonyella Riverside, Norwich Park and Blackwater coal mines in central Queensland. Conclusions from this study are:

- Pasture-based coal mine rehabilitation has the capacity to support cattle grazing;
- Estimated sustainable stocking rates on rehabilitation are 2.2 to 5.6 ha/head;
- High productivity pasture at Norwich Park coal mine can sustain a stocking rate of 3 ha/head, and this is comparable to rates on better improved pastures on unmined land in the region.

1.3.2 Local trials

Yongala Grazing Trial and Assessment, 2016 Report (CHRRUP, 2016)

This study assessed soil and pasture condition pre- and post-grazing in rehabilitation at Y Pit, in the northern most area of the mine. Grazing consisted of 110 cows with calves at foot on 94 ha of rehabilitation, plus minor other areas and unmined land summing to 115 ha total. Cattle were grazed for a period of 142 days between December and April 2016. Key results of this trial were:

- Grazing removed about 50% of the pasture (standing dry matter);
- Groundcover was reduced only slightly from 94% to 89%;
- Grazing did not affect soil condition;
- Cows held their condition and this was unexpected by the cattle owner because the condition of his lactating cows typically declines.

Nogoa Pastoral Company grazing trial 2017 (unpublished)

In 2017 Nogoa Pastoral Company introduced cattle to an area at A Pit, in the southern part of the mine, which included 92 ha of rehabilitation, plus minor areas of other disturbance and unmined land. Approximately 83 head of 18-24 month old Santa Gertrudis steers were grazed for 240 days. The weight of each beast was recorded on the first and last day of the grazing period. Although there was some variation within the herd, the average daily weight gain per beast was 0.335 kg/head/day.

2 METHODS

The methodologies used in this assessment are detailed as follows.

2.1 Applying recognised standards

In this land resource assessment, Highlands Environmental has applied the following suite of recognised industry standards and guidelines.

Soil and landscape field assessment

National Committee on Soil and Terrain (2009) *Australian Soil and Land Survey Field Handbook*, Third Edition, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Soil survey specifications

McKenzie N, Grundy M, Webster R and Ringrose-Voase A (2008) *Guidelines for Surveying Soil and Land Resources*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Soil classification

Isbell RF (1996) *The Australian Soil Classification*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Field vegetation assessment

Hnatiuk R, Thackway R and Walker J (2009) *Vegetation*, In: Australian Soil and Land Survey Field Handbook, Third Edition, Australian Soil and Land Survey Handbook Series, National Committee on Soil and Terrain, CSIRO Publishing, Melbourne.

Soil chemistry

Rayment G and Lyons D (2011) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Soil physics

McKenzie N, Coughlan K and Cresswell H (2002) *Soil Physical Measurement and Interpretation for Land Evaluation*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Land suitability for sustainable grazing

DNRM/DSITIA (2013a) *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition, Queensland Government, Brisbane.

DNRM/DSITIA (2013b) *Regional Land Suitability Frameworks for Queensland, Chapter 10 - Suitability framework for the Inland Fitzroy and Southern Burdekin area*, Queensland Government, Brisbane.

QDME (1995) *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Mines and Energy, Brisbane.

2.2 Mapping scale and sampling intensity

The mine had previously identified 21 'rehabilitation polygons' summing to approximately 1,000 ha of existing rehabilitation. Polygon boundaries were defined by the core rehabilitation attributes of year sown, spoil type, topsoil and vegetation, to group areas of like rehabilitation. Adopting these rehabilitation polygons as a basis for fieldwork, and with consideration to the degree of landscape complexity this accounted for, a final mapping scale of 1:50,000 is considered appropriate.

According to Queensland Government (2017b) mapping at this scale requires an investigation density of 1 site per 20-100 ha. As rehabilitation polygon boundaries were untested, it was decided to target a site density

of 1 per 25 ha, knowing that this would also allow mapping at moderately high intensity scale of 1:25,000 if required in future. This equates to 47 sites across the study area.

McKenzie *et al.* (2008) recommend at least 5% of sites should include soil profile description with laboratory analysis, 35% sites should include soil profile description only, and 60% of sites should be observational only. However, to ensure that each of the previously identified polygons could be mapped with certainty, a constraint of at least one detailed soil profile description with laboratory testing per polygon was applied. In addition, other recent soil sampling data was also incorporated to provide a total of 59 sites, and a very high level of detail in the investigation (Table 2-1).

Table 2-1 Recommended and actual site densities within the study area

Site density	Detailed	Check	Observation	Total
Recommended	2	17	28	47
Actual	33	24	2	59

The location of each site within polygons across the rehabilitated landscape is provided (Appendix A).

2.3 Fieldwork

Fieldwork was completed in August and September 2017. Within polygon constraints, fieldwork used 'free survey' techniques (McKenzie *et al.* 2008) to collect site information. All field descriptions were collected in accordance with standards outlined by the Soil and Terrain (2009), Hnatiuk *et al.* (2009) and Isbell (1996). Soil profiles were excavated by hand auger to a depth of 900mm or refusal on rock or impenetrable gravel. Soil profiles were described, photographed and sampled for laboratory testing in the field. Depending on total hole depth, soil samples were taken from the following depth increments: 0-100mm, 200-300mm, 400-500mm, 600-700mm and 800-900mm.

2.4 Laboratory analyses

Soil samples were analysed at Incitec Pivot Limited's Nutrient Advantage Laboratory Services in Werribee, Victoria. This facility holds the following accreditations:

- NATA Accredited Laboratory (Accreditation No. 11958), demonstrating technical competence to operate in accordance with ISO/IEC 17025 for chemical testing;
- ASPAC (Australian Soil and Plant Analysis Council Inc.), certifying the laboratory meets proficiency criteria to conduct analysis in accordance with Rayment and Lyons (2010); and,
- FERTCARE, by AgSafe, accredited advisor.

The following laboratory analyses were performed.

1. For all surface soil fractions, a full soil fertility suite
Ammonium, nitrate, phosphorus (P) (Colwell), phosphorus buffer index (PBI), sulphur (MCP), exchangeable cations (calcium, magnesium, potassium, sodium and aluminium), pH (water) and pH (CaCl₂), chloride, electrical conductivity (water and saturated), organic carbon, colour, and texture, and copper, iron, manganese, zinc and boron
2. For other depth fractions, a limited salinity based suite
pH (water) and pH (CaCl₂), electrical conductivity (water and saturated), exchangeable cations (calcium, magnesium, potassium, sodium and aluminium), calcium/magnesium ratio, exchangeable sodium percentage, colour and texture

2.5 Land suitability framework

2.5.1 Land classes

Five land suitability classes are defined for use in Queensland (DNR/DSITIA 2013a), with land suitability decreasing progressively from Class 1 to Class 5. These classes are used to describe an area of land in terms of suitability for a particular land use which allows optimum, sustainable production with current technology, while minimising degradation to the land resource in the short, medium or long-term. Land is considered less suitable as the severity of limitations affecting a particular land use increases, reflecting either:

- Reduced potential for production; and/or,
- Increased inputs required to achieve an acceptable level of production; and/or,
- Increased inputs required to prepare the land for successful production; and/or,
- Increased inputs required to prevent land degradation.

The five land suitability classes defined for Queensland are described (Table 2-2).

Table 2-2 Land suitability classes (adapted from DNR/DSITIA, 2013a and QDME, 1995)

Class	Suitability	Limitations	Description
1	Suitable	Negligible	Highly productive land that is well suited to the proposed use
2	Suitable	Minor	Land with limitations that either constrain production, or require more than the simple management practices of class 1 land to maintain sustainable production
3	Suitable	Moderate	Land with limitations that either further constrain production, or require significant inputs to ensure sustainable use
4	Marginally suitable	Severe	Land which is marginally suited for a proposed use and would require major inputs to ensure sustainability; often the inputs required may not be justified in terms of the benefits to be gained from using the land for a proposed use and the land is considered presently unsuitable for that use
5	Unsuitable	Extreme	Land with extreme limitations that preclude any possibility of successful sustained use of the land in the proposed manner

Classes 1 to 3 are considered suitable for a specified land use because the benefits from using the land (for that particular use) outweigh the inputs required to initiate and maintain production.

Typically, the benefits from using Class 4 land are similar in magnitude to the level of inputs required to achieve production and its long-term suitability for the specified land use is doubtful. Class 4 is also used in situations where reducing the effect of a particular limitation may indicate production is possible, but additional studies are needed to determine the feasibility of such actions, e.g. fertilisation.

In contrast, there is no doubt regarding the long-term suitability of Class 1–3 lands or the unsuitability of Class 5 land. Class 5 land has limitations that in aggregate are so severe that the benefits do not justify the inputs required to initiate and maintain production. It would require a major change in economics, technology or management expertise before the land could be considered suitable for the land use being considered. Many Class 5 lands have physical characteristics that totally preclude any form of development, e.g. mountains, and will always remain unsuitable for agriculture.

2.5.2 Land suitability for sustainable beef cattle grazing

The suitability classification for grazing evaluates soils in terms of the potential to graze and finish cattle on improved pastures (QDME 1995, Shields and Williams 1991). Typically, grazing systems in inland central Queensland aim to produce young, finished, grassfed, export quality cattle without inputs other than pasture development. Most production is based around improved grass-legume pastures. Improved pasture development in many areas is dominated by buffel grass, although Rhodes grass, introduced bluegrasses (Indian bluegrass, creeping bluegrass), purple pigeon grass and panic species all have a role in certain situations. Legume establishment and species vary significantly depending on soil characteristics and

microclimates. Commonly used legumes include shrubby stylos species, Desmanthus species, Wynn cassia (sandy soils), butterfly pea (clay soils), siratro, medics and leucaena (cropping soils).

Class 1 and 2 land is considered suitable for grazing improved pastures and is capable of attaining maximum grazing productivity (QDME 1995, Shields and Williams 1991). In inland central Queensland this can be defined as the production of young, finished, grassfed, export quality cattle in most seasons, and such country is termed 'fattening country'.

Class 3 land is suitable for grazing improved pastures but is generally less productive than Classes 1 and 2 and encompasses a range in productivity. Land in this class is often termed 'growing country' and is defined as country on which younger cattle perform well but may be difficult to finish at a young age, depending on seasonal conditions, i.e. cattle on Class 3 land may take longer to achieve the desired weight class or finished grade than equivalent cattle on Classes 1 and 2 land.

Class 4 land is considered marginal for grazing improved pastures, but is generally considered suitable for grazing native pastures of varying quality all year round, depending on soil characteristics, (QDME 1995, Shields and Williams 1991). In inland Central Queensland such country is typically termed 'breeding country'. It encompasses a range in productivity from the lower end of Class 3 growing country through to the poorer end of Class 4 breeding country. Shields and Williams (1991) suggest 3 possible subclasses exist within Class 4:

- Land with native pasture of low productivity, which while physically capable of being developed to improved pasture, is subject to low soil fertility and doubtful long term productivity;
- Land with high quality native pasture (typically black soil downs) on which improved pasture establishment is marginal because of unfavourable soil characteristics and limited species; and
- Land with native pasture of low productivity, which has physical limitations that preclude fully improved pasture development, but allow over-sowing of legumes such as shrubby stylo.

For coal mine rehabilitation that is Class 4 breeding country, the appropriate production system is a store weaner production model. In this model herds will consist mostly of cows (>2 years of age) with or without calves at foot, replacement heifers (<2 years of age) and a low percentage of bulls (≤3%). The primary product is store weaners for sale or growing on better country, with surplus heifers and empty cows as secondary products.

Class 5 land is unsuitable for any form of pasture improvement and land use is limited to extensive grazing of native pastures of low productivity. In many cases, lands are of such poor quality they are considered marginal as breeding country and may be destocked in the winter/dry season, unless grazed in conjunction with better quality country. Land in this class is mostly used as breeding country during the summer/wet season when planes of nutrition are higher.

2.5.3 Land use requirements and limitations

Following DNR/DSITIA (2013a, 2013b), QDME (1995), and Shields and Williams (1991), a set of 15 land use requirements and associated limitations has been identified as important for sustainable grazing of land rehabilitated after mining in central Queensland (Table 2-3).

Table 2-3 Land use requirements & limitations for sustainable cattle grazing on rehabilitation

Land use requirement	Limitation	Criteria	Subclass code
Slope gradients appropriate to soil types.	Surface soil erodability	Moderately stable soils, <5%; non-cohesive soils, <5%; dispersive soils, <3%; highly erodible soils, <1%.	Ea1
		Moderately stable soils, 5-10%; non-cohesive soils, 5-8%; dispersive soils, 3-5%; highly erodible soils, 1-3%.	Ea2
		Moderately stable soils, 10- 15%; non-cohesive soils, 8-10%; dispersive soils, 5-8%; highly erodible soils, 3-5%.	Ea3
		Moderately stable soils, 15- 20%; non-cohesive soils, 10-15%; dispersive soils, 8-10%; highly erodible soils, 5-8%.	Ea4
		Moderately stable soils, >20%; non-cohesive soils, >15%; dispersive soils, >10%; highly erodible soils, >8%.	Ea5

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Land use requirement	Limitation	Criteria	Subclass code
	Subsoil erodability	Non-dispersive, <5%; Non-cohesive, <1%; Dispersive, <0.5%; Extremely dispersive, n/a.	Eb1
		Non-dispersive, 5-10%; Non-cohesive, 1- 5%; Dispersive, 0.5-3%; Extremely dispersive, <0.5%.	Eb2
		Non-dispersive, 10-15%; Non-cohesive, 5-10%; Dispersive, 3-10%; Extremely dispersive, 0.5- 3%.	Eb3
		Non-dispersive, 15-20%; Non-cohesive, 10-15%; Dispersive, 5-10%; Extremely dispersive, 3- 8%.	Eb4
		Non- dispersive, >20%; Non-cohesive, >15%; Dispersive, >10%; Extremely dispersive, >8%.	Eb5
Adequate water supply. Soil has capacity to hold rainfall and make it available to pasture species at a later time.	Soil water availability	PAWC >125mm PAWC 100-125mm PAWC 75-100mm PAWC 50-75mm PAWC ≤50mm Estimated via method described in QDME (1995).	M1 M2 M3 M4 M5
Seedbed for seed germination.	Surface condition	Soft or loose sandy to sandy loam; or very fine self-mulching clays (peds less than 2mm). Soils with soft, firm or only weakly had setting, sandy to loamy surface; or fine self-mulching clays (peds 2-5mm) or coarse self- mulching clays (peds >5-10mm). Clay soils with hard setting, firm pedal or weakly self-mulching surface; or very coarse self-mulching clays (peds >10mm). Loamy, fine sand, silty or clayey surface, extremely hard setting, massive or crusting.	Ps1 Ps2 Ps3 Ps4
Rock-free surface soils	Rockiness	<20% pebbles <60mm and rock outcrop. 20-50% pebbles <60mm and rock outcrop. >50% pebbles <60mm; or 20-50% cobbles 60-200mm. >50% cobbles 60-200mm; or 20-50% stone >200mm. >50% stone or rock outcrop.	R1 R2 R3 R4 R5
Accessible land	Micro-relief	Nil. Shallow melonhole gilgai, 0.3-0.6m, 30- 70% surface area. Normal linear gilgai, 0.1-0.3m), <30% surface area. Strong, deep melonhole gilgai, 0.6-1.5m, <30% surface area. Normal linear gilgai, 0.1-0.3m), 30-50% surface area. Strong, deep melonhole gilgai (0.6-1.5m), 30- 70% of land surface. Normal linear gilgai, 0.1-0.3m), >50% surface area. Strong, deep melonhole gilgai (0.6- 1.5m), >70% of land surface	Tm1 Tm2 Tm3 Tm4 Tm5
Aerobic soil conditions (soil drainage conditions)	Wetness	Rapid draining to moderately well drained and slowly permeable. Imperfectly drained and highly permeable. Imperfectly drained and moderately permeable. Imperfectly drained and slowly permeable. Poorly to very poorly drained.	W1 W2 W3 W4 W5
Not affected by AMD or acid-sulphate soils	Acid drainage, real	pH<4 not present or present at depths >2m pH4 present at depths 1-2m pH4 present at depths 0-0.5m pH4 present at in surface soils	Ar2 Ar3 Ar4 Ar5
	Acid drainage, potential	%S > action threshold not present %S > action threshold at depths >1.5m %S > action threshold at depths >1-1.5m %S > action threshold at depths >0.5m %S > action threshold in surface soils	Ap1 Ap2 Ap3 Ap4 Ap5
Adequate nutrient supply	Nutrient deficiency	P >20mg/kg P 10-20mg/kg P 5-10mg/kg	Nd1 Nd2 Nd3 Nd4

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Land use requirement	Limitation	Criteria	Subclass code
		P <5mg/kg	
Nutrient imbalance	Nutrient imbalance	pH 6.6 – 7.3 pH 6.0 – 6.5 pH 5.1 – 5.5 or pH 7.4 – 8.4 pH 4.1-5.0 or pH 8.5 to 9.9 pH ≥10 or ≤4	Tx1 Tx2 Tx3 Tx4 Tx5
Adequate soil depth to support vegetation	Soil depth	>750mm 500 – 750mm 250 – 500mm <250mm	Sd1 Sd2 Sd3 Sd4
Salinity free root zone	Root zone salinity, in 0-60cm fraction (QDME, 1995)	ECe <2dS/m ECe 2-4dS/m ECe 4-8dS/m ECe 8-16dS/m ECe >16	Sa1 Sa2 Sa3 Sa4 Sa5
Absence of undesirable vegetation	Vegetation	Improved pastures (grass and legumes) with Eucalypt dominated overstory on non- gilgai forming soils. Improved pastures (grass and legumes) with or without overstory species on non-gilgai forming soils. Native pastures with or without Acacia dominated overstory on non-gilgai forming soils. Native pastures with Acacia dominated overstory on gilgai forming soils.	V1 V2 V3 V4
Practical land area available	Landscape complexity	>10ha 5-10ha 2.5-5ha <2.5ha	Lc1 Lc2 Lc3 Lc4

The overall objective of land suitability classification is to allocate a final suitability class for a specific land use, in this case sustainable cattle grazing. The suitability subclasses for all limitations must be considered and these function as a set of rules to determine overall suitability classes. In this assessment there are 71 rules (see Table 2-3), developed from literature review and local experience. As in all land suitability assessments, the limitation with the lowest subclass ranking score determines the overall suitability score.

3 RESULTS

This section provides a comprehensive summary of field descriptions, analytical data, interpreted attributes of soils and land suitability within rehabilitation. Traditionally, results of land suitability assessments are presented on a soil mapping unit basis. For the reasons outlined in the previous section, and because most soil profiles in rehabilitation are Anthroposols, the following results are presented on a rehabilitation polygon basis.

Anthroposols are soils resulting from human activities which have led to profound modification, truncation or burial of the original soil horizons, or the creation of new soil parent materials by a variety of mechanical means (Isbell, 1996). These soils are different from all others and it may or may not be possible to understand their origin using pedogenic attributes. For example, it may not be possible to say that a particular Anthroposol was derived from stripping and replacing the surface fraction of a Dermosol or Sodosol in the mining process. In this section only key analytical data is presented and original laboratory reporting sheets are also provided (Appendix B).

3.1 Rehabilitation Polygon 1

Rehabilitation Polygon 1 has a total area of 61.6ha and is located in A Pit, south of the Nogoa River. The current land use is grazing and cattle were present on the land during fieldwork. Rehabilitation works were conducted in 2009.

3.1.1 Sites

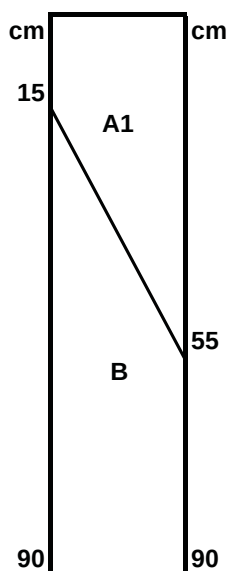
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
1	0649555,7396129	Detail	Top of landform	<2%	Rhodes grass, minor Buffel grass, minor Stylo spp.	25cm	Tertiary	90cm
2	0649419,7395462	Detail	Upper slope	10%	Rhodes grass, minor Stylo spp.	15cm	Permian	90cm
3	0649388,7395246	Check	Lower slope	10%	Rhodes grass	25cm	Permian	90cm
4	0649864,7396146	Check	Lower slope	10%	Buffel grass	n/a	n/a	20cm
5	0649670,7397045	Check	Upper slope	<5%	Rhodes and Buffel grasses	55cm	n/a	55cm
6	0649760,7396947	Obs.	Upper slope	10%	Rhodes and Buffel grasses	25cm	n/a	25cm

3.1.2 Representative photographs



Surface and vegetation conditions at Site 1 (left), Site 2 (middle) and Site 5 (right)

3.1.3 Soil profile description



The **topsoil (A1)** is a brown (7.5YR4/3, Site 1) to dark red brown (2.5YR3/4, Site 2), yellow red (5YR4/6, Site 3) and brown (7.5YR4/1, Site 5) colour, sandy loam to sandy clay, with a granular (free draining) structure. Soil can be stoney (Site 4). Field pH was neutral to alkaline, ranging from 6.5 (Site 1) to 8.0 (Site 5). Clear change to:

Subsoil (B) is mine overburden, mostly of Permian age by field observation. Texture is sandy clay to clay, and structure is blocky to massive with some mottling (45cm, Site 3) indicating low permeability. Gravel and rock is present. Subsoil is alkaline, ranging from 8.0 (Sites 1 and 2) to 8.5 (Site 3) and 9.0 (Site 5).

Profile photo is Site 2.



3.1.4 Laboratory analyses

Site 1

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.4	0.4	3.09	2.3	0.26	0.54	<0.02	<1.0	4.3	8
20-30	8.5	0.5	6.52	4.6	0.18	1.5	0.26	4	3.1	-
40-50	9.3	1.2	18.7	10	0.21	6.4	1.7	8.9	1.6	-
60-70	9.2	2	24.5	14	0.23	7.2	2.5	10	1.9	-
80-90	8.8	3	23.7	12	0.32	8.2	3.2	14	1.5	-

Site 2

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.3	0.3	7.39	5.4	0.35	1.6	0.04	0.6	3.4	5
20-30	9.1	0.7	27.3	19	0.32	7.8	0.51	1.9	2.4	-
40-50	9.4	1	30	19	0.36	9.7	1.5	4.9	2	-
60-70	9.5	1.4	31.2	18	0.39	10	2.5	8	1.8	-
80-90	9.5	1.9	30.8	18	0.34	9.4	3.1	10	1.9	-

Site 4

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	5.83	4.3	0.54	0.98	0.03	0.5	4.4	15

Soil pH is neutral to alkaline in surface soils and very strongly alkaline at depth (pH>9). Saturated EC levels indicate low salinity to only slight salinity at depth (3dS/m). Surface CEC is very low (3.09-7.39 Meq/100g), reflecting the sandy texture of topsoils and an inherent low capacity to retain plant nutrients. CEC increases with depth and increasing clay content of subsoils to high levels (>30 Meq/100g). ESP indicates surface soils are non-sodic (<0.6%) and not prone to dispersion when wet. Subsoils are sodic to moderately sodic (≤14%) and although relatively benign in central Queensland coal mining terms, will be prone to dispersion and accelerated erosion if uncovered.

3.1.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	1	1	2	2	1	1	3	3	1	2	2	1

Rehabilitation Polygon 1 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitation/s making it marginally suited for cattle grazing and will require major inputs to ensure

sustainability and prevent land degradation. The key limitation/s to sustainable cattle grazing in this rehabilitation are: subsoil erosion risk (Eb4).

3.2 Rehabilitation Polygon 2

Rehabilitation Polygon 2 has a total area of 30.3ha and is located in A Pit, south of the Nogoia River. It was rehabilitated in three stages in 2004, 2006 and 2009, and the current land use is cattle grazing.

3.2.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
7	0649876,7397049	Detail	Upper slope	7%	Buffel grass	25cm	Tertiary	90cm
8	0650157,7396932	Check	Lower slope	10%	Buffel grass	35cm	Tertiary	45cm

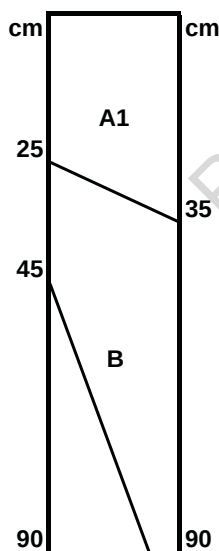
3.2.2 Representative photographs



Surface and vegetation condition at Site 7 (left and right)

3.2.3 Soil profile description

Profile photo is Site 7.



The **topsoil (A1)** is a brown (7.5YR4/4, Site 7) to black (7.5YR/2.5/1, Site 8) colour, sandy clay with a fine blocky/granular (free draining) structure; field pH 7.5 (Site 7) to 8.0 (Site 8). Clear change to:

The **subsoil (B)** is mine overburden of Tertiary age. Colour is variable from yellow brown (10YR5/4, 55cm depth, Site 7) to red brown (2.5YR5/4, 90cm depth, Site 7). Texture is sandy clay to clay, and structure is massive. Subsoil is alkaline, pH 8.0 (75cm depth, Site 7). Some gravel is present throughout and rock prohibited hand augering at Site 8 at 45cm. Where present, abrupt change to:

Substrate rock (B/C) is present from 45cm depth.



3.2.4 Laboratory analyses

Site 7

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.3	0.6	13.2	11	0.68	1.9	0.03	0.2	5.8	42
20-30	8.9	0.9	17.5	12	0.31	3.8	0.86	4.9	3.2	-
40-50	9.6	2.2	26.7	14	0.21	8.3	4	15	1.7	-
60-70	9.6	2.7	26.5	14	0.21	7.8	5	19	1.8	-
80-90	9.5	3.5	25.7	11	0.25	8.9	5.6	22	1.2	-

Site 8

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.8	31.1	25	0.65	5.5	0.08	0.3	4.5	15

Soil pH is alkaline to very strongly alkaline at depth (pH>9.5). Soil salinity is low to slightly saline at depth (3.5dS/m). Surface CEC is moderate to high throughout due to clay content, indicating soil has sufficient capacity to retain plant nutrients. Surface soil is non-dispersive but ESP increases with depth (22% at 80-90cm depth), indicating subsoil is highly dispersive and will be prone to excessive erosion if uncovered. Calcium levels are sufficient in surface soil but decline with depth. Magnesium levels increase with depth and this will exacerbate subsoil dispersion risk.

3.2.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	2	1	2	2	2	1	2	4	3	2	2	1

Rehabilitation Polygon 2 has a land suitability class of 4 for sustainable beef cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: subsoil erosion risk (Eb4) and strong soil alkalinity (Tx4).

3.3 Rehabilitation Polygon 3

Rehabilitation Polygon 3 has a total area of 26.25ha and was rehabilitated in three stages in 2004, 2007 and 2009. No post-mining land use has been established on this polygon. The following soils data was collected at an intense scale in 2017 for the verification of remote sensing vegetation data and has been repurposed here.

3.3.1 Sites

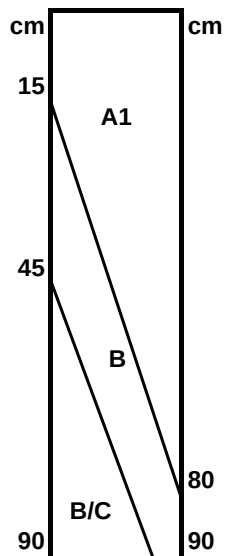
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
A1	650364,7397429	Detail	Upper slope	10%	Rhodes grass	15cm	Tertiary	90cm
A2	650388,7397439	Detail	Upper slope	10%	Rhodes grass	70cm	Permian	90cm
B1	650371,7397355	Detail	Upper slope	10%	Buffel grasses	60cm	Tertiary	60cm
B2	650343,7397344	Detail	Upper slope	10%	Buffel grasses	50cm	Tertiary	50cm
B3	650362,7397345	Detail	Upper slope	10%	Rhodes and buffel grasses	80cm	Tertiary	90cm
C1	650524,7397321	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Permian	45cm
C2	650532,7397329	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Tertiary	90cm
C3	650534,7397337	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Tertiary	50cm
D1	650476,7397274	Detail	Lower slope	10%	Buffel grass, Stylo spp.	20cm	Permian	45cm
D2	650466,7397284	Detail	Lower slope	10%	Buffel grass, minor legume	20cm	Permian	90cm
D3	650461,7397294	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Permian	90cm

3.3.2 Representative photographs



Surface and vegetation conditions at Sites A (left), Site B (centre) and Site D (right)

3.3.3 Soil profile description



The **topsoil (A1)** is a grey or brown colour sandy loam / clay loam, with weak blocky structure. No field pH was measured. Clear change to:

The **subsoil (B)** is either Permian or Tertiary age mine overburden. Texture is generally clay, and structure is blocky to massive. Where present, abrupt change to:

Substrate rock (B/C) is present from 45cm depth.

Profile photo is Site D2.



3.3.4 Laboratory analyses

Representative soil profile analyses follow.

Site A1

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.6	10.6	8.1	0.6	1.9	0.05	0.5	4.3	10
20-30	8.9	0.7	16	11	0.29	4	0.31	2	2.8	-
40-50	8.9	0.9	14.7	11	0.22	3.1	0.37	2.5	3.5	-
60-70	9.7	1.6	22.4	12	0.23	7.8	2.5	11	1.5	-
80-90	9.7	2.4	28	12	0.29	11	4.8	17	1.1	-

Site C2

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8	0.5	4.88	3	0.6	1.3	<0.02	<1.0	2.3	20
20-30	9.4	0.9	22.3	12	0.22	8.9	0.83	3.7	1.3	-
40-50	10.1	2.9	25	11	0.31	8.9	5.3	21	1.2	-
60-70	10.1	2.5	24.3	9.4	0.27	9.9	4.7	19	1	-
80-90	10.1	3	27	11	0.34	9.4	6.3	23	1.2	-

Site D2

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	5.68	4	0.63	1	<0.02	<1.0	4	25
20-30	8.6	0.6	11.5	8.7	0.28	2.4	0.12	1	3.6	-
40-50	9.7	1.5	25	11	0.29	11	2.3	9.3	1	-

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
60-70	10.1	2.9	26.2	10	0.34	10	5.7	22	1	-
80-90	10.1	3.1	25.7	11	0.32	9.1	5.6	22	1.2	-

Soil pH is alkaline to strongly alkaline at depth (pH>10). Saturated EC levels indicate low salinity to only slight salinity at depth (3.1dS/m). Topsoil CEC is low to very low (4.8-10.6Meq/100g) but increase to high levels in the clayey subsoil (>25Meq/100g). ESP indicates surface soil is non-sodic but subsoils are highly sodic and prone to dispersion and excessive erosion if uncovered. Calcium is deficient. Magnesium levels increase with depth exacerbating the subsoil erosion risk.

3.3.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	3	1	2	3	2	1	2	4	3	2	3	1

Rehabilitation Polygon 3 has a land suitability class of 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: subsoil erosion risk (Eb4) and very strong alkalinity (Tx4).

3.4 Rehabilitation Polygon 4

Rehabilitation Polygon 4 has a total area of 44.7ha and is located in A Pit, south of the Nogoia River. It was rehabilitated in 2017, and vegetation is in the establishment phase.

3.4.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
11	0650777,7397796	Detail	Upper slope	14%	Establishing pasture	15cm	Tertiary	90cm
14	0651062,7397406	Check	Lower slope	<14%	Establishing pasture	45cm	Tertiary	45cm
15	0651954,7397923	Check	Lower slope	5%	Establishing pasture	15cm	Permian	50cm

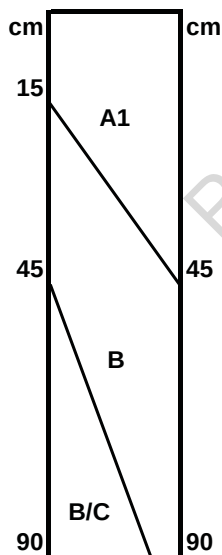
3.4.2 Representative photographs



Surface and vegetation condition at Site 11 (left) and Site 14 (right)

3.4.3 Soil profile description

Profile photo is Site 11.



The **topsoil (A1)** is a brown (7.5YR4/2, Site 11), very dark greyish brown (10YR3/2, Site 14) and dusky red (2.5YR3/2, Site 15), sandy loam to sandy clay, with a weakly blocky structure (highly permeable); field pH 8.0 (all sites). Clear change to:

The **subsoil (B)** is mine overburden, both Tertiary and Permian age. Texture is clay. Gravel is a feature throughout. Field pH is neutral (7.0, Site 11). Where present, abrupt change to:

Substrate rock (B/C) is present from 45cm depth.



3.4.4 Laboratory analyses

Site 11

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.8	1.4	26.5	18	0.61	6.1	1.6	6.1	3	10
20-30	8.7	1.6	16.7	12	0.38	3.7	1	6.2	3.2	-
40-50	8.7	2.2	16.5	9.3	0.3	5.4	1.5	9	1.7	-
60-70	8.3	2.4	13.5	6.7	0.22	5.3	1.3	9.5	1.3	-
80-90	8.3	2.2	13.5	6.7	0.26	5.3	1.2	9	1.3	-

Site 14

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.5	1.1	20.2	16	0.42	3	0.44	2.2	5.3	15

Site 15

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	1.1	29.8	21	0.78	7.3	0.68	2.3	2.9	27

Soil pH is strongly alkaline (8.5-8.8) to the extent that nutrient availability is reduced, e.g. phosphorus and trace elements. Soils are non-saline (<2.5dS/m). ESP indicates a propensity to dispersion when wet (>6, Site 11) but this is variable. CEC is moderate (20-26) in surface soils. The ratio of calcium to magnesium is low.

3.4.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	3	3	3	3	2	3	2	1	2	4	2	2	2	1

Rehabilitation Polygon 4 has a land suitability class of 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: topsoil erosion risk (Ea4); and, strong soil alkalinity (Tx4).

3.5 Rehabilitation Polygon 5

Rehabilitation Polygon 5 has a total area of 44.2ha and is located in A Pit, south of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010. Current land use is mine site rehabilitation.

3.5.1 Sites

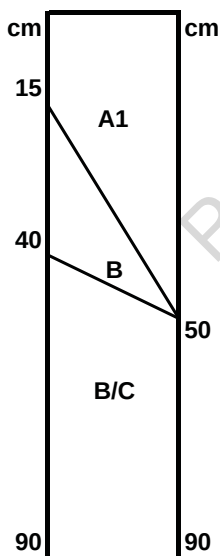
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
9	0650883,7397849	Check	Upper slope	<5%	Rhodes grass, Stylo spp.	50cm	Tertiary	50cm
10	0650789,7397929	Check	Upper slope	>10%	Rhodes grass, Stylo spp.	15cm	Tertiary	50cm
13	0651758,7398281	Check	Lower slope	<10%	Rhodes grass	20cm	Tertiary	40cm

3.5.2 Representative photographs



Surface and vegetation conditions at Site 9 (left), Site 10 (middle) and Site 13 (right)

3.5.3 Soil profile description



Profile photo is Site 10.

The **topsoil (A1)** is a yellowish brown (10YR5/6, Site 9), brown (7.5YR4/4, Site 10) to very dark grey (5YR3/1, Site 13), sandy clay with a weak blocky structure (free draining); field pH 7.5 (Sites 9 and 10) and 8.0 (Site 13). Clear change to:

The **subsoil (B)** is mine overburden of Tertiary age. Gravel throughout. Abrupt change to:

Substrate rock (B/C) is present from 40cm depth.



3.5.4 Laboratory analyses

Site 9

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.6	21.8	15	0.74	6.4	0.06	0.3	2.3	11

Site 10

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.7	0.7	16.4	14	0.32	2.2	0.1	0.6	6.4	8

Site 13

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.7	0.9	26.5	18	0.83	7.2	0.71	2.7	2.5	61

Topsoil pH is strongly alkaline (8.6-8.7) to the extent that nutrient availability is reduced, e.g. phosphorus and trace elements. Soil is non-saline and non-sodic. CEC is moderate to high indicating adequate capacity to hold nutrients, and the exchange surface is dominated by calcium. Soil phosphorus levels are adequate.

3.5.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	3	4	3	2	2	2	2	1	2	4	2	1	2	1

Rehabilitation Polygon 5 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: poor soil water holding capacity (M4); and, strong soil alkalinity (Tx4).

3.6 Rehabilitation Polygon 6

Rehabilitation Polygon 6 has a total area of 53.9ha and is located in B Pit, south of the Nogo River. It was rehabilitated in 2017. This rehabilitation polygon was not assessed in this study.

3.7 Rehabilitation Polygon 7

Rehabilitation Polygon 7 is a 38.6ha area of rehabilitation in B Pit, south of the Nogoa River. Rehabilitation works were conducted in 2003 and no post-mining land use has been established to date.

3.7.1 Sites

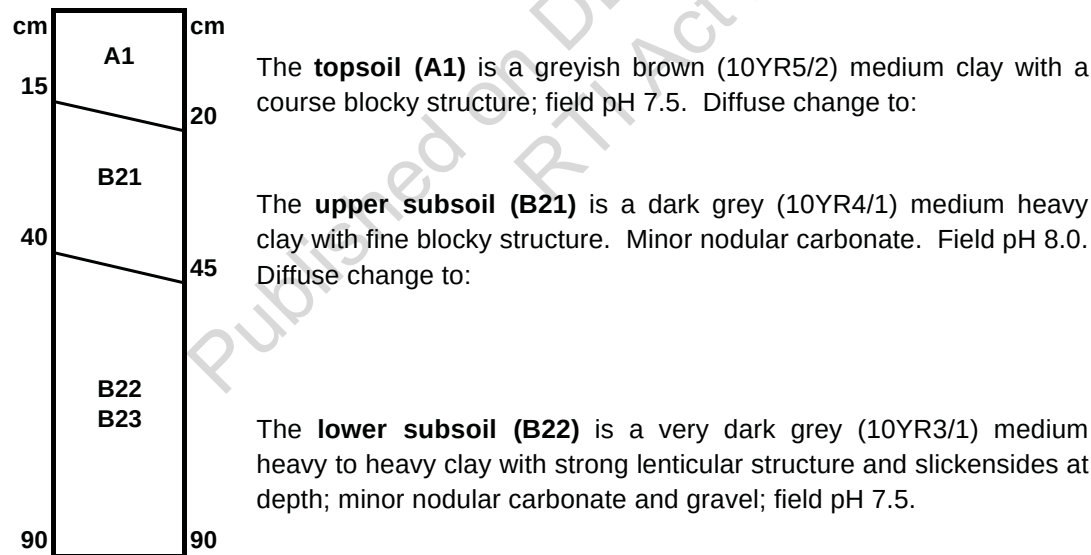
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
19	0652453,7398431	Detail	Flat	<2%	Eucalypt and Acacia over storey with mixed grass groundcover	15cm	None	90cm

3.7.2 Representative photographs



Surface and vegetation condition at Site 19

3.7.3 Soil profile description



This soil profile has not been disturbed by mining, at least not in any significant way. This soil is a Vertosol (Isbell, 1996) and likely a variant of the Adelong AMU as described by Bourne and Tuck (1993) with the following characteristics:

- Alluvial plains with slopes <1%
- Low to very high P
- Surface pH 7.5 tending alkaline at depth
- Saline and sodic at depth

- Very high PAWC and imperfectly drained

3.7.4 Laboratory analyses

Site 19

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.9	1.1	33.8	20	0.84	11	2	6	1.8	21
20-30	8.8	2.1	35.2	17	0.74	13	5.1	14	1.3	-
40-50	8.5	6.6	39.8	20	0.77	13	6.6	17	1.5	-
60-70	8.5	7.7	39	21	0.64	12	6.3	16	1.8	-
80-90	8.3	8.6	38.4	21	0.66	11	5.8	15	1.9	-

Soil pH is strongly alkaline throughout (8.3-8.9) to the extent that nutrient availability is reduced, e.g. phosphorus and trace elements. Salinity is moderate to high (>8dS/m) at depth, which will restrict rooting depth of some plant species. CEC is high (>25). Topsoil (A1) is marginally sodic but below 20cm depth subsoils are highly sodic. This soil is prone to dispersion and erosion. Phosphorus level is adequate.

3.7.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	1	3	1	2	1	2	3	2	1	1	4	1	3	2	1

Rehabilitation Polygon 7 is land suitability class 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: strongly alkaline soil conditions (Tx4).

3.8 Rehabilitation Polygon 8

Rehabilitation Polygon 8 has a total area of 64.45ha and is located in B Pit, south of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010, and the current land use is mine rehabilitation.

3.8.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
18	0652132,7398684	Detail	Lower slope	<1%	Rhodes grass, Stylo spp.	50cm	Permian	90cm
20	0652867,7399723	Detail	Lower slope	<2%	Mixed grass spp., Acacia salicina	20cm	None	90cm
21	0652569,7400034	Detail	Lower slope	<5%	Rhodes and Buffel grass	40cm	Tertiary	90cm

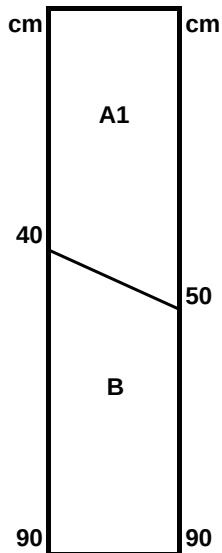
Site 20 is an intact soil profile that has not been disturbed by mining. It is not representative of the rehabilitation polygon, which is predominantly an elevated overburden emplacement, and for that reason it is not included in the assessment following.

3.8.2 Representative photographs



Surface and vegetation conditions at Site 18 (left) and Site 21 (right)

3.8.3 Soil profile description



Profile photo is Site 21.

The **topsoil (A1)** is a yellowish brown (10YR5/4) to dark brown (10YR3/3) light clay with a fine blocky structure; field pH 6.5 to 8.0. Clear change to:

The **subsoil (B)** is mine overburden of Permian and Tertiary age. It is a grey (5YR6/1, Site 21) gravelling clay to a dark grey gravel (Site 18).



3.8.4 Laboratory analyses

Site 18

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9	0.7	20.2	11	0.49	7.5	0.91	4.5	1.5	12
20-30	9.4	1.6	21.3	10	0.39	7.7	2.9	14	1.3	-
40-50	9.2	3.2	22.3	9.7	0.38	8	4.1	18	1.2	-
60-70	8.6	6.6	27	14	0.45	8.5	4.2	15	1.6	-
80-90	8.7	5.5	24.9	13	0.42	8.2	3.6	14	1.6	-

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

Site 21

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.9	1.4	37.5	23	0.66	11	2.1	5.6	2.1	18
20-30	8.9	1.9	33.2	19	0.57	10	2.8	8.4	1.9	-
40-50	8.8	2.9	26.9	14	0.46	9.9	2.3	8.7	1.4	-
60-70	9.3	3.3	29.9	13	0.36	14	2.7	9	0.9	-
80-90	9.2	3.2	29	13	0.41	13	2.5	8.7	1	-

The topsoil (A1) is strongly alkaline (8.9-9.4) to the extent that the availability of plant nutrients is significantly affected. At pH 9, the availability of nitrogen, phosphorus, base cations and micronutrients to plants is limited. Topsoil is non-saline and extremely sodic (18%) in the lower fraction of the horizon. Dispersion and accelerated erosion is a risk. The subsoil (B) is similarly highly alkaline, non-saline and highly sodic, and has a similar dispersion and erosion risk.

3.8.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	3	3	3	3	2	2	3	2	1	2	4	3	2	2	1

Rehabilitation Polygon 8 is land suitability class 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: strongly alkaline soil conditions (Tx4).

3.9 Rehabilitation Polygon 9

Rehabilitation Polygon 9 has a total area of 28.1ha and is located in B Pit, south of the Nogo River. It was rehabilitated in 2009, and the current land use is mine rehabilitation.

3.9.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Soil depth	Spoil type	Hole depth
16	0651711,7399071	Check	Top of dump	<2%	Rhodes and Buffel grass, Aacia Salicina	25cm	Tertiary	25cm
17	0651854,7398899	Detail	Top of dump	5%	Rhodes and Buffel grass, Stylo spp.	10cm	Quaternary	50cm

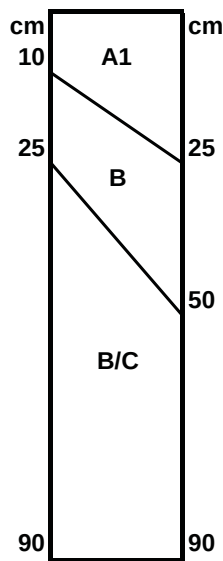
3.9.2 Representative photographs



Vegetation and surface conditions at Site 16 (left) and Site 17 (right)

3.9.3 Soil profile description

Profile photo is Site 17.



The **topsoil (A1)** is a brown (7.5YR4/3, Site 16) to very dark grey (10YR3/1) coloured, fine blocky structured light clay; field pH 7.5 (both). Clear change to:

The **subsoil (B)** is Tertiary age mine overburden. Texture is sand. Gravel and rock is present.

Substrate rock (B/C) is present from 25cm depth.



3.9.4 Laboratory analyses

Site 16

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.1	1.1	36.5	23	0.8	11	2	5.5	2.1	13

Site 17

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	1.6	36.3	22	1.1	12	1	2.8	1.8	23
20-30	9.5	1.1	7.86	4.5	0.14	2.7	0.48	6.1	1.7	-
40-50	9.5	1.0	6.67	3.7	0.11	2.4	0.43	6.4	1.5	-

The topsoil is strongly to very strongly alkaline (pH8.6-9.1) to the extent that the availability of plant nutrients is significantly affected. At pH 9, the availability of nitrogen, phosphorus, base cations and micronutrients is limited. Soil is non-saline (<2dS/m) throughout and only slightly sodic at depth. CEC in topsoil is high but low in subsoil due to its sandy texture. Calcium is deficient and phosphorus levels are adequate.

3.9.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	2	4	3	2	1	1	2	1	2	4	3	1	2	1

Rehabilitation Polygon 9 is land suitability class 4 for sustainable beef cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: poor soil water holding capacity (M4) and strongly alkaline soil conditions (Tx4).

3.10 Rehabilitation Polygon 10

Rehabilitation Polygon 10 has a total area of 40.3ha and is located in C Pit, north of the Nogoja River. It was rehabilitated in 2007, and the current land use is mine rehabilitation.

3.10.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
49	0653259,7403419	Detail	Lower slope	5%	Buffel grass	10cm	Tertiary	55cm

3.10.2 Representative photographs



Surface and vegetation condition at Site 49

3.10.3 Soil profile description

cm 10	A1	cm 10	The topsoil (A1) is very dark greyish brown (10YR3/2), medium clay with a fine blocky structure; field pH is 8.0. Diffuse change to:
	A2		The subsurface layer (A2) is conspicuously bleached, grey or light brown, gravelly coarse sand with massive or single grain structure. Abrupt change to:
30	B	30	The subsoil (B) is grey, gravelly coarse sandy clay; massive. Abrupt change to:
55	B/C	55	Substrate rock (B/C) is present from 55cm depth.
90		90	



3.10.4 Laboratory analyses

Site 49

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.9	1.1	22.2	9.6	0.86	9.6	2.2	9.9	1	12
20-30	9.3	0.6	16.4	3	0.26	9.1	4	24	0.3	-
40-50	9.3	1.4	17	3.1	0.27	9.2	4.5	26	0.3	-

This soil is strongly to very strongly alkaline (pH8.9-9.3). CEC levels decline with depth reflecting the clay content of the material. Soil is non-saline but ESP is high to extremely high and reflects the dominance of sodium and magnesium on the exchange, and calcium deficiency. Phosphorus level is adequate, albeit unavailable to plants at this pH.

3.10.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	4	4	3	2	2	2	1	2	4	3	1	2	1

Rehabilitation Polygon 10 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: high topsoil and subsoil erosion risk (Ea4 and Eb4); poor soil water holding capacity (M4); hardsetting and massive soil surface conditions (Ps4); and, strongly alkaline soil conditions (Tx4).

3.11 Rehabilitation Polygon 11

Rehabilitation Polygon 11 has a total area of 54.6ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in 2007, and the current land use mine rehabilitation. Cattle have never grazed this rehabilitation.

3.11.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
30	0652872,7403840	Check	Upper slope	<10%	Buffel grass	n/a	Tertiary	20cm
31	0653158,7404778	Detail	Upper slope	<10%	Buffel and Rhodes grasses	20cm	Tertiary	60cm

3.11.2 Representative photographs



Surface and vegetation condition at Site 31

3.11.3 Soil profile description

cm	A1	cm	
20		20	The topsoil (A1) is brown (7.5YR4/3) medium clay with fine blocky structure; gravelly; field pH 7.5-8.0. Abrupt change to:
	B		
60		60	The subsoil (B) is gravelly, coarse sanding clay; massive; field pH8. Abrupt change to:
	B/C		
90		90	Substrate rock (B/C) is present from 60cm depth.

Profile photo is Site 31.



3.11.4 Laboratory analyses

Site 30

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.7	17.2	11	1.5	4.8	0.09	0.5	2.3	61

Site 31

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.4	1.0	31.6	23	0.85	7.1	0.27	0.9	3.2	13
20-30	8.7	1.1	28.8	21	0.49	6.6	1	3.5	3.2	
40-50	9.1	1.5	31.4	21	0.42	7.9	2.4	7.7	2.7	

pH in topsoil is alkaline and subsoil is very strongly alkaline. EC indicates low salinity to 50cm depth. CEC is moderate (17.2) to high (>28.8), indicating the capacity of the soil to hold and exchange cations important in

plant fertility. Calcium is low with a Ca/Mg ratio less than 4. Topsoil is non-sodic but subsoil is weak to moderately sodic. Phosphorus levels are adequate for pasture nutrition.

3.11.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	3	4	3	3	2	2	2	1	2	3	3	1	2	1

Rehabilitation Polygon 11 is land suitability class 4 for sustainable beef cattle grazing. This rehabilitation has moderate limitation/s that will require significant inputs to ensure sustainability and prevent land degradation following instatement of grazing land use. The key limitation/s to sustainable cattle grazing in this rehabilitation are: poor soil water holding capacity (M4).

3.12 Rehabilitation Polygon 12

Rehabilitation Polygon 12 has a total area of 46ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in 2010, and the current land use is mine rehabilitation.

3.12.1 Sites

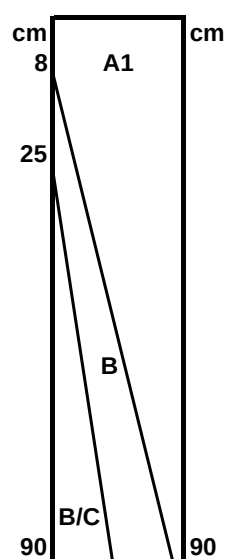
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
27	0652384,7404515	Check	Top of landform	<2%	Rhodes grass	n/a	n/a	35cm
28	0652543,7403871	Check	Top of landform	<2%	Buffel and Rhodes grasses, A. salicina	8cm	Permian	25cm
29	0652762,7403838	Detail	Top of landform	≈2%	Buffel and Rhodes grasses, A. salicina	90cm	None	90cm

3.12.2 Representative photographs



Surface and vegetation conditions at Site 28 (left) and Site 29 (right)

3.12.3 Soil profile description



Profile photo is Site 28.

The **topsoil (A1)** is grey (7.5YR5/1, Site 28) to brown (7.5YR4/2, Sites 27 and 29) clay with a fine blocky structure (lenticular at depth, Site 29); field pH 8.0-8.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian age; gravelly clay; contains rocks. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.



3.12.4 Laboratory analyses

Site 27

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.1	1.3	34.7	22	0.79	9.8	2.4	6.9	2.2	18
20-30	9.4	1.2	26.8	16	0.57	8.3	2.4	9	1.9	-

Site 28

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.8	1.4	29.7	18	0.7	8.4	2.1	7	2.1	17

Site 29

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.0	2.7	35.4	20	0.73	10	4.2	12	2.0	22
20-30	8.2	12.2	42.1	23	0.7	11	7	17	2.1	-
40-50	8	20.7	52.8	29	0.75	13	10	19	2.2	-
60-70	8.1	17.2	49.2	23	0.84	14	11	23	1.6	-
80-90	8	17.9	49.4	24	0.77	14	11	22	1.7	-

Surface soil pH is strongly to very strongly alkaline throughout and nutrient availability is limited at these levels (pH>8.5). EC analysis indicates low levels of soluble salts (<3dS/m) in surface fractions, but extreme salinity (>16dS/m) below this. Extreme salinity (Site 29) and rockiness (Sites 27 and 28) restricts the effective root zone and soil water holding capacity. CEC is high throughout due to high clay content. ESP indicates sodicity throughout, increasing to extreme sodicity at depth, meaning this high clay soil will be prone to dispersion when wet and accelerated erosion. Calcium levels are low. Phosphorus levels are adequate, however unavailable to plants are these high pH levels. Plant nutrient deficiency is likely.

3.12.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	5	3	3	2	3	2	1	2	4	3	4	2	1

Rehabilitation Polygon 12 is land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that make it unsuitable to sustained cattle grazing. The key limitation to sustainable cattle grazing in this rehabilitation is: soil water holding capacity (M5) due to near surface extreme salinity.

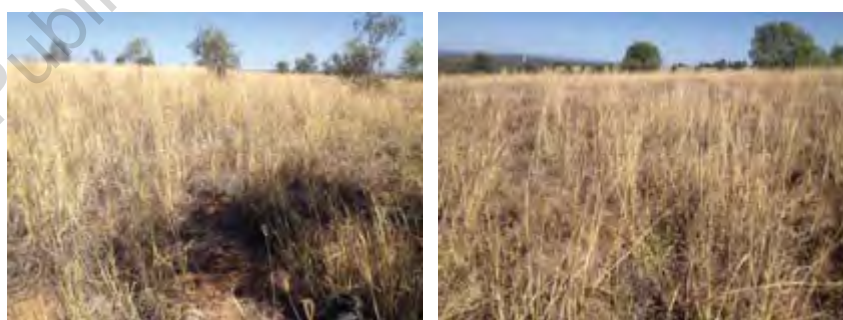
3.13 Rehabilitation Polygon 13

Rehabilitation Polygon 13 has a total area of 50.6ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010, and the current land use is mine rehabilitation.

3.13.1 Sites

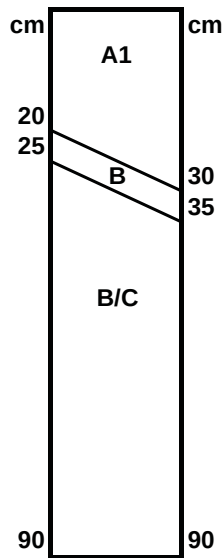
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
23	0652477,7405571	Check	Top of landform	<5%	Rhodes and Buffel grasses	20cm	n/a	25cm
24	0652610,7405563	Detail	Upper slope	5%	Rhodes and Buffel grasses	30cm	Permian	35cm
25	0652776,7404885	Check	Upper slope	<10%	Rhodes and Buffel grasses; Acacia salicina	n/a	n/a	20cm
26	0652961,7404888	Check	Lower slope	10%	Rhodes and Buffel grasses	n/a	n/a	20cm

3.13.2 Representative photographs



Surface and vegetation condition at Site 23 (left) and Site 24 (right)

3.13.3 Soil profile description



Profile photo is Site 24.

The **topsoil (A1)** is brown (7.5YR5/4) to reddish brown (5YR4/4) light clay with a weak sub-angular blocky to massive structure; field pH is 8.0-8.5. Clear change to:

The **subsoil (B)**, where present, is mine overburden of Permian age; gravelly clay with rock present; massive. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.



3.13.4 Laboratory analyses

Site 23

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.3	1.5	29.8	18	0.34	8.6	2.7	8.9	2.1	6

Site 24

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.7	25.7	21	0.51	3.8	0.16	0.6	5.5	<5
10-20	8.7	0.8	19.3	14	0.36	4.2	0.48	2.5	3.3	-

Site 25

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.0	1.2	32.4	21	0.68	9.2	1.6	5.1	2.3	10

Site 26

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.5	0.9	24.7	16	1.1	7.1	0.46	1.9	2.3	38

Soil is strongly alkaline (8.5) to very strongly alkaline (pH>9) and nutrient availability is limited at these levels. Soil is non-saline and generally non-sodic, though Site 23 is moderately sodic. CEC is moderate to high indicating an adequate capability to hold and exchange cations important in plant nutrition. Soil phosphorus levels are generally below that required for productive and resilient grazing pastures. Effective rooting depth is shallow (each <35cm) due to rock and this will severely limit soil water storage capacity.

3.13.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	3	4	4	3	2	3	2	1	4	4	3	2	2	1

Rehabilitation Polygon 13 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: low soil water storage (M4); hardsetting massive topsoil (Ps4); low soil nutrients (Nd4); and very strong alkalinity leading to elemental imbalance (Tx4).

3.14 Rehabilitation Polygon 14

Rehabilitation Polygon 14 has a total area of 97ha and is located in D Pit, north of the Nogo River. It was rehabilitated in two stages in 2007 and 2010, and the current land use is mine rehabilitation.

3.14.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
32	0652940,7406713	Check	Mid slope	10%	Rhodes and Buffel grass	30cm	n/a	30cm
33	0652966,7406710	Check	Mid slope	10%	Rhodes and Buffel grass	30cm	n/a	30cm
34	0653015,7406321	Check	Lower slope	10%	Rhodes and Buffel grass	10cm	n/a	10cm
34b	0652725,7407118	Detail	Top of landform	<10%	Rhodes and Buffel grass	5cm	Tertiary	50cm

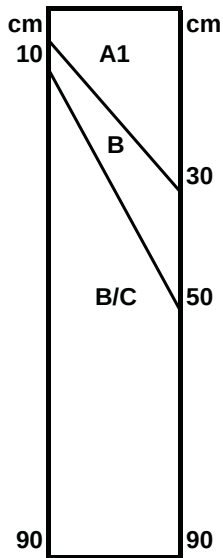
3.14.2 Representative photographs



Surface and vegetation conditions at Site 32 (left), Site 33 (middle) and Site 34b (right)

3.14.3 Soil profile description

Profile photo is Site 34b.



The **topsoil (A)** is a brown (7.5YR4/3, 7.5YR4/4) to dark brown (7.5YR3/3), clay loam with a sub-angular blocky to massive structure; field pH is 7.0 to 8.5. Clear change to:

The **subsoil (B)**, where present, is mine overburden of Tertiary age; very gravelly clay with rock present, massive. Abrupt change to:

Substrate rock (B/C) is present from 10cm depth.

Profiles varied in depth from 10cm to 50cm, with each limited by rock.



3.14.4 Laboratory analyses

Site 32

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	16.3	11	1.2	4.3	0.09	0.5	2.6	59
20-30	8.1	0.6	16.6	11	0.56	4.3	0.25	1.5	2.6	-

Site 33

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.4	0.6	15.5	8.3	0.72	5.8	0.65	4.2	1.4	18
20-30	8.6	0.7	16.1	8.4	0.56	5.8	1.3	8.0	1.4	-

Site 34

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	16.0	9.5	0.81	5.3	0.38	2.4	1.8	25

Site 34b

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.5	0.9	30.5	23	0.79	6.3	0.32	1.1	3.7	14
20-30	9.5	1.5	32.8	18	0.35	12	2.9	8.7	1.5	-
40-50	9.7	1.9	33.7	17	0.35	12	4.4	13	1.4	-

The topsoil (A1) is alkaline and beneath this the subsoil (B) is very strongly alkaline. Nutrient availability is limited at these levels. Profiles are non-saline but sodic at depth (ESP>8). CEC is moderate to high,

indicating a capacity to hold and exchange cations important for plant nutrition. Calcium levels are low but phosphorus levels are adequate.

3.14.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	3	4	4	4	3	2	3	2	1	2	4	3	1	2	1

Rehabilitation Polygon 14 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: high subsoil erosion risk (Eb4); low soil water holding capacity (M4); hardsetting, crusting and massive topsoils (Ps4); and, very strongly alkaline conditions (Tx4).

3.15 Rehabilitation Polygon 15

Rehabilitation Polygon 15 has a total area of 11ha and is located in F Pit, north of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010, and the current land use mine rehabilitation.

3.15.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
35	0654145,7408677	Detail	Lower slope	<10%	Buffel and Rhodes grasses	25cm	Permian	90cm
36	0653880,7408450	Check	Lower slope	<10%	Buffel and Rhodes grasses	35cm	n/a	35cm

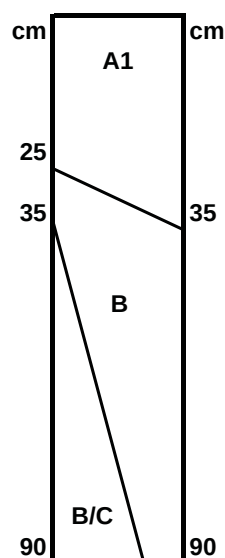
3.15.2 Representative photographs



Surface and vegetation condition at Site 35 (left) and Site 36 (right)

3.15.3 Soil profile description

Profile photo is Site 35.



The **topsoil (A1)** is a reddish brown (5RY4/3) to dark reddish brown (5YR3/2) colour, sandy loam with a sub-angular blocky structure; minor gravel; field pH is 7.0 to 7.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian age; bluish grey (GLE2 6/10B) colour; field pH 8.5. Abrupt change to:

Substrate rock (B/C) is present from 35cm depth.



3.15.4 Laboratory analyses

Site 35

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	1	29.3	23	0.65	5.4	0.58	2	4.3	6
20-30	9.4	2	29.1	17	0.43	8.1	3.5	12	2.1	-
40-50	9.8	3.7	22.3	8.1	0.37	7.4	6.5	29	1.1	-
60-70	9.7	4.1	23.7	9.2	0.44	7.1	6.9	29	1.3	-
80-90	9.7	5.2	22.9	8.1	0.4	7	7.4	32	1.2	-

Site 36

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.1	0.7	15.2	7.6	1.2	6	0.35	2.3	1.3	35

The topsoil (A1) is neutral to strongly alkaline (7.1-8.6) and subsoil (B) is very strongly alkaline (9.4-9.8). Nutrient availability is limited at these levels. ECe shows topsoil is non-saline and subsoil grades with depth from slightly (2dS/m) to moderately saline (5.2dS/m). CEC indicates a moderate capacity to hold and exchange cations important for plant nutrition. Topsoil is non-sodic but subsoil is extremely sodic and will be prone to dispersion when wet and accelerated erosion if uncovered. Calcium levels are low, particularly in subsoils. Phosphorus levels are variable, low to high.

3.15.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	3	4	4	4	3	2	3	2	1	3	4	3	3	2	1

Rehabilitation Polygon 15 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: high subsoil erosion risk (Eb4); low soil water holding capacity (M4); hardsetting, crusting and massive topsoils (Ps4); and, very strongly alkaline conditions (Tx4).

3.16 Rehabilitation Polygon 16

Rehabilitation Polygon 16 has a total area of 27ha and is located in F Pit, north of the Nogoia River. It was rehabilitated in 2013, and the current land use is mine rehabilitation.

3.16.1 Sites

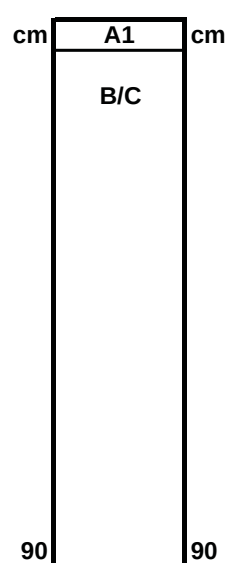
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
37	06514018,7409028	Check	Elevated	<10%	Buffel grass and woody regrowth	n/a	n/a	15cm

3.16.2 Representative photographs



Surface and vegetation condition at Site 37

3.16.3 Soil profile description



Profile photo is Site 37.

The **topsoil (A1)** is a brown (7.5YR5/3) loamy sand (medium to coarse sand fraction) with massive single grain fabric; field pH is 6.0.

Hole could not be hand augered deeper than 15cm due to gravelly stones at this depth.



3.16.4 Laboratory analyses

Site 37

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.3	0.2	4.81	3.3	0.32	1	0.04	0.7	3.3	6

Topsoil (A1) is slightly acid, non-saline and non-sodic. CEC is low due to sand fraction. Ca and P are deficient. Profile has a very shallow rooting depth and very low soil water holding capacity.

3.16.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	2	4	4	4	2	2	2	1	3	2	4	1	3	1

Rehabilitation Polygon 16 is land suitability class 4 for sustainable beef cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: low soil water holding capacity (M4); hardsetting, crusting and massive topsoil (Ps4); high stone content (R4); and, very shallow soil (Sd4).

3.17 Rehabilitation Polygon 17

Rehabilitation Polygon 17 has a total area of 39ha and is located in Y Pit, north of the Nogo River. It was rehabilitated in two stages in 2007 and 2009, and the current land use is mine rehabilitation.

3.17.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
38	0654511,7413018	Check	Upper slope	<10%	Rhodes grass	30cm	n/a	30cm
39	0654538,7413113	Detail	Upper slope	<10%	Rhodes grass, Acacia salicina	35cm	Permian	90cm
40	0654964,7415367	Detail	Lower slope	<10%	Rhodes grass	15cm	Tertiary	90cm

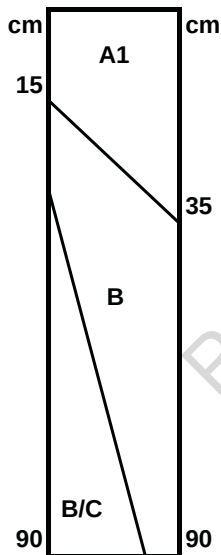
3.17.2 Representative photographs



Surface and vegetation condition at Site 38 (left), Site 39 (middle) and Site 40 (right)

3.17.3 Soil profile description

Profile photo is Site 39.



The **topsoil (A1)** is a brown (7.5YR4/3, 7.5YR4/4, 10YR4/3) sandy loam with a fine subangular blocky structure; field pH is 7.0-7.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian age; bluish grey (GLE Y2 6/10B) colour; mudstone/shale fragments present; field pH 8.5. Abrupt change to:

Substrate rock (B/C) is present from 35cm depth.



3.17.4 Laboratory analyses

Site 38

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.2	0.6	10.3	6	1.2	2.9	0.23	2.3	2.1	20
20-30	7.5	0.5	12.2	7.3	0.56	3.9	0.46	3.8	1.9	-

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

Site 39

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.8	0.6	11.6	7.5	0.77	2.9	0.43	3.7	2.6	23
20-30	8.2	0.6	10.4	6.6	0.29	2.7	0.86	8.2	2.4	-
40-50	9.2	2	18.7	8.1	0.27	7.2	3.1	17	1.1	-
60-70	9.5	3.6	26.7	12	0.4	10	4.9	18	1.2	-
80-90	9.6	3.5	19.1	4.1	0.46	9.7	4.8	25	0.4	-

Site 40

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.8	0.6	8.34	4.3	0.66	2.7	0.62	7.4	1.6	5
20-30	8.8	1.8	16.1	7.9	0.37	5.9	2	12	1.3	-
40-50	9.4	3.1	19.8	8.7	0.35	6.9	3.9	20	1.3	-
60-70	9.1	3.6	13.1	4.7	0.22	4.5	3.7	28	1	-
80-90	7.6	3	5.63	0.5	0.09	2.5	2.6	46	0.2	-

The topsoil (A1) is neutral (6.8) to alkaline (8.2) and is non-saline (0.6dS/m). CEC is low indicating a low capacity to hold and exchange cations important in plant nutrition. ESP indicates topsoil is non-sodic to sodic (7.4%). Calcium is low. Levels of phosphorus are variable from deficient (5mg/kg) to adequate (20-23mg/kg).

The subsoil (B) is strongly to very strongly alkaline, slightly saline and extremely dispersive (ESP 46%). The dominance of magnesium on the CEC at depth will add to the dispersion risk. This material will be prone to dispersion when wet and excessive erosion is uncovered.

3.17.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	3	3	2	3	2	1	3	3	3	2	2	1

Rehabilitation Polygon 17 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitation/s to sustainable cattle grazing in this rehabilitation is: subsoil erosion risk (Eb4).

3.18 Rehabilitation Polygon 18

Rehabilitation Polygon 18 has a total area of 94ha and is located in Y Pit, north of the Nogo River. It was rehabilitated in two stages in 2007 and 2009, and the current land use is cattle grazing.

3.18.1 Sites

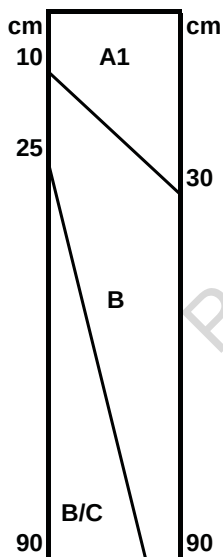
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
41	654825,7415673	Detail	Upper slope	<10%	Rhodes grass	30cm	Permian	90cm
42	654822,7416618	Detail	Upper slope	<10%	Rhodes grass	25cm	Tertiary	90cm
47	0654373,7417118	Check	Mid slope	<10%	Rhodes grass, Acacia spp.	25cm	n/a	25cm
48	0653259,7403419	Check	Lower slope	<5%	Buffel grass, Acacia spp.	10cm	Tertiary	35cm

3.18.2 Representative photographs



Surface and vegetation conditions at Site 41 (left), Site 47 (middle) and Site 48 (right)

3.18.3 Soil profile description



The **topsoil (A1)** is a reddish brown (5YR4/3, 5YR4/4) to strong brown (7.5YR4/6) loamy sand with a fine sub-angular blocky structure; field pH is 6.0-6.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian or Tertiary age; rock is present; mottles below 70cm; field pH 7.0-7.5. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.

Profile photo is Site 42.



3.18.4 Laboratory analyses

Site 41

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	2.4	6.71	2.7	0.53	2.4	0.97	14	1.1	<5
20-30	5.7	2.4	7.24	2.1	0.25	3.6	1.2	17	0.6	
40-50	7	3.7	14.7	3	0.45	8.6	2.6	17	0.4	
60-70	7.8	4.7	14	2.9	0.47	7.9	2.6	19	0.4	
80-90	7.6	4.2	13.6	2.7	0.48	7.9	2.4	18	0.3	

Site 42

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	1.4	5.35	2	0.75	1.6	0.77	14	1.3	<5
20-30	5.5	1.4	5.02	1.1	0.28	2.1	1.2	23	0.5	
40-50	6.9	2	6.93	1.3	0.16	3.7	1.8	26	0.4	
60-70	7	2.6	12.4	2.2	0.3	6.9	3.1	25	0.3	
80-90	7.2	2.3	11.1	2.3	0.22	5.9	2.7	24	0.4	

Site 47

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.7	0.4	4.69	1.9	0.63	1.7	0.19	4.1	1.1	<5

Site 48

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.9	1.1	5.19	1.6	0.26	2.2	1	20	0.7	9

Soil pH is moderately acid (5.5) grading to neutral and mildly alkaline at depth (7.8). Topsoil is non-saline but subsoil can be moderately saline (4.7dS/m). CEC low to very low, indicating the capacity of the soil to hold and exchange cations important in plant nutrition. ESP shows topsoil is non-sodic to extremely sodic (20%) and subsoil is extremely sodic (26%), meaning soil is prone to dispersion when wet and excessive erosion. Low calcium and a prevalence of magnesium on the exchange surfaces will exacerbate dispersion and erosion risk. Phosphorus is deficient in this soil.

3.18.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	4	3	3	2	3	2	1	4	3	3	2	2	1

Rehabilitation Polygon 18 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: topsoil and subsoil erosion risk (Ea4 and Eb4), poor soil water holding capacity (M4); and nutrient deficiency (Nd4).

3.19 Rehabilitation Polygon 19

Rehabilitation Polygon 19 has a total area of 17ha and is located in Y Pit, north of the Nogoia River. It was rehabilitated in 2011, and the current land use is mine rehabilitation.

3.19.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
44	0653980,7416682	Detail	Slope	<5%	Rhodes grass	25cm	Permian Tertiary	90cm

3.19.2 Representative photographs



Surface and vegetation condition at Site 44

3.19.3 Soil profile description

Profile photo is Site 44.

cm	A1	cm
25		25
40	B1	40
	B2	
90		90

The **topsoil (A1)** is reddish brown (5YR4/3) sandy loam with a massive/single grain fabric; field pH is 6.0. Clear change to:

The **upper subsoil (B1)** is mine overburden of Permian age; gravelly, light clay loam with a massive or weak blocky structure; field pH is 6.0. Clear change to:

The **lower subsoil (B2)** is mine overburden of Tertiary age; sandy clay with a strongly blocky structure; field pH is 7.0.



3.19.4 Laboratory analyses

Site 44

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.4	1.2	5.79	2.4	0.55	1.9	0.67	12	1.3	6
20-30	5.3	3	6.64	1.5	0.28	2.7	2	30	0.6	-
40-50	5.7	4.6	10.6	0.98	0.32	5	4.3	40	0.2	-
60-70	6.6	5	12.3	1.1	0.41	5.7	5	41	0.2	-
80-90	6.9	5.3	13.1	1.1	0.41	6.1	5.4	41	0.2	-

The topsoil (A1) is strongly acid (pH5.3-5.4). This pH is suboptimal for pasture growth and aluminium toxicity may be a problem for some species. The profile is moderately saline below 40cm. This will affect the growth of some species by limiting rooting depth. CEC indicates soil has a low capacity to hold and exchange cations important in plant nutrition. Soil is highly sodic to extremely sodic (ESP 41%) at depth and will be prone to dispersion when wet and excessive erosion. Magnesium dominates the exchange and this will add to the dispersion and erosion risk. Calcium and phosphorus are deficient.

3.19.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	5	4	2	2	3	2	1	3	3	3	3	2	1

Rehabilitation Polygon 19 is land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that make it unsuitable to sustained cattle grazing. The key limitation to sustainable cattle grazing in this rehabilitation is: soil water holding capacity (M5) due to near surface extreme sodicity.

3.20 Rehabilitation Polygon 20

Rehabilitation Polygon 20 has a total area of 25.3ha and is located in Y Pit, north of the Nogoia River. It was rehabilitated in 2015, and the current land use is mine rehabilitation. Cattle have never grazed this rehabilitation.

3.20.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
43	0653995,7416598	Detail	Natural surface	<10%	Rhodes grass, Acacia spp.	10cm	n/a	90cm
46	0654038,7417373	Obs.	Natural surface	<5%	Very little groundcover	n/a	n/a	n/a

3.20.2 Representative photographs



Surface and vegetation conditions at Site 43

3.20.3 Soil profile description

cm		cm
10	A1	10
	B1	
30		30
	B2	
90		90

Profile photo is Site 43.

The **topsoil (A1)** is a reddish brown (5YR4/4) sandy loam to sandy clay loam with a massive structure; field pH 6.5. Clear change to:

The **upper subsoil (B1)** is a light brown (7.5YR7/4 - 7.5YR6/4) sandy clay loam with a massive structure; field pH 6.0. Diffuse change to:

The **lower subsoil (B2)** is a light brown (7.5YR6/4) sandy clay loam with massive structure.

According to the Australian Soil Classification (Isbell, 1996) this soil is a Brown Kandosol.



3.20.4 Laboratory analyses

Site 43

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	10.9	13.7	2.6	0.48	4.5	6	44	0.6	<5
20-30	4.7	3.9	5.96	0.45	0.14	2.5	2.7	45	0.2	
40-50	4.5	4.4	7	0.28	0.17	2.9	3.3	48	0.1	
60-70	4.6	4.4	7.41	0.29	0.17	3.1	3.5	47	0.1	
80-90	4.7	4	7.32	0.29	0.18	3.1	3.3	46	0.1	

This soil is strongly acid to very strongly acid at depth. Topsoil is highly saline while subsoil is moderately saline. CEC is low and the exchange is dominated by sodium (ESP >40) and magnesium. This soil is inherently highly dispersive when wet and prone to excessive erosion if disturbed. Calcium and phosphorus are deficient.

3.20.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	5	4	2	2	3	2	1	4	4	1	4	2	1

Rehabilitation Polygon 20 is land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that make it unsuitable to sustained cattle grazing. The key limitation to sustainable cattle grazing in this rehabilitation is: soil water holding capacity (M5) due to near surface extreme salinity and sodicity.

3.21 Rehabilitation Polygon 21

Rehabilitation Polygon 21 has a total area of 13ha and is located in Y Pit, north of the Nogoia River. It was rehabilitated in 2010, and the current land use mine rehabilitation. Cattle have never grazed this rehabilitation.

3.21.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
45	0653459,7416891	Detail	Slope	<5%	Rhodes grass, Acacia spp.	10cm	n/a	55cm

3.21.2 Representative photographs



Surface and vegetation conditions at Site 45

3.21.3 Soil profile description

Profile photo is Site 45.

cm	10	A1	cm	10
		B1		
	35	B2		35
	55	B2/C		55
	90			90

The **topsoil (A1)** is a brown (7.5YR4/4) sandy loam with a massive/single grain fabric; field pH is 6.0. Diffuse change to:

The **upper subsoil (B1)** is a sandy loam with a massive/single grain fabric. Diffuse change to:

The **lower subsoil (B2)** is a dark red (2.5YR3/6) sandy loam with a massive/single grain fabric; field pH 6.5. Abrupt change to rock.

According to the Australian Soil Classification (Isbell, 1996) this soil is a Red Kandosol.



3.21.4 Laboratory analyses

Site 45

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.9	0.3	5.11	2.5	0.93	1.5	0.05	1	1.7	<5
20-30	6.1	0.2	3.75	2	0.13	1.4	0.09	2.3	1.4	-
40-50	5.7	0.2	4.54	2.2	0.35	1.5	0.1	2.1	1.5	-

This soil is moderately acid throughout and non-saline. CEC is very low, indicating the capacity of the soil to hold and exchange cations important in plant nutrition. Calcium is deficient but the soil is non-sodic. Phosphorus is deficient.

3.21.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	2	4	4	3	2	3	2	1	4	3	2	1	2	1

Rehabilitation Polygon 21 is land suitability 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: low soil water holding capacity (M4); hardsetting, massive topsoil (Ps4); and, nutrient deficiency (Nd4).

3.22 Summary of results

The land suitability class and primary limitations for each of the 21 rehabilitation polygons have been summarised (Table 3-1).

Table 3-1 Land suitability summary for each rehabilitation polygon

#	Limitation subclasses	Limitation description	Class
1	Eb4	Subsoil erosion risk	4
2	Eb4, Tx4	Subsoil erosion risk; high soil pH	4
3	Eb4, Tx4	Subsoil erosion risk; high soil pH	4
4	Eb4, Tx4	Subsoil erosion risk; high soil pH	4
5	M4, Tx4	Poor water holding capacity; high soil pH	4
6	n/a	--	--
7	Tx4	High soil pH	4
8	Tx4	High soil pH	4
9	M4	Poor water holding capacity	4
10	M4, Tx4	Poor water holding capacity; high soil pH	4
11	M4	Poor water holding capacity	4
12	M5	Very poor water holding capacity	5
13	M4, Ps4, Nd4, Tx4	Poor water holding capacity; hardsetting soil; low P; high soil pH	4
14	Eb4, M4, Ps4, Tx4	Subsoil erosion risk; poor water holding capacity; hardsetting soil; high soil pH	4
15	Eb4, M4, Ps4, Tx4	Subsoil erosion risk; poor water holding capacity; hardsetting soil; high soil pH	4
16	M4, Ps4, R4, Sd4	Poor water holding capacity; hardsetting soil; rockiness; shallow soil	4
17	Eb4	Subsoil erosion risk	4
18	Ea4, Eb4, Nd4	Topsoil and subsoil erosion risk; low P	4
19	M5	Very poor water holding capacity	5
20	M5	Very poor water holding capacity	5
21	M4, Ps4, Nd	Poor water holding capacity; hardsetting soil; low P	4

4 DISCUSSION OF RESULTS

4.1 Land use limitations

A range of limitations affects the suitability of rehabilitation for sustainable cattle grazing. Most of these limitations are inherent to the constructed post-mining landscape and are enduring characteristics of the rehabilitation. Common limitations at Ensham include soil erosion risk, high soil pH, low soil water holding capacity, hardsetting topsoils and low soil fertility. In a regional context, land use limitations like these are not uncommon for grazing land in central Queensland (DPI&F, 2007).

Most rehabilitation at Ensham is land suitability class 4, breeding country, for sustainable cattle grazing. This land is marginally suited for sustainable cattle grazing but requires significant inputs to ensure sustainability and prevent land degradation. Those significant inputs might relate to managing total grazing pressure, using appropriate pasture utilisation rates, types of grazing systems and herd management strategies, strategic supplementation, forage budgeting strategies, utilising climate and seasonal forecasting resources, managing fire, fencing, distance to water and monitoring of pastures, amongst others.

It may be possible in certain instances to mitigate a limitation and by doing so, reduce the nature of inputs required to prevent land degradation and possibly improve land suitability class ranking. For example, much of the rehabilitation in the southern part of the mine has strong to very strong soil alkalinity, pH >8 and approaching 10. This is a serious limitation to sustainable grazing because high soil alkalinity affects the speciation and solubility of some essential plant nutrients, changing the amount of those nutrients that are available to plants. This will have knock-on effects in pasture productivity, pasture health and resilience to grazing, and ultimately feed intake quality, and cattle nutrition, health and productivity.

At pH >8 the availability of copper and zinc decreases; at pH >8.5 the availability of phosphorus decreases; and at pH >9.5 the availability of nitrogen, calcium, magnesium and a suite of micronutrients decreases (Hazelton and Murphy, 2007). This will occur regardless of fertiliser application of those nutrients, and the pasture and grazing cattle will be deficient.

There are two possible ways to address this limitation to ensure sustainability and prevent land degradation, viz. (i) cattle mineral supplementation via injection, water infusion or lick (block or liquid), or (ii) soil pH amendment via application of elemental sulphur to reduce the soil alkalinity by at least 1 pH unit (x100 reduction). Only the latter reduces management inputs and can potential improve land suitability class ranking. The feasibility of this action in existing rehabilitation should be examined. For future rehabilitation, pH correction should be a routine requirement when strongly alkaline materials are identified.

Three rehabilitation polygons are land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that usually preclude sustainable grazing. Grazing of this rehabilitation may only be possible sometimes, when summer rainfall promotes pasture growth and even then, probably only if it can be used in conjunction with other better quality land. Class 5 rehabilitation should be destocked seasonally to prevent excessive utilisation and land degradation.

4.2 Broad recommendations for grazing trials

Grazing trials should employ a production system matched to the land suitability of rehabilitation – Class 4 breeding country. Following are some broad recommendations for rehabilitation grazing management.

The appropriate production model for rehabilitation is a *store weaner production* model. In this system the main products are store weaners for sale or growing on better country, which is not rehabilitation. Surplus weaner heifers (not needed for replacements) and cull cows (empty) are secondary products.

In rehabilitation particular attention should be given to utilisation rates. Utilisation rate is the proportion of annual pasture growth (from July to June) that is consumed by grazing animals. Excessive utilisation adversely affects the capacity of the pasture to convert water and nutrients into growth, thereby having

detrimental impacts on sustainability (Chilcott *et al.* 2005). Impacts of over utilisation include tussock size reduction, loss of groundcover and accelerated erosion, and weed invasion. According to DPI&F (2007) utilisation rates in central Queensland vary depending on the fertility of the land but are typically 15% to 30% of annual pasture production. Although a low utilisation rate may appear to 'waste' feed, it is actually allowing pasture to recover from stress, set seed, and maintain groundcover and soil health. For these reasons, an appropriately low utilisation rate is critical to the sustainable grazing of rehabilitation.

Other important management considerations to ensure sustainability and prevent land degradation in rehabilitation include:

- Short-term forage budgeting strategies, i.e. using Stocktake Plus.
- Fencing according to land types.
- Managing distance to water and supplementation points to encourage paddock utilisation.

If possible, the store weaner production model in rehabilitation should be mimicked on unmined land of the same land suitability class ranking to allow direct comparison of system performance metrics. These metrics should include:

- The seasonal condition of cattle (live weights), particularly pregnant and lactating cows that can lose condition rapidly.
- Pregnancy, calving and weaning rates.
- Weaner age and live weight at turn off.
- Pasture and soil condition.

Modern grazing systems that promote rapid rumen development in calves and early weaning should also be considered, e.g. creep feeding. If achieved, early weaning will reduce the maintenance feed intake requirements for lactating cows, which in turn reduces the pressure on pastures.

5 REFERENCES

Bourne G and Tuck G (1993) *Understanding and managing soils in the Central Highlands*, Land Management Manual Project, Training Series QE93002, Department of Primary Industries, Brisbane.

Chilcott C, Sandral C, Aisthorpe J, Paton C, and McCallum B (2005). *Grazing Land Management- Fitzroy Basin Version*, Meat and Livestock Australia Limited, Australia.

CHRRUP (2016) *Ensham Resources, Yongala Grazing Trial and Assessment, 2016 Report*, Central Highlands Regional Resources Use Planning Cooperative Ltd, Emerald.

DNRM/DSITIA (2013a) *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition, Queensland Government, Brisbane.

DNRM/DSITIA (2013b) *Regional Land Suitability Frameworks for Queensland, Chapter 10 - Suitability framework for the Inland Fitzroy and Southern Burdekin area*, Queensland Government, Brisbane.

DPI&F (2007) *The economics of beef in central Queensland, Gross margins and production notes*. Department of Primary Industries and Fisheries, Brisbane.

GCAA (undated) *Fact Sheet, Land Use – Liddell Grazing Trial*, Glencore Coal Assets Australia, viewed on 13 November 2017 at <http://www.glencore.com.au/en/publications/fact-sheets/FactsheetsGCAA/Land-Use-Liddell-Grazing-Trial.pdf>

Grigg A, Mullen B, Bing So H, Shelton M, Bisrat S, Horn P and Yatapange K (2006) Sustainable grazing on rehabilitated lands in the Bowen Basin – Stages 1 and 2, ACARP Project No C9038, Australian Coal Research Limited, Brisbane.

Gunn R, Galloway R, Pedley L and Fitzpatrick E (1967) *Lands of the Nogoa-Belyando Area, Queensland*, Land Research Series No. 18, Commonwealth Scientific and Industrial Research Organisation, Melbourne.

Gunn R and Nix H (1977) *Land units of the Fitzroy region, Queensland*, Land Research Series No. 39, Commonwealth Scientific and Industrial Research Organisation, Melbourne.

Hollingsworth Dames and Moore (1991) *Ensham Coal Project Final Impact Assessment Study*.

Hnatiuk R, Thackway R and Walker J (2009) *Vegetation*, In: Australian Soil and Land Survey Field Handbook, Third Edition, Australian Soil and Land Survey Handbook Series, National Committee on Soil and Terrain, CSIRO Publishing, Melbourne.

Isbell RF (1996) *The Australian Soil Classification*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

McKenzie N, Coughlan K and Cresswell H (2002) *Soil Physical Measurement and Interpretation for Land Evaluation*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

McKenzie N, Grundy M, Webster R and Ringrose-Voase A (2008) *Guidelines for Surveying Soil and Land Resources*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

National Committee on Soil and Terrain (2009) *Australian Soil and Land Survey Field Handbook*, Third Edition, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Northcote K and Skene J (1972) Australian soils with saline and sodic properties, CSIRO Soil Publication 27.

QDME (1995) *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*, Queensland Department of Mines and Energy, Brisbane.

Queensland Government (2017a) *Land evaluation schemes*, viewed on 13 November 2017 at <https://www.qld.gov.au/environment/land/soil/soil-data/land-evaluation>

Queensland Government (2017b) *Interpreting data, map scales and site density*, viewed on 10 July 2017 at <https://www.qld.gov.au/environment/land/soil/soil-data/interpreting/>

Rayment G and Lyons D (2011) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Shields P and Williams P (1991) *Soils and land suitability for the Kilcummin area, central Queensland*, Department of Primary Industries, Brisbane.

State of NSW and Office of Environment and Heritage Protection (2012) *The land capability assessment scheme, second approximation: A general rural land evaluation scheme for New South Wales*, NSW Government, Sydney.

6 GLOSSARY OF TERMS

Cations – a ion with a net positive electrical charge.

Cation exchange capacity (CEC) – capacity of soil to hold and exchange cations.

Dispersion – occurs when clay particles separate from one another when wet, causing soil aggregates to break down, a loss of soil structure and an increased risk of erosion.

Electrical conductivity – a measure of soil salinity.

Electrochemical stability index - the ratio of the electrical conductivity (EC1:5 in dS/m) and the exchangeable sodium percentage (ESP = the sodium proportion of the cation exchange capacity, CEC) in a soil sample. An indication of a soils propensity to disperse when wet.

pH – a measure of soil acidity or basicity defined as the negative logarithm (base 10) of the activity of hydrogen ions in soil solution.

Horizon – distinctive layer of a soil profile.

Imperfectly drained – water is removed only slowly in relation to supply causing some horizons to be mottled and/or have orange or rusty linings of root channels, and are wet for several weeks following rainfall.

Massive – without structure, appearing as a solid mass devoid of peds.

Mottles – refers to secondary soil colours not associated with compositional properties and typically a sign of anaerobic conditions, i.e. imperfect drainage.

Ped – an individual soil aggregate.

Profile – vertical section that depicts soil horizons.

Salinity – the accumulation of water soluble salts, mainly sodium but also potassium, calcium and magnesium, which may be chlorides, sulphates or carbonates.

Sodicity – a measure of exchangeable sodium in relation to other exchangeable cations in soil and expressed Exchangeable Sodium Percentage (ESP). A soil with an ESP greater than 6 is generally regarded as being a sodic soil in Australia (Northcote and Skene, 1972).

Subsoil – horizon immediately below the surface soil or topsoil.

Texture – the proportion of sand, loam and clay sized particles that make up the mineral fraction of soil.

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APPENDIX A

The location of rehabilitation polygons and assessment sites

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APPENDIX B

Original laboratory reporting sheets

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November 2017



Ramp 22 Grazing Assessment 2017 Report

Version History			
Date	Version	Author	Description
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1.0 Introduction

Greenfields Agricultural and Environmental Services (Greenfields) has been commissioned by Ensham Resources to conduct a grazing assessment and report of rehabilitated areas at Ramp 22, Ensham mine.

The purpose of the grazing assessment is to provide evidence that demonstrates the ability of rehabilitated mine spoil to meet an end land use of a grazing rangeland system. The priorities of the grazing assessment will be to;

- A) demonstrate the rehabilitated areas can support a carrying capacity of similar land types and conditions of grazing areas in the surrounding district; and
- B) that rehabilitation remains a safe and stable landform prior to and following the grazing trial; and
- C) to ensure established rehabilitation pasture species remain viable following the grazing trial.

Whilst not thoroughly analyzed in this assessment, condition and performance of the cattle was considered as they were weighed prior and post grazing.

2.0 Methodology

A Stocktake assessment incorporating land and pasture condition was undertaken prior to the introduction of cattle and following their removal. Seven rehabilitation monitoring sites (refer to Appendix A for locations) of improved pasture namely Buffel (*Cenchrus ciliaris*) and Rhodes grass (*Chloris gayana*) were used. In September 2016 and prior to the introduction of cattle, fire was used to remove all moribund vegetation. Previously monitored rehabilitation sites were used for comparison against rehabilitation monitoring data.

Parameters included in the stocktake assessment are as follows;

- a) Ground cover (%) and species
- b) Dry matter (DM) yield kg/ha
- c) Yield unpalatable (%)
- d) Pasture and soil condition ratings

At each of the monitoring sites a 100m transect was established and at every 20m interval visual assessments for the above parameters were conducted using a 1m quadrat. Each monitoring location was marked and photographed at the existing steel picket and recorded with a handheld GPS. Monitoring was then repeated following the removal of cattle. Soil condition and pasture condition ratings are described in appendix D.

3.0 Cattle & Grazing Assessment Area

Rehabilitation at Ramp 22 was established in 2006/2007 and sown with improved pastures Buffel (*Cenchrus ciliaris*) and Katambora Rhodes (*Chloris gayana*), legumes Seca Stylo (*Stylosanthes scabra*) and Butterfly Pea (*Clitoria ternatea*). All species as indicated in the pre-assessment and in previous rehabilitation monitoring are present. Rehabilitation monitoring conducted in 2016 indicate ground cover at Ramp 22 was at 100%. However as identified in the field notes, grasses had become rank with substantial bulk considered unpalatable, initiating the need to burn and promote new growth prior to grazing.

The area used for the grazing assessment consisted of 134 hectares located at and around ramp 22. Subtracting infrastructure, total grazed area which contained available forage was 120 hectares (105 hectares of rehabilitation, 15 hectares stock pile/auxiliary). Fencing was constructed and watering infrastructure was put in place prior to the introduction of cattle. Grazing consisted of 83 light to medium weighted steers, providing a stocking rate of 1.4 beast per hectare.

Cattle were introduced on the 18th February 2017 and removed on the 16th October 2017, resulting in 1/1.4 stocking rate for a period of 240 days. Grazing was conducted during wet and dry seasons which provided further watering for growth and available protein with 364.58mm falling within the assessment period.

4.0 Pre-Assessment

The rehabilitation pre-assessment was conducted on Thursday 9th February 2017, 9 days prior to the introduction of cattle. Rehabilitation showed clear signs of the fire 5 months previous with blackened tussocks of grass present. However new growth, particularly Buffel grass had established and provided substantial forage. Prior to the assessment it was determined that a minimum requirement of dry matter yield be set, as well as a performance criteria for ground cover ensuring that rehabilitation areas were not overgrazed leading to potential instability of the battered slopes. Subsequently minimum requirements of 1800 kg/ha dry matter yield and 70% ground cover be maintained prior to the introduction of cattle. Monitoring results for rehabilitation sites concluded that the total average dry matter (DM) yield on the rehabilitation was 4540 kg/ha, resulting in combined total kilograms of available forage of 544 800 kg (4540kg/ha x 120 ha).

This figure however must be subtracted by the percent yield unpalatable to determine the amount of forage (grass) available to cattle as nutrients. The assessment identified that the average total percent yield unpalatable was 5% (227 kg/ha), this result is indicative of newly established pasture. Also, the retained dry matter yield of 1800 kg/ha had to be subtracted to determine available forage, therefore the pre -assessment determined the average total dry matter yield for the entire rehabilitation was 301 560 kg (4540 kg/ha - 5% - 1800 kg/ha x 120 ha)

In comparison determining forage demand for cattle can be calculated by using a 1 Adult Equivalent (AE) consuming 10 kg per day multiplied by the number of head of cattle and the number of days grazing. Light to medium weighted steers have an AE of .93, therefore the required forage demand for 83 steers is 771.9 kg per day (83 x 9.3 kg/per day). In this case the total number of days grazed was not determined at the time of the pre-assessment, therefore forage demand was calculated over a whole year, subsequently total forage demand for 365 days is 281 744 kg. In summary, the total available forage for the rehabilitation area exceeded the amount required by the cattle for 12 months.

The other parameters recorded included total average ground cover of 70.5%, at or only just above the minimum requirement of 70%. Further recovery of the rehabilitation (end of the wet season) following the fire in September was required for total average ground cover to be well above the minimum requirement. Soil condition rating recorded a total average of 1.34 and pasture condition rating a total average of 1.17. Soil condition was stable with no visual signs of movement with only minor crusting occurring and pasture condition recorded a high to moderate density of healthy perennial pasture species.

Rehabilitation - Grazing (Improved Pasture)					
Site ID	Soil condition	Pasture Condition	DM Yield	Ground Cover	
R22S (N)		1.8	1.4	3910	54
R22S _4_1		1.4	1	5200	82
R22S		1.2	1	5300	82
R21N_1_1		1	1	5350	82.5
R20_1_2		1.2	1	3940	61
R20_1_1		1.4	1.4	4110	69
R21N_1_2		1.4	1.4	3970	63
Rehab Averages	1.34	1.17	4540	70.5	

Table 1: Pre - assessment results for rehabilitation monitoring points

5.0 Post Assessment and Comparison

Following the removal of cattle on the 16th October 2017, a post assessment was conducted on the 25th October 2017 with results presented in Tables 2 and comparison of results in Tables 3 and 4. Total average live weight is presented in Table 5. In the 240 days of grazing, the rehabilitation sites recorded a decrease of DM yield of 19% from 4540 kg/ha to 3650 kg/ha. Total average percent yield unpalatable remained the same at 5% leaving the remaining available forage (available DM yield) also decreasing by 19%. Only a 19% decrease in DM yield/available forage for 240 days of grazing is attributed to late wet season/spring rainfall and pasture growth during the grazing period, also contributing was the amount of forage available to cattle inside the fenced area but outside the rehabilitation area.

Rehabilitation - Grazing (Improved Pasture)					
Site ID	Soil condition	Pasture Condition	DM Yield	Ground Cover	
R22S (N)		1.4	1.2	4420	89
R22S _4_1		1.2	1	4200	91
R22S		1	1	3180	70
R21N_1_1		1	1	3650	81
R20_1_2		1	1	3520	85
R20_1_1		1.2	1	2820	80
R21N_1_2		1.2	1	3760	84
Rehab Averages	1.14	1.03	3650	83	

Table 2: Post assessment results for rehabilitation monitoring points

Assessment	Total Avg DM Yield Kg/ha	Total Avg % yield unpalatable	Total Avg Available DM Yield kg/ha
Pre -Assessment	4540 kg/ha	5%	4313 kg/ha
Post Assessment	3650 kg/ha	5%	3467 kg/ha

Table 3: Comparison of pre and post assessment (yield)

Assessment	Soil Condition Rating	Pasture Condition Rating	Ground Cover %
Pre -Assessment	1.34	1.17	70.5
Post Assessment	1.14	1.03	83

Table 4: Comparison of pre and post assessment (ratings)

Environmental parameters such as soil condition, pasture condition and ground cover all improved from pre to post assessment. Post assessment total average ground cover recorded 83%, an increase of 17.7% from the pre-assessment total average ground cover of 70.5%. Soil and pasture condition ratings also improved from pre to post assessment with soil condition improving 17% and pasture improving 13%. Again, changes in pasture condition and ground cover can be attributed to rainfall and pasture growth throughout the grazing period. Grazing could contribute to the improvement in soil condition rating, however more specific monitoring is required to determine the effects of grazing on mine spoil in relation to the improvement of soil condition.

Cattle	Avg Live Weight Pre Assessment	Avg Live Weight Post Assessment	Avg Weight Gain kg Total	Avg Weight Gain Per day kg
83 Steers	327.5 kg	407.7 kg	80.2 kg	.33 kg per day

Table 5: Total average live weight assessment

No deaths were recorded during the grazing assessment with cattle averaging .33kg LWG per day. Table 5 identified total average weight, pre and post assessment. Refer to data set in Appendix E for individual statistics for live weight.

6.0 Discussion and Conclusion

Priorities set out prior to the commencement of the trial; to have a safe and stable landform that supports the carrying capacity similar to that of land types and conditions to those of surrounding properties, ensuring pasture species of the rehabilitation remains viable.

Conclusions following analysis of the monitoring data include the following;

- A) The Department of Employment, Economic Development, and Innovation (DEEDI), *Best-bet practices for managing the grazing lands of the Fitzroy Woodlands, Technical guide of options for optimising animal production, profitability and land condition (DEEDI, 2010)*, provides a guideline, generally proven to be the most successful long term approach to managing stocking rates. Stocking at close to the long-term carrying capacity is equal to or less than 30% average annual pasture utilisation depending on land type.
- 30% of average annual pasture utilisation in this assessment is 155 268 kg (average available dry matter yield = 4313 kg/ha x area available forage = 120 ha / 30%), dividing 155 268 kg by the forage demand of 771.9 kg (83 steers x 9.3 kg per day) per day equates to 201 days for 83 steers to reach 30% average annual pasture utilisation. In this assessment grazing was conducted over 240 days or 36% average annual pasture utilisation, exceeding the guideline for long term carrying capacity with no detrimental effect on soil, pasture and landform.
- B) DEEDI describes average LWG (live weight gain) on Buffel pastures in the Fitzroy during the growing season as .5kg/per head/per day if adequate crude protein is available. Cattle in this assessment achieved an average LWG of .33 kg/hd/day in a dominate dry season cell situation without the provision of supplements . Typically, without the provision of supplements LWG remains 0% or decreases during the winter months. Therefore live weight gain during this assessment can be considered a positive result.
- C) Total rainfall of 364.58mm fell during the grazing assessment. The conversion of rainfall to protein and pasture growth during the assessment would have typically occurred between January and April dependent on rainfall, temperature, soil, species, growth phase and slope. Due to grazing overlapping multiple seasons and pasture recording conducted pre and post assessment, it is difficult to quantify the exact pasture growth which occurred during the assessment. However, it can be considered significant as pasture was in phase 2 (mid growth) following the fire and at pre assessment.
- D) Ground cover during the assessment increased by 17.7% from 70.5% to 83%, a significant increase considering the assessment incorporated a complete dry season. Both soil and pasture condition ratings also improved with a 17% and 13% improvement respectively.

Results indicate that grazing whilst decreasing dry matter yield, increased environmental parameters of the grazed area/rehabilitation. Pasture and soil condition ratings improved as well as ground cover percentage indicating that grazing following fire at least maintained priorities set out at the commencement of the trial, having no detrimental effect on the landform and pasture while being grazed at an increased long term carrying capacity then those generally accepted in the Fitzroy Basin. It is important to note that the recommendation for long term

carrying capacity of equal to or less than 30% annual pasture utilisation should be considered a provisional maximum long term carrying capacity with further assessment and analysis conducted. The implications of land degradation on rehabilitation of mine spoil has the potential to exceed those of natural systems, therefore a more conservative stocking rate may be preferable.

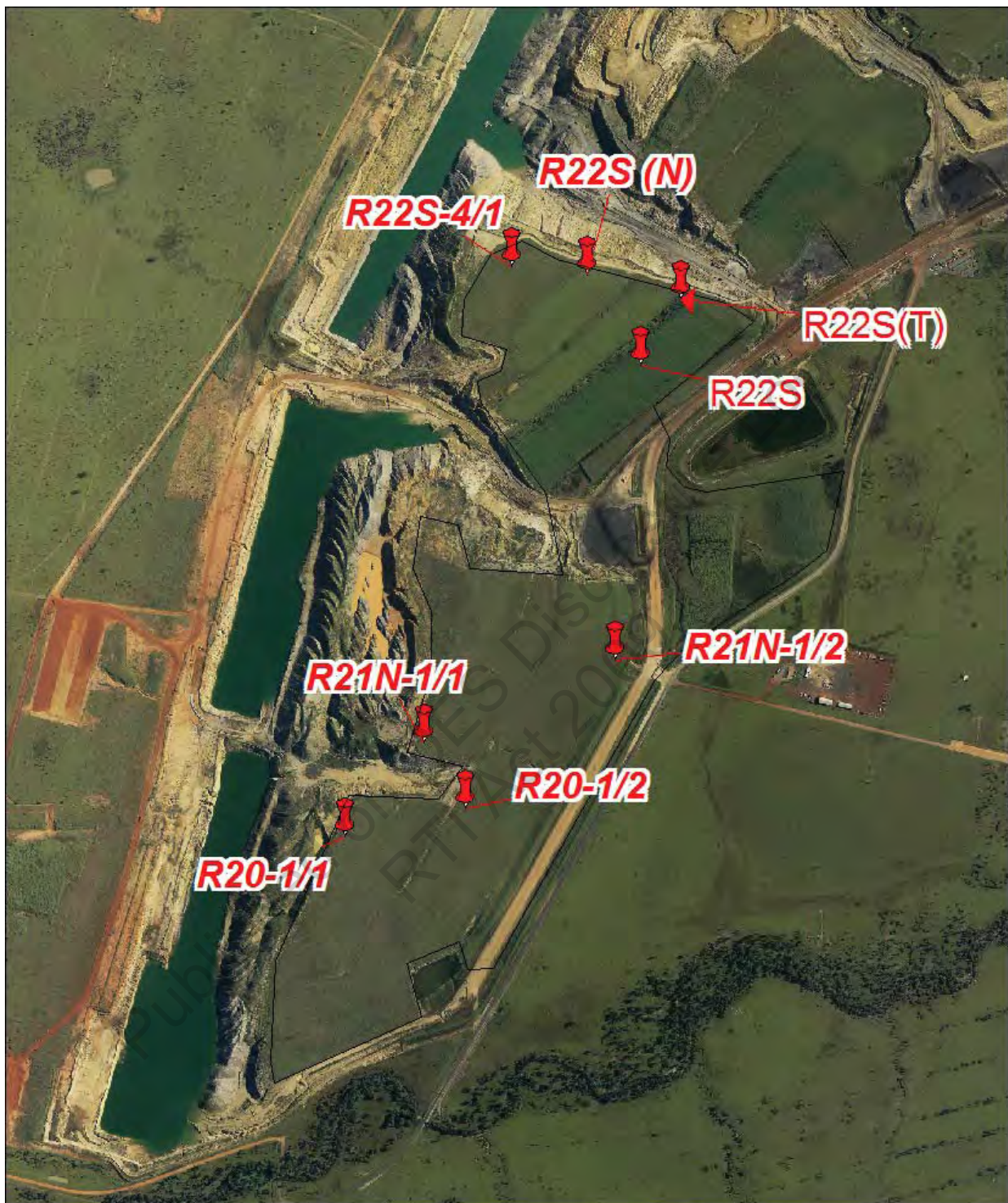
While a Stocktake assessment is considered appropriate industry practice in identifying grazing management regimes whilst maintaining and or improving land condition, it has been developed for grazing on natural land types and systems, therefore more specific and detailed assessment may be required, specifically soil sampling to identify any chemical limitations and or nutrient deficiencies which occur as a result of a modified land system. Faecal sampling during assessment would also be beneficial in determining the availability of major nutrients affecting growth and performance of the cattle.

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Appendix A

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Figure 1: Ramp 22 Grazing Assessment Monitoring Locations



Appendix B

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Table 6: R22S (N) Monitoring point field sheet pre assessment

ID Site:	R22S (N)					AVG
Date:	2/09/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 22					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy Cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	60	40	60	70	40	54
Soil Condition (1-5)	2	2	2	1	2	1.8
Pasture						
Condition rating (1-4)	2	2	1	1	1	1.4
DM Yield (kg/ha)	3500	4000	4000	4050	4000	3910
% Yield unpalatable	5	5	5	5	5	5
Photos:	1202					
GPS:	401					

Table 7: R22S (N) Monitoring point field sheet post assessment

ID Site:	R22S (N)					AVG
Date:	25/10/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 22					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy Cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	65	90	95	100	95	89
Soil Condition (1-5)	1	1	2	1	2	1.4
Pasture						
Condition rating (1-4)	1	1	1	1	2	1.2
DM Yield (kg/ha)	2200	3200	5400	5800	5500	4420
% Yield unpalatable	5	5	5	5	5	5
Photos:	1202					
GPS:	401					

Table 8: R22S 4_1 Monitoring point field sheet pre assessment

ID Site:	R22S 4_1					AVG	
Date:	2/09/2017						
Recorder:	Benn Knott						
Paddock Name:	Ramp 22						
Stock in Paddock:	83 Steers						
Land Type:	Rehab - Improved Pasture						
Area:	134 ha						
Tree cover:	0% Canopy cover						
Assessment:	20m	40m	60m	80m	100m		
Ground Cover (%)	80	90	70	90	80	82	
Soil Condition (1-5)	2	1	2	1	1	1.4	
Pasture							
Condition rating (1-4)	1	1	1	1	1		
DM Yield (kg/ha)	5000	5500	4500	6000	5000		5200
% Yield unpalatable	5	5	5	5	5		5
Photos:	1203						
GPS:	402						

Table 9: R22S 4_1 Monitoring point field sheet post assessment

ID Site:	R22S 4_1					AVG
Date:	25/10/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 22					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	85	80	100	90	100	91
Soil Condition (1-5)	1	1	2	1	1	1.2
Pasture						
Condition rating (1-4)	1	1	1	1	1	
DM Yield (kg/ha)	3800	2400	5400	3200	6200	
% Yield unpalatable	5	5	5	5	5	
Photos:	1203					
GPS:	402					

Table 10: R22S Monitoring point field sheet pre assessment

ID Site:	R22S					AVG
Date:	2/09/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 22					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	80	80	90	90	70	82
Soil Condition (1-5)	1	1	1	1	2	1.2
Pasture						
Condition rating (1-4)	1	1	1	1	1	1
DM Yield (kg/ha)	5000	5000	6000	6000	4500	5300
% Yield unpalatable	5	5	5	5	5	5
Photos:	1204					
GPS:	403					

Table 11: R22S Monitoring point field sheet post assessment

ID Site:	R22S					AVG
Date:	25/10/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 22					
Stock in Paddock:						
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	90	85	70	10	95	70
Soil Condition (1-5)	1	1	1	1	1	1
Pasture						
Condition rating (1-4)	1	1	1	1	1	1
DM Yield (kg/ha)	4200	3800	3200	1200	3500	3180
% Yield unpalatable	5	5	5	5	5	5
Photos:	1204					
GPS:	403					

Table 12: R21N_1_1 Monitoring point field sheet pre assessment

ID Site:	R21N_1_1					AVG
Date:	2/09/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 21 <i>Start Peg Outside Fence</i>					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	n/a	80	80	90	80	82.5
Soil Condition (1-5)	n/a	1	1	1	1	1
Pasture						
Condition rating (1-4)	n/a	1	1	1	1	1
DM Yield (kg/ha)	n/a	5000	5000	6000	5400	5350
% Yield unpalatable	n/a	5	5	5	5	5
Photos:	1205					
GPS:	404					

Table 13: R21N_1_1 Monitoring point field sheet post assessment

ID Site:	R21N_1_1						AVG
Date:	25/10/2017						
Recorder:	Benn Knott						
Paddock Name:	Ramp 21 <i>Start Peg Outside Fence</i>						
Stock in Paddock:	83 Steers						
Land Type:	Rehab - Improved Pasture						
Area:	134 ha						
Tree cover:	0% Canopy cover						
Assessment:	20m	40m	60m	80m	100m		
Ground Cover (%)	n/a	80	80	75	90	81.25	
Soil Condition (1-5)	n/a	1	1	1	1	1	
Pasture							
Condition rating (1-4)	n/a	1	1	1	1	1	
DM Yield (kg/ha)	n/a	3800	4200	2400	4200	3650	
% Yield unpalatable	n/a	5	5	5	5	5	
Photos:	1205						
GPS:	404						

Table 14: R20_1_2 Monitoring point field sheet pre assessment

ID Site:	R20_1_2					AVG
Date:	2/09/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 20					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	50	60	75	60	60	61
Soil Condition (1-5)	2	1	1	1	1	1.2
Pasture						
Condition rating (1-4)	1	1	1	1	1	1
DM Yield (kg/ha)	3500	4000	4200	4000	4000	3940
% Yield unpalatable	5	5	5	5	5	5
Photos:	1206					
GPS:	405					

Table 15: R20_1_2 Monitoring point field sheet post assessment

ID Site:	R20_1_2					AVG
Date:	25/10/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 20					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					
Tree cover:	0% Canopy cover					
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	90	100	70	75	90	85
Soil Condition (1-5)	1	1	1	1	1	1
Pasture						
Condition rating (1-4)	1	1	1	1	1	1
DM Yield (kg/ha)	3800	4200	3200	3800	2600	3520
% Yield unpalatable	5	5	5	5	5	5
Photos:	1206					
GPS:	405					

Table 16: R20_1_1 Monitoring point field sheet pre assessment

ID Site:	R20_1_1					AVG
Date:	2/09/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 20					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					90
Tree cover:	0% Canopy cover					0
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	70	70	70	70	65	69
Soil Condition (1-5)	1	2	1	1	2	1.4
Pasture						
Condition rating (1-4)	1	2	1	2	1	1.4
DM Yield (kg/ha)	4100	4100	4200	4150	4000	4110
% Yield unpalatable	5	5	5	5	5	5
Photos:	1207					
GPS:	406					

Table 17: R20_1_1 Monitoring point field sheet post assessment

ID Site:	R20_1_1					AVG
Date:	25/10/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 20					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					90
Tree cover:	0% Canopy cover					0
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	70	90	80	90	70	80
Soil Condition (1-5)	1	1	2	1	1	1.2
Pasture						
Condition rating (1-4)	1	1	1	1	1	1
DM Yield (kg/ha)	2800	3400	2400	3000	2500	2820
% Yield unpalatable	5	5	5	5	5	5
Photos:	1207					
GPS:	406					

Table 18: R21N_1_2 Monitoring point field sheet pre assessment

ID Site:	R21N_1_2					AVG
Date:	2/09/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 21					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					90
Tree cover:	0% Canopy cover					0
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	65	60	60	65	65	63
Soil Condition (1-5)	2	1	1	1	2	1.4
Pasture						
Condition rating (1-4)	1	2	1	2	1	1.4
DM Yield (kg/ha)	4000	3900	3950	4000	4000	3970
% Yield unpalatable	5	5	5	5	5	5
Photos:	1208					
GPS:	407					

Table 19: R21N_1_2 Monitoring point field sheet post assessment

ID Site:	R21N_1_2					AVG
Date:	25/10/2017					
Recorder:	Benn Knott					
Paddock Name:	Ramp 21					
Stock in Paddock:	83 Steers					
Land Type:	Rehab - Improved Pasture					
Area:	134 ha					90
Tree cover:	0% Canopy cover					0
Assessment:	20m	40m	60m	80m	100m	
Ground Cover (%)	80	80	90	80	90	84
Soil Condition (1-5)	1	1	1	1	2	1.2
Pasture						
Condition rating (1-4)	1	1	1	1	1	1
DM Yield (kg/ha)	4500	4800	1200	3800	4500	3760
% Yield unpalatable	5	5	5	5	5	5
Photos:	1208					
GPS:	407					

Appendix C

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Figure 2: R22S N Photo monitoring point (Pre Assessment)



Figure 3: R22S_4 _1 Photo monitoring point (Pre Assessment)



Figure 4: R22S Photo monitoring point (Pre Assessment)



Figure 5: R21N_1_1 Photo monitoring point (Pre Assessment)



Figure 6: R20 _1_2 Photo monitoring point (Pre Assessment)



Figure 7: R20 _1_1 Photo monitoring point (Pre Assessment)



Figure 8: R20N_1_2 Photo monitoring point (Pre Assessment) - post not found



Figure 9: R22S (N) Photo monitoring point (Post Assessment)



Figure 10: R22S_4 _1 Photo monitoring point (Post Assessment)



Figure 11: R22S Photo monitoring point (Post Assessment)



Figure 12: R21N_1_1 Photo monitoring point (Post Assessment)



Figure 13: R20_1_1 Photo monitoring point (Post Assessment) - *Incorrect label (R20_1_2 photo missing)*



Figure 14: R20N_1_2 Photo monitoring point (Post Assessment) - *incorrect label (Post found and replaced)*



Appendix D

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Table 20: Soil surface condition rating assessment table

Surface Description	Soil Condition Rating	Indicators
Stable	1	No visual evidence of soil movement
Slight disturbance	2	Soil slightly disturbed by erosion, indicators include; Soil surface compaction or crusting Signs of increased surface run - off Signs of increased soil movement by wind or water Cattle tracks affecting water movement
Moderate disturbance	3	Soil moderately affected by erosion, indicators include; Plant pedestalling occurring Definite signs of sheet or rill erosion Definite signs of soil mounding around obstructions Salt affected areas occurring Gravel and stone pavements common
Severe disturbance	4	Soil severely affected by erosion, indicators include; Any rocks or plants on pedestals Run-off concentrated in channels Prominent sheet, rill or gully erosion to 15 cm deep Prominent sand mounds blown against objects Vegetated areas isolated in mounds or depressions Scalds, exposed subsoil Gravel and stone pavements prominent Bedrock at the surface
Very severe disturbance	5	Soil very severely disturbed by erosion, indicators are as for severely disturbed above but more extreme Sheet, rill or gully erosion greater than 15cm deep

Table 21: Pasture condition rating assessment table

Condition Rating	Condition Indicators				
	3P Grasses		Annual Grass	Undesirable	Species
	% DM Yield	Crown Cover	% DM Yield	grasses and other weeds	Diversity Desirables
1	> or = 80%	Dense and plants healthy	< or = 20%	< or = 20%	> 5 species
2	60 - 80%	High to moderate density and some	20 - 40%	20 - 30%	3-5 species
3	10 - 60%	Moderate to low density and some	40 - 70%	30 - 80%	2-3 species
4	< 10%	Sparse and many plants dead	>70%	>80%	1 or less

Appendix E

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Table 22: Cattle Weight Pre Assessment

Identification	Sex	Weight (kg)			
OR0535	S	294.00	OR0579	S	300
OR0536	S	384	OR0580	S	346
OR0537	S	392	OR0581	S	360
OR0538	S	372	OR0582	S	377
OR0539	S	230	OR0583	S	332
OR0540	S	382	OR0584	S	331
OR0541	S	354	OR0585	S	332
OR0542	S	327	OR0586	S	265
OR0543	S	293	OR0587	S	383
OR0544	S	398	OR0588	S	284
OR0545	S	280	OR0589	S	229
OR0546	S	294	OR0590	S	327
OR0547	S	390	OR0591	S	303
OR0548	S	311	OR0592	S	410
OR0549	S	308	OR0593	S	413
OR0550	S	336	OR0594	S	352
OR0551	S	265	OR0595	S	408
OR0552	S	294	OR0596	S	250
OR0553	S	315	OR0597	S	413
OR0554	S	303	OR0598	S	261
OR0555	S	377	OR0599	S	322
OR0556	S	365	OR0600	S	264
OR0557	S	426	OR0601	S	386
OR0558	S	376	OR0602	S	314
OR0559	S	354	OR0603	S	313
OR0560	S	335	OR0604	S	347
OR0561	S	298	OR0605	S	251
OR0562	S	308	OR0606	S	361
OR0563	S	248	OR0607	S	331
OR0564	S	353	OR0608	S	389
OR0565	S	261	OR0609	S	348
OR0566	S	342	OR0610	S	294
OR0567	S	314	OR0611	S	297
OR0568	S	350	OR0612	S	296
OR0569	S	358	OR0613	S	346
OR0570	S	305	OR0614	S	339
OR0571	S	280	OR0615	S	334
OR0572	S	301	OR0616	S	346
OR0573	S	323	OR0617	S	308
OR0574	S	241	83 Animals	Av. Weight	327.5
OR0575	S	331			
OR0576	S	255			
OR0577	S	324			
OR0578	S	353			

Table 23: Cattle Weight Post Assessment

Identification	Sex	Weight (kg)			
OR0535	S	360	OR0579	S	379
OR0536	S	443	OR0580	S	410
OR0537	S	436	OR0581	S	417
OR0538	S	447	OR0582	S	442
OR0539	S	413	OR0583	S	415
OR0540	S	475	OR0584	S	430
OR0541	S	422	OR0585	S	395
OR0542	S	422	OR0586	S	372
OR0543	S	396	OR0587	S	460
OR0544	S	465	OR0588	S	359
OR0545	S	343	OR0589	S	326
OR0546	S	374	OR0590	S	405
OR0547	S	436	OR0591	S	391
OR0548	S	384	OR0592	S	500
OR0549	S	395	OR0593	S	487
OR0550	S	408	OR0594	S	427
OR0551	S	359	OR0595	S	478
OR0552	S	389	OR0596	S	343
OR0553	S	401	OR0597	S	485
OR0554	S	371	OR0598	S	345
OR0555	S	488	OR0599	S	417
OR0556	S	463	OR0600	S	344
OR0557	S	488	OR0601	S	466
OR0558	S	438	OR0602	S	393
OR0559	S	454	OR0603	S	401
OR0560	S	437	OR0604	S	432
OR0561	S	387	OR0605	S	333
OR0562	S	387	OR0606	S	411
OR0563	S	352	OR0607	S	408
OR0564	S	413	OR0608	S	468
OR0565	S	363	OR0609	S	411
OR0566	S	405	OR0610	S	357
OR0567	S	417	OR0611	S	363
OR0568	S	395	OR0612	S	367
OR0569	S	432	OR0613	S	417
OR0570	S	409	OR0614	S	407
OR0571	S	367	OR0615	S	420
OR0572	S	361	OR0616	S	416
OR0573	S	416	OR0617	S	387
OR0574	S	328	83 Animals	Av. Weight	407.7
OR0575	S	413			
OR0576	S	366			
OR0577	S	388			
OR0578	S	454			



Ensham
R E S O U R C E S

REHABILITATION MANAGEMENT PLAN

Pursuant to condition G12 of permit
Environmental Authority EPML00732813

May 2017

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ACRONYMS AND DEFINITIONS

ACARP	Australian Coal Association Research Program	NRM	Queensland Department of Natural Resources and Mines
CMLR	Centre for Mined Land Rehabilitation, Sustainable Minerals Institute, The University of Queensland	Plan	How we will do it
Completion criteria	These are the standards that are to be met by successful rehabilitation. They will generally be in the form of numerical values that can be verified by measurement of the indicators selected for the rehabilitation objectives.	PoO	Plan of Operations
Domain	Land management units for rehabilitation planning and execution	Reference site	A locality undisturbed by mining with similar land and soil attributes, vegetation characteristics and land use, which provides 'target conditions' for assessment of rehabilitation
EA	Environmental Authority EPML00732813	Residual risk	As defined in schedule 4 of the EP Act, includes the risk that: <ul style="list-style-type: none"> • Rehabilitation will fail and need repair, replacement or maintenance; • Rehabilitation will need ongoing maintenance; or
EHP	Queensland Department of Environment and Heritage Protection	RI	Potential environmental harm needs monitoring or management
EMS	Environmental Management System	RMP	Recordable injury
EP Act	Environmental Protection Act 1994	SHMS	Rehabilitation Management Plan (this document)
ESD	Ecologically sustainable development	Stakeholder	Safety and Health Management System
FA	Financial assurance		A person or organisation that is potentially affected by a decision, such as a resident, land owner, community group, government agency, company, traditional owner, or environmental group.
Goals	Policy objectives for rehabilitation set by Government: <ul style="list-style-type: none"> • Safe • Stable • Non-polluting, and • Agreed land use 	Strategy	What we will do
Indicator	Something that can be measured and audited according to an established protocol and used to evaluate changes in a system		
ML	Mining lease		

1 INTRODUCTION

This Rehabilitation Management Plan (RMP) describes rehabilitation at Ensham coal mine, located 40 kilometres (km) northeast of Emerald in central Queensland. Ensham is an open-cut and underground mining complex, producing high energy, low ash thermal coals from the Permian age Rangal Coal Measures. It operates on an aggregation of seven mining leases and in accordance with Environmental Authority (EA) EPML00732813 conditions.

Ensham Resources Pty Limited manages the mine on behalf of joint venture partners and Environmental Authority holders Bligh Coal Limited and Idemitsu Australia Resources Pty Limited (jointly 85%) and Natural Resources Investment (Australia) Pty Limited (15%). La Tierra Pty Limited, as independent consultants and an appropriately qualified person¹, has prepared this report for and on behalf of Ensham Resources.

1.1 Plan purpose

The purpose of this RMP is to describe rehabilitation at Ensham mine in accordance with requirements of condition G11 of the EA.

1.1.1 Plan structure

The RMP is structured as follows.

Section 1	Introductory context and purpose
Section 2	Strategy for progressive rehabilitation including schedule of works to end of mine life
Section 3	Material characteristics and management
Section 4	Landform design objectives
Section 5	Soil resource management
Section 6	Rehabilitation methods
Section 7	Native vegetation corridors
Section 8	Description of reference sites
Section 9	Objectives, indicators and completion criteria for each domain, including post-mining land use/s
Section 10	Continuous improvement
Section 11	Triple bottom line assessment – people, planet & profit
Section 12	Full references for all citations within the text of the RMP
Appendix A	Limitation subclass threshold limits for Land Suitability Assessment of rehabilitation for sustainable cattle grazing in central Queensland
Appendix B	Ensham risk matrix tool

¹ “Appropriately qualified person” has the same meaning as in EHP Guideline EM1122, version 2, dated 2014.

1.1.2 Complying with EA requirements

The RMP addresses each requirement of EA condition G11 (Table 1-1).

Table 1-1 Addressing EA requirements

Relevant criteria		Where addressed
a)	A map existing of areas of rehabilitation including classification of stage (i.e. time since establishment) and quality	Section 2, Figure 2-3
b)	A strategy for progressive rehabilitation, including a progressive rehabilitation schedule	Section 2, Table 2-1
c)	Details of the design objectives for rehabilitation of each domain to achieve rehabilitation success criteria and the identified post mining land uses	Section 4, Section 9, Table 9-1
d)	Specify the spoil characteristics, soil analysis and soil separation for use on rehabilitation	Section 3, Section 5
e)	Specify the topsoil requirements for the site and how topsoil will be managed for use in rehabilitation	Section 5
f)	Details of any topsoil deficit and how any deficit will be managed for successful rehabilitation	Section 5
g)	Details of rehabilitation methods to be applied to areas	Section 6, Table 6-1
h)	Details of landform design including end of mine design	Section 4
i)	Details of how landform design will be consistent with surrounding topography	Section 4.5
j)	Identification of planned native vegetation rehabilitation areas and corridors	Section 7
k)	Identification of at least a minimum of three (3) reference sites for use in rehabilitation monitoring	Section 8
l)	Description of rehabilitation indicators and how these will be monitored	Section 9 Section 10, Table 10-1
m)	Description of management actions to address unsuccessful rehabilitation or redesign	Section 10
n)	Description of end of mine landform design planning and post mining land uses across the mine	Section 4, Section 9
o)	Include a triple bottom line assessment (or a comparative alternative assessment method) of the proposed final landform design criteria and alternatives	Section 11

2 STRATEGY FOR PROGRESSIVE REHABILITATION

Following is the overarching strategy for progressive rehabilitation at Ensham. The areas and timing of works nominated herein are indicative only and may vary due to operational and other requirements. Specific areas for rehabilitation will continue to be nominated in successive Plans of Operations.

2.1 Rehabilitation to date and life-of-mine forecast

To end-2016, Ensham had disturbed 4,591 hectares (ha) of land and rehabilitated 1,170 ha or 25% of this area (Figure 2-1, 2-2 and 2-3). By the time coal production ceases in 2029, a total disturbance footprint of 4,743 ha is forecast. Rehabilitation earthworks are scheduled for completion by 2031.

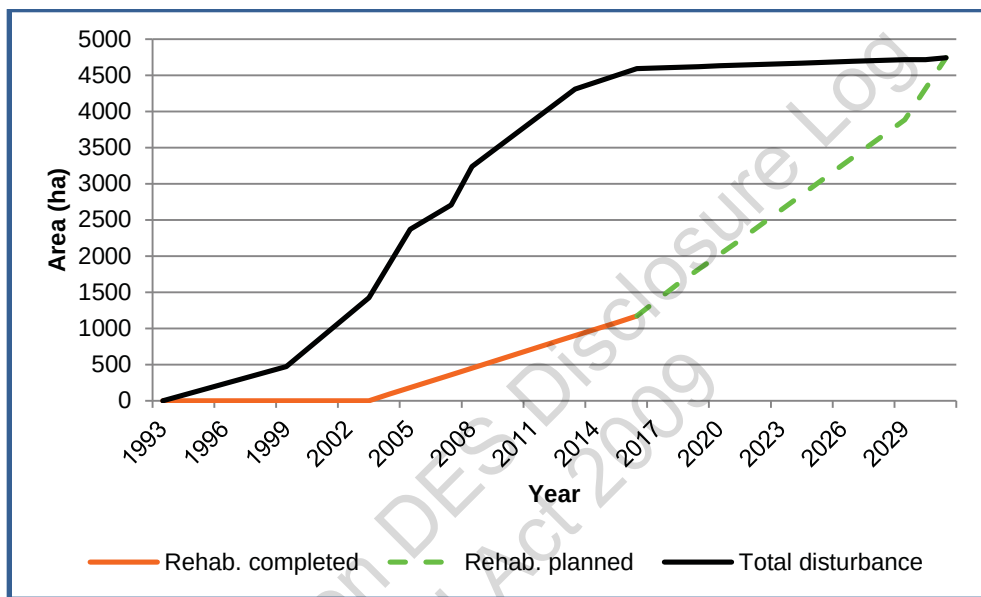


Figure 2-1 Life-of-mine disturbance and rehabilitation

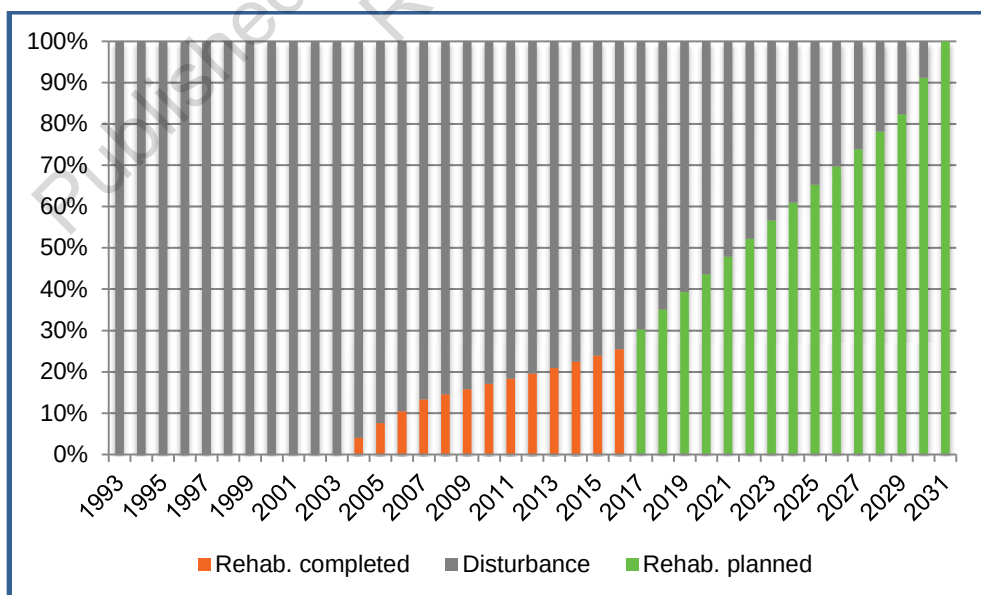


Figure 2-2 Rehabilitation as a percentage of disturbance over life-of-mine

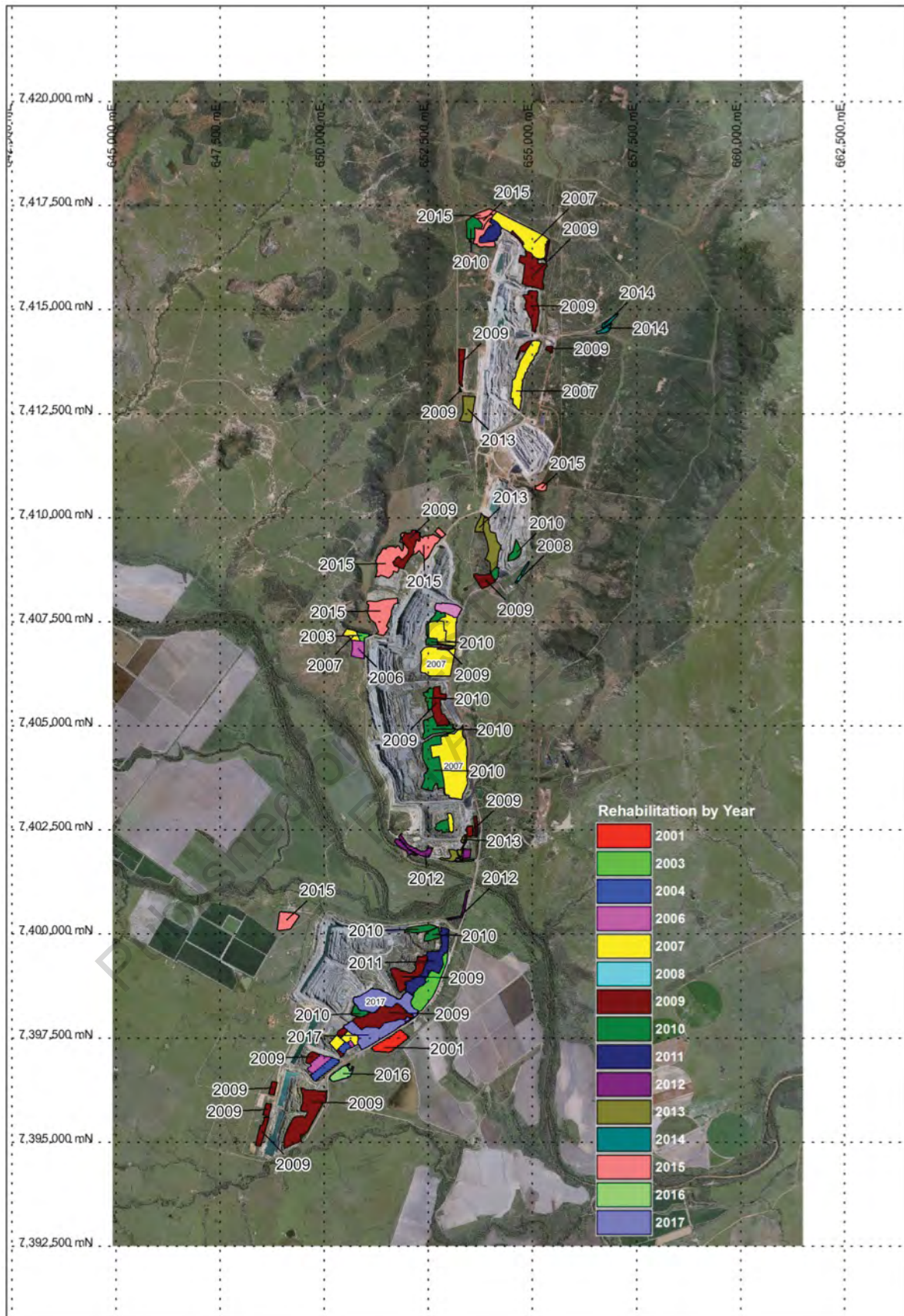


Figure 2-3 Chronology of rehabilitation completed to date

Completion of all rehabilitation requirements has been forecast based on the following constraints:

- Complete as much rehabilitation as is possible before coal production ceases and spread this more or less evenly across the 13-year period from 2017 to 2029;
- There is 861 ha associated with the safe and efficient operation of the open-cut and underground and this area is not available for rehabilitation until after production ceases in 2029; and,
- Finish rehabilitation as soon as practicable after production ceases and within two years.

This rehabilitation forecast highlights several important matters for Ensham:

- Little permanent rehabilitation was completed in the first 10 years of operation. Permanent rehabilitation commenced in 2004.
- The gap between disturbance and rehabilitation has widened, year-on-year from 1993 to 2016. This has deferred rehabilitation on-ground and costs.
- In the next 5 years from 2017 to 2021, the plan is to complete 1,050 ha of rehabilitation. This is almost as much rehabilitation as has been completed in the preceding 24 years (1,170 ha).
- The rehabilitation rate required from 2017 to 2029 is about 210 ha/y (mean).
- In the final two years of the rehabilitation program, i.e. 2030-31, the required rehabilitation rate is 431 ha/y.

2.2 Strategy

Rehabilitation works have been scheduled to end of mine life at strategic time intervals (Table 2-1). Based on constraints listed (see previous section) all disturbance, current and forecast, has been allocated a time period for rehabilitation (Figure 2-4).

Table 2-1 Indicative rehabilitation schedule to end of mine life

Interval (years)	Year	Period	Note	Area (ha)
Historic	End-2016	1993-2016	Period to date	1,170
2	End-2018	2017-2018	Rolling period for detailed planning	447
5	End-2021	2019-2021	Rolling period for conceptual planning	603
10	End-2026	2022-2026	Rolling period for conceptual planning	1,046
13	End-2029	2027-2029	Fixed period, end of planned production	616
15	End-2031	2030-2031	Fixed period, all rehabilitation completed	861
TOTAL				4,743

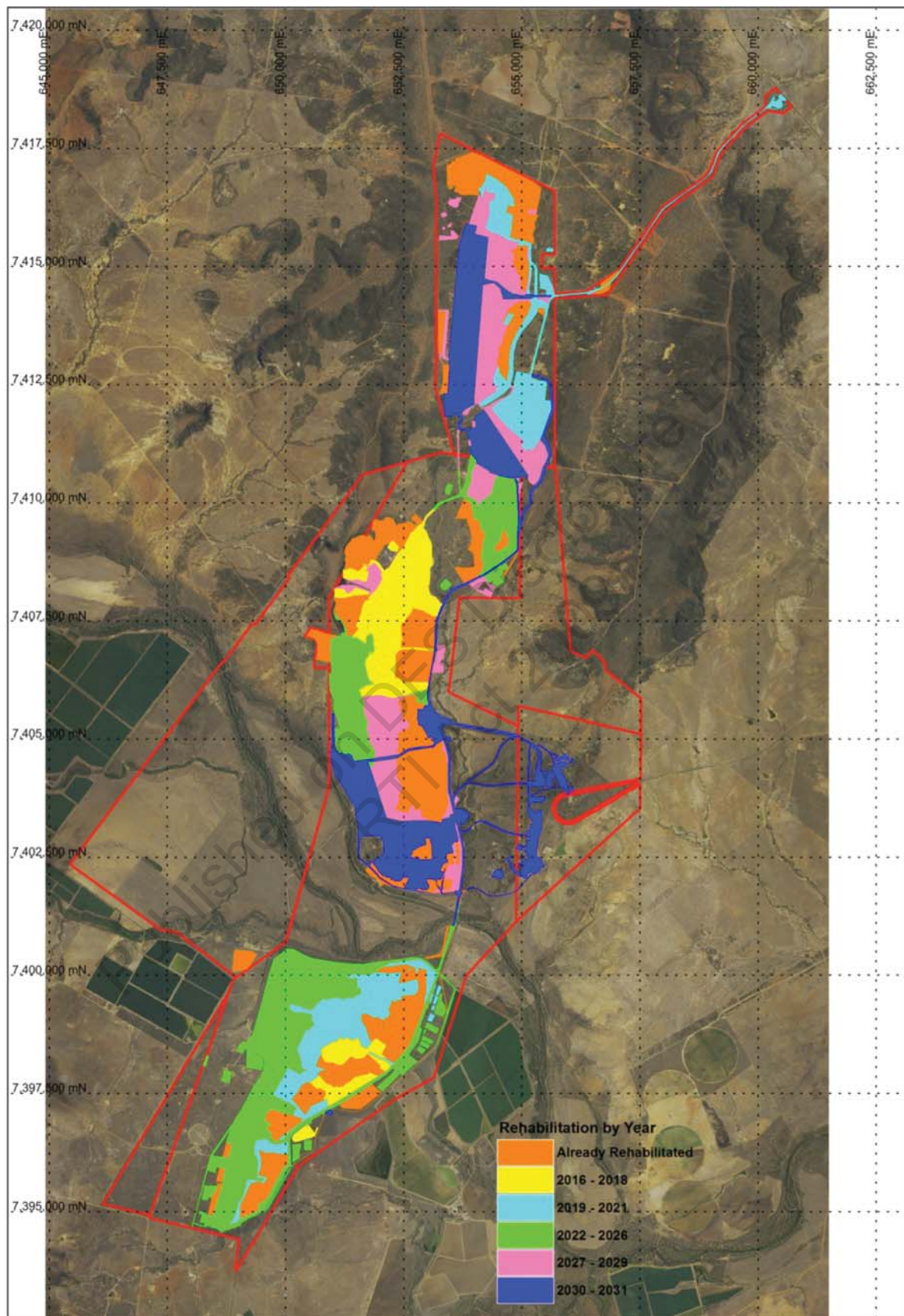


Figure 2-4 Indicative forecast progressive rehabilitation to end of mine life

3 MATERIAL CHARACTERISTICS

To determine appropriate landform design parameters for rehabilitation, it is crucial to understand material characteristics. Several reports have described materials at Ensham to varying extents, e.g. Loch (2015), URS (2005), URS (2015) and CMLR (2005), and each contain some useful information. Reports demonstrate that spoils and soils are typically sodic and saline, and non-acid forming.

3.1 Overburden types and distribution

CMLR (2005) provides a simple and practical classification of overburdens based on geology and measured physical and chemical parameters. Four distinct spoils were identified, described and mapped throughout the mine (Table 3-1).

Table 3-1 Spoil types and their distribution (adapted from CMLR, 2005)

Era	Period	Group	Description	Ensham pit						
				A	B	C	D	E	F	Y
Cainozoic	Quaternary	n/a	Alluvial sands, silt gravel	Q						
	Tertiary	n/a	Sandstone, siltstone, claystone		T2				T2	
				T1						
Palaeozoic	Upper Permian	Blackwater	Rangal coal measures	P						
				COAL						

A description of each overburden type follows.

3.1.1 Quaternary (Q) overburden

Pale brown to yellow alluvial sands and gravels (Figure 3-1). Low clay content means material has little water or nutrient holding capacity. Non-saline but sodic with low surface cohesion, this overburden is highly dispersive and prone to excessive erosion when exposed to rainfall.



Figure 3-1 Quaternary overburden in B Pit is screened for gravel and sand for use around site (left) and erosion of in situ Quaternary overburden on B Pit endwall (right)

3.1.2 Tertiary (T2) overburden

This overburden is Tertiary age material that appears above T1 overburden in B, C, F and Y pits. It is distinguishable from T1 by its darker colour but is otherwise physically and chemically similar.

3.1.3 Tertiary (T1) overburden

Overlying the Permian overburden, this material is derived from Tertiary age alluvium or colluvium (Figure 3-2). It is consistently saline to extremely saline, with chloride levels toxic to plants at Y Pit, and consistently sodic to extremely sodic. This material is extremely dispersive.



Figure 3-2 Tertiary overburden overlying Permian overburden in Y Pit (left) and F Pit (right)

3.1.4 Permian (P) overburden

Easily distinguished by its bluish grey colour, consisting on rapidly weathering mudstones and siltstones, with orange/yellow resistant sandstone fragments (Figure 3-3). Derived from Permian sedimentary rocks of the Blackwater Group, it is generally non-saline to saline and sodic.

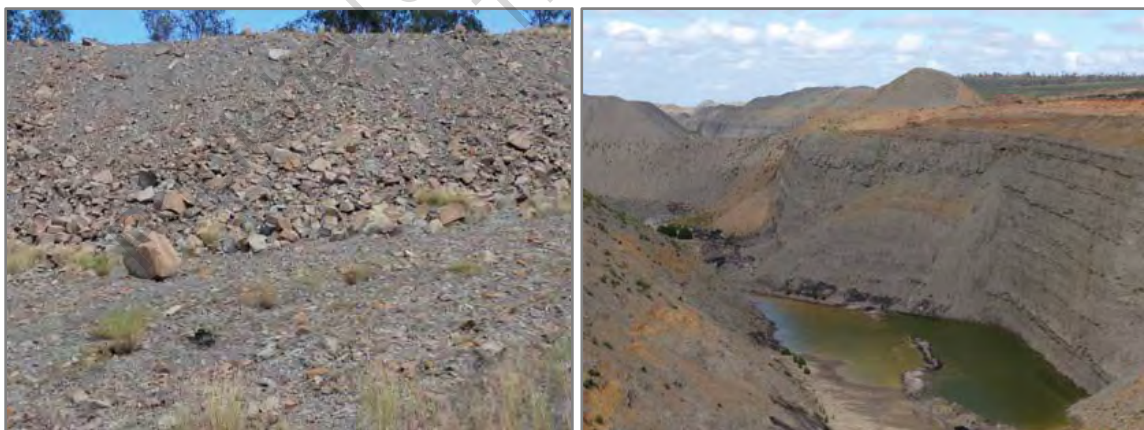


Figure 3-3 Permian overburden in D Pit emplacement (left) and E Pit highwall (right)

3.2 Soil types and distribution

A range of soil types is present at Ensham and these have previously been grouped into six major types (Hansen 2006):

- *Soil Group (1) – Shallow Rocky Soils* (Rudosols) that occur on low rocky hills and steep escarpment slopes and eroded plateau remnants. These soils are shallow (<0.5m), exhibit very little profile development and contain gravel and rock cobbles from various geological formations.

- *Soil Group (2) – Moderately Shallow Gravelly Sands, Loams and Clay Soils* (Rudosols and Tenosols) that occur on eroded middle and lower slopes and broad low gravelly rises. These soils are shallow to medium depth and comprise uniform or weakly gradational sands, loamy sands or sandy loams, loams or clayey soils with varying amounts of ferruginous and siliceous gravel or stone. These soils exhibit low soil fertility and water storage capacity.
- *Soil Group (3) – Gradational Red and Yellow Earth Soils* (Kandosols-Tenosols, Kandosols and Ferrosols) present on the elevated dissected and eroded Tertiary plateau remnants and undulating plains associated with the Tertiary Emerald Formation. These soils include sandy, sandy loam or loamy surface soils grading to red, reddish brown or yellowish brown sandy loam to light to medium massive or structured clay subsoils often with appreciable amounts of ferruginous gravel.
- *Soil Group (4) – Texture Contrast (Duplex) Soils* (Sodosols) that have formed on Permo- Triassic sedimentary rocks, on gently inclined slopes, dissection slope interfluvies, broad low rises and plains and on alluvial terraces and drainage flats. These soils are sandy, silty or loamy on the surface with a clear to abrupt change to a clayey subsoil horizon.
- *Soil Group (5) – Uniform Fine-textured (non-cracking) Clay Soils* (Dermosols) present on erosional plains, levees and high terraces along stream systems, undulating alluvial plains and associated with cracking clays of Soil Group 6. These soils exhibit uniform profiles or weakly gradational profiles where clay content may increase slightly with depth.
- *Soil Group (6) – Cracking Clay Soils (Vertosols)* that form the dominant soil type within the alluvial plains associated with the Nogoa River and its tributaries. These soils have uniform medium to high clay content, pronounced swelling and shrinkage properties and commonly feature gilgai.

Most soils are highly weathered, chemically and physically poor, and can be saline and sodic at depth.

3.3 Effect of salinity and sodicity

Salinity is the presence of soluble salts in soil solution, while sodicity is the relative percentage of Na^+ attached to clay particles, i.e. on the cation exchange surfaces. Salinity and sodicity are opposing forces in soil / overburden stability: salinity is aggregating and sodicity is dispersing. Salinity and sodicity often occur together and salt affected materials have historically been grouped as saline, non-saline and sodic, or saline and sodic, depending on the relative composition of the salts present. Using available data, Ensham overburdens and soils can be grouped into these categories (Figures 3-4 and 3-5). Here, a saturated electrical conductivity (ECe) >4 (dS/m) and an exchangeable sodium percentage (ESP) >6 are the generally

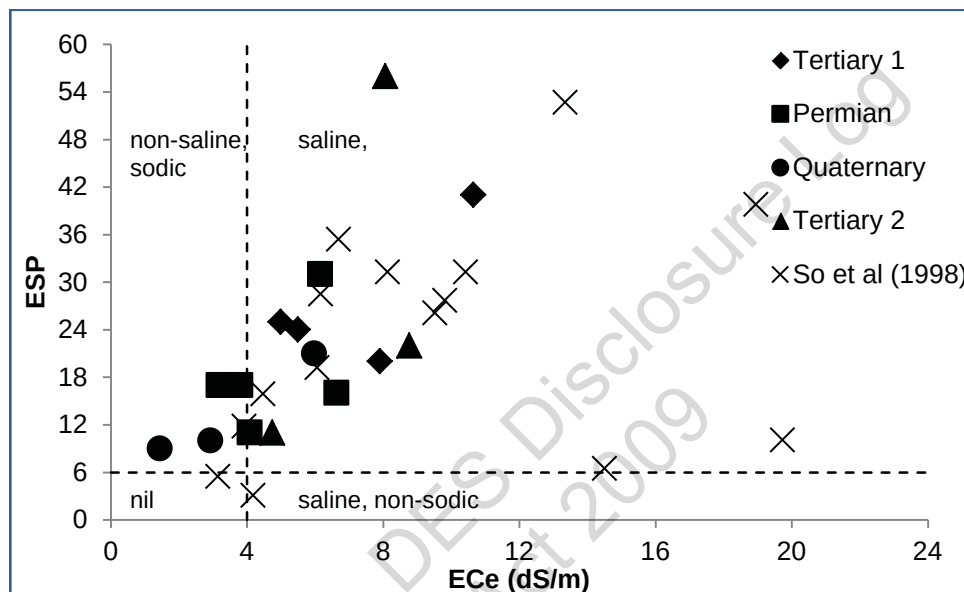


Figure 3-4 Salinity and sodicity categorisation of Ensham overburdens (after CMLR 2005) and 16 central Queensland overburdens by ACARP C4011 (So et al 1998)

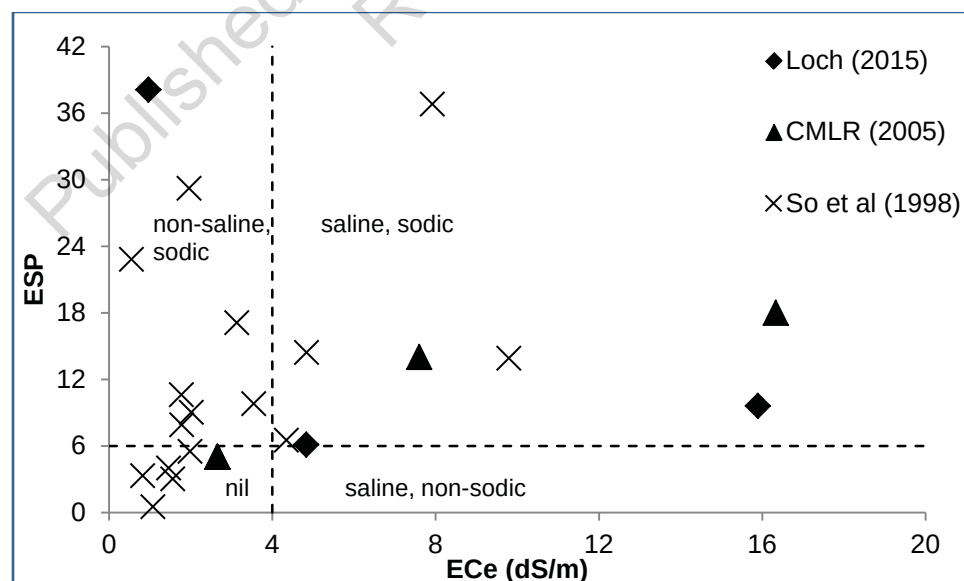


Figure 3-5 Salinity and sodicity categorisation of Ensham soils (after Loch 2015 and CMLR 2005) and 16 central Queensland soils by ACARP C4011 (So et al 1998)

accepted threshold limits for salinity impacts on plants and sodicity impacts on soil structure. For regional context, the 32 central Queensland soils and overburdens assessed by So *et al* (1998) in ACARP Project C4011 are included.

However, for a given sodicity value, as EC increases soil dispersion decreases. Conversely, very low EC values mean that a soil may become dispersive where the ESP is very low, e.g. ESP of 2. The relationship between salinity and sodicity is the electrochemical stability index (ESI). ESI is determined by calculating the ratio of EC to ESP, i.e. $ESI = EC_{1:5}/ESP$. The adopted critical ESI value for Australian soils is 0.05 (McKenzie 1998). Materials with an ESI less than the critical value will be prone to dispersion. Most of the Ensham overburdens and soils are highly dispersive (Figures 3-6 and 3-7).

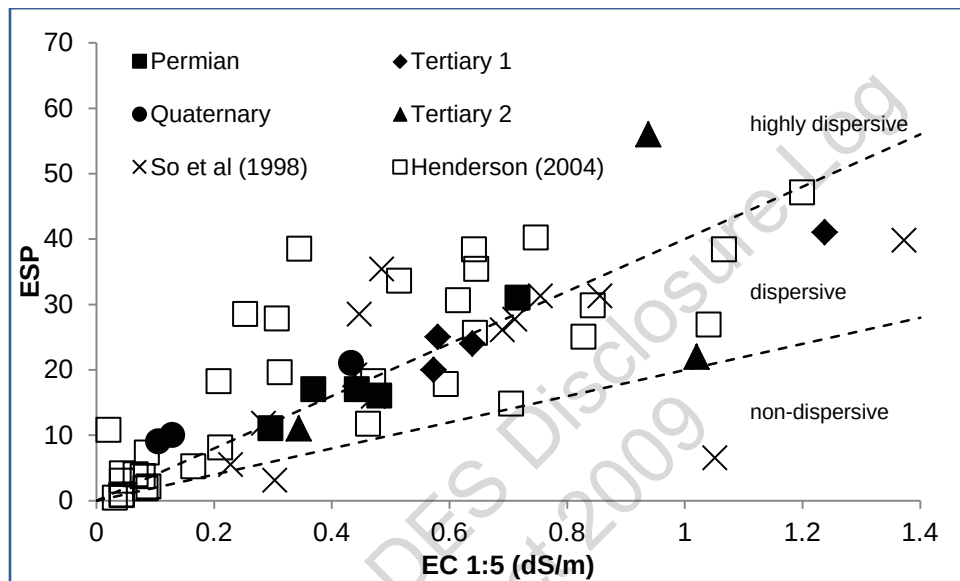


Figure 3-6 Classification of dispersive materials showing Ensham overburdens (after CMLR 2005), 16 central Queensland overburdens by ACARP C4011 (So *et al* 1998) and 40 central Queensland overburdens by ACARP C12031 (Henderson 2004)

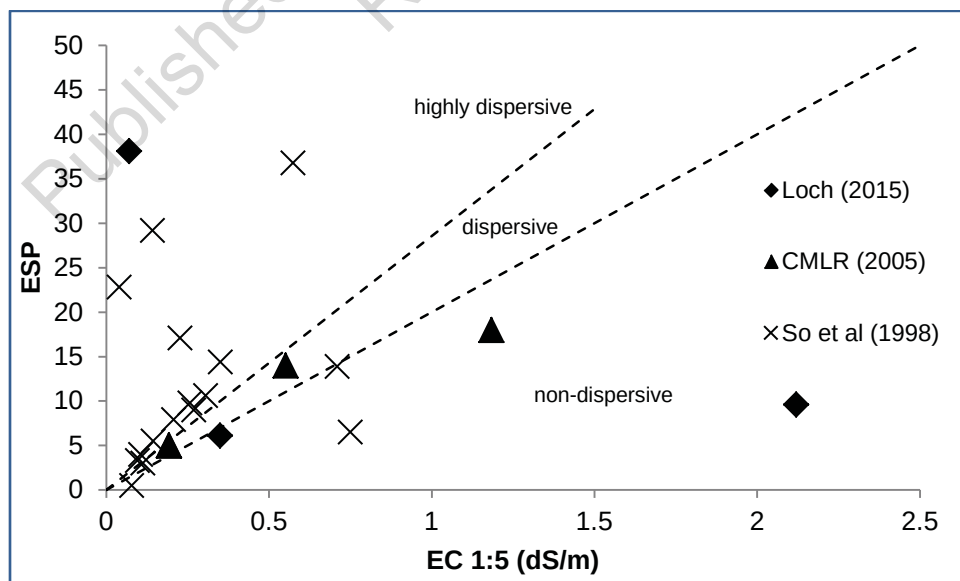


Figure 3-7 Classification of dispersive materials showing Ensham soils (after CMLR 2005 and Loch 2015) and 16 soils by ACARP C4011 (So *et al* 1998)

ESI explains the extremely dispersive nature of some overburdens, particularly Tertiary age materials. Although also highly saline, this salinity is insufficient to counter the effects of extreme sodicity, and the material disperses readily and is prone to excessive erosion.

Ensham overburdens can be ranked in terms of salinity, sodicity and dispersivity (Figure 3-8).

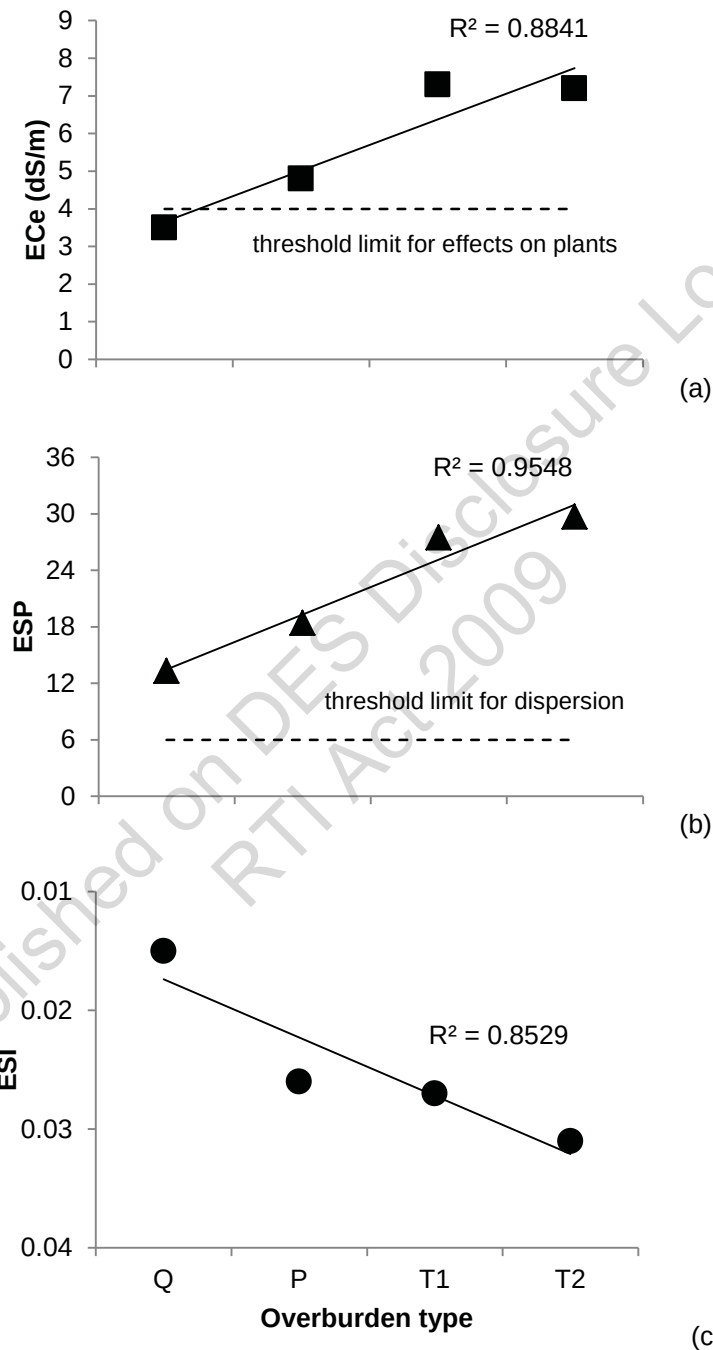


Figure 3-8 Relative salinity (a), sodicity (b) and dispersivity (c) of Ensham overburdens (after CMLR 2005)

This analysis shows that:

- Quaternary overburden is the most dispersive, but Tertiary overburdens are the most saline and most sodic;
- Tertiary overburdens are about twice as saline as Permian overburdens; and,

- All overburdens are highly dispersive.

3.4 Management of overburdens in rehabilitation landscapes

3.4.1 Quaternary (Q) overburden

Quaternary overburden is the most dispersive and least cohesive overburden at Ensham, making it prone to excessive tunnel and gully erosion. This material will be selectively placed and buried beneath other material to ensure it does not present at or near the surface of final landforms. It is not suitable for topsoil application and rehabilitation.

3.4.2 Tertiary (T1 and T2) overburden

Tertiary overburdens are the most saline and sodic, are prone to excessive dispersion and erosion, and occur in every pit at Ensham. Common throughout central Queensland mines, Tertiary overburdens have been extensively studied by ACARP and other industry-led research.

For example, ACARP C12031 *Rehabilitation of Dispersive Tertiary Spoil in the Bowen Basin* by Henderson (2004) made the following recommendations in ascending order of risk of poor outcome, i.e. decreasing hazard control effectiveness.

- Bury under another spoil type.
- Cover with at least a metre of rocky spoil to create a 'store and release' cover system.
- Topsoil and grass cover at slope angles that avoid sliding failure along the soil/spoil interface when wet. Provide measures to assist erosion control until grass is established.

Practice at Ensham and other mines in central Queensland shows that conservative slope gradients are required to control erosion of Tertiary overburden. The common approach is to limit slope gradients to not more than 10%. Ensham can demonstrate appropriate hazard control effectiveness with respect to dispersion and erosion risks when:

- Slope gradients of Tertiary overburden do not exceed 10% maximum gradient;
- Slope lengths do not exceed 200m;
- Contour banks and rock-lined waterways are not used; and,
- Hay mulch is applied at the time of sowing.

3.4.3 Permian (P) overburden

Permian overburden is about 50% less saline and 50% less sodic than Tertiary overburdens. Though similarly dispersive, the material is favoured for rehabilitation because it is:

- Less hostile to the establishment and growth of plants; and,
- More erosion resistant, due in part to its variable content of coarse sandstone fragments.

Practice at Ensham and other mines in central Queensland shows that this material can be effectively rehabilitated with slope gradients of up to 15%. If steeper than this, then Permian overburdens should be clad with at least 1m of durable rock to prevent erosion.

4 LANDFORM DESIGN OBJECTIVES

Ensham has developed an innovative rehabilitation domain model and determined rehabilitation objectives for each area. The overarching objectives for rehabilitation are:

1. Conduct safe operations;
2. Meet regulatory requirements;
3. Minimise social and environmental risk; and,
4. Control costs.

Specific objectives for each rehabilitation domain are detailed as follows.

4.1 Rehabilitation domains

Ensham has developed an enhanced domain model in which there are two types of domains to consider for rehabilitation, i.e. primary and secondary domains (Table 4-1). All areas to be rehabilitated have been assigned primary and secondary domains that describe the type of mining disturbance and a target post-mining land use.

Primary domains are areas of mining disturbance with unique operational purpose or function and therefore similar geophysical characteristics and rehabilitation treatment requirements. Secondary domains are areas in the post-mining landscape with the same sustainable land use objective, e.g. sustainable cattle grazing. It is possible that a primary domain could have more than one secondary domain, e.g. 3A (sustainable cattle grazing on mine infrastructure areas) and 3E (landholder retained infrastructure on mine infrastructure areas), in different areas at Ensham. Whilst secondary domains may exist adjacent to each other, they are mutually exclusive on-ground and not overlapping. This allows clear and unambiguous indicators and criteria to be nominated for each combination of primary and secondary domains.

Table 4-1 Ensham rehabilitation domain model

Code	Primary domains	Code	Secondary domains
1	Overburden emplacement	A	Sustainable cattle grazing
2	Mining pit	B	Water storage
3	Mining infrastructure	C	Remnant mining voids
4	Boggy creek diversion	D	Watercourse bed, banks and riparian vegetation
		E	Landholder retained infrastructure

The location and extent of each rehabilitation domain in the post-mining landscape has been determined (Figure 4-1).

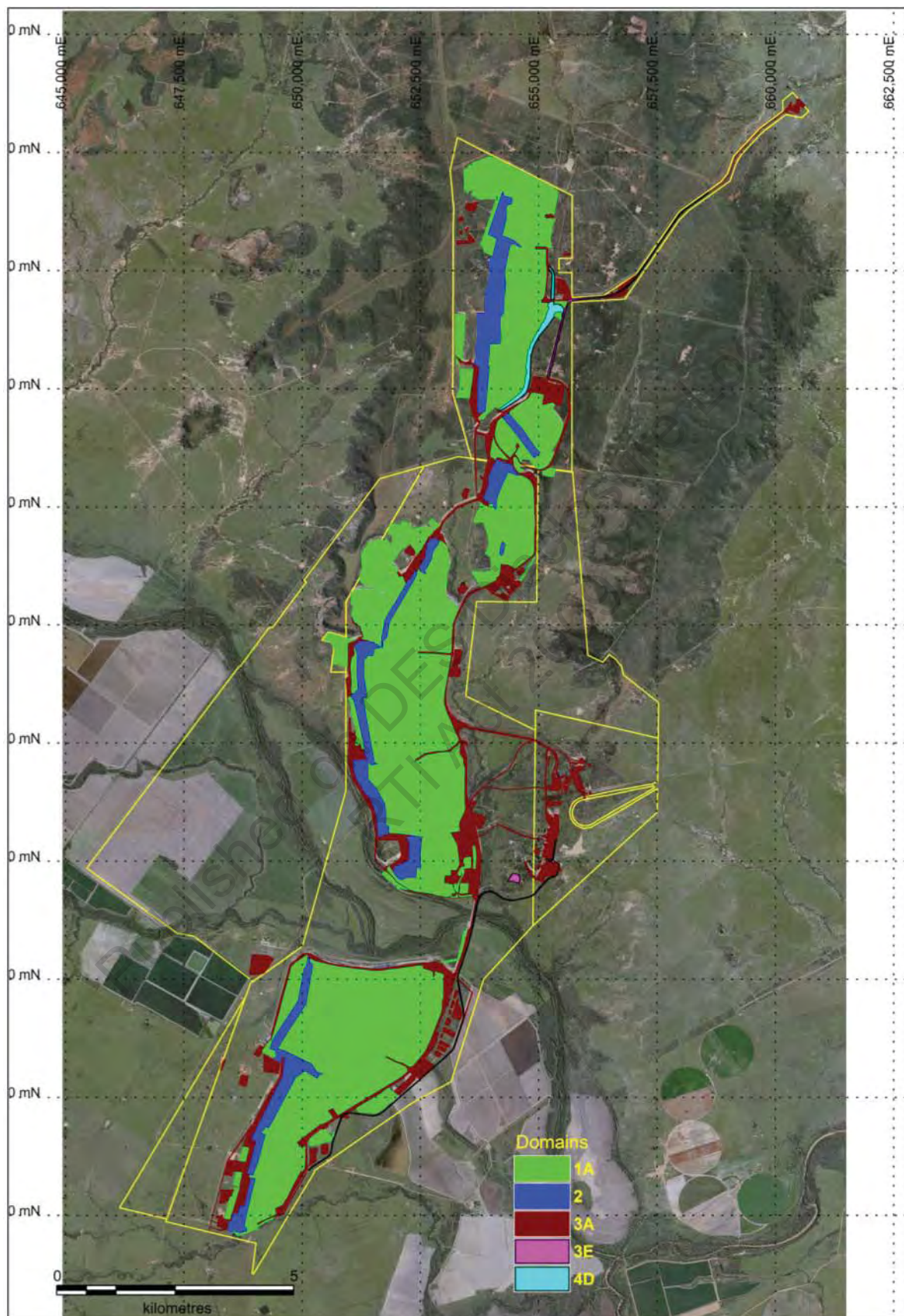


Figure 4-1 Location and extent of rehabilitation domains in the post-mining landscape

4.2 Rehabilitation goals

In accordance with EHP *Guideline - Rehabilitation requirements for mining projects* (EM1122)², Ensham has adopted the Government's policy objectives for rehabilitation and called these 'rehabilitation goals'. These goals are:

1. Safe to humans and wildlife
2. Non-polluting;
3. Stable; and
4. Able to sustain an agreed post-mining land use.

Ensham has determined that there are no additional goals that are relevant to the site.

4.3 Objectives

Ensham has developed objectives that clearly describe desired rehabilitation outcomes within each domain on the mine site (Table 4-2). Objectives recognise the general rehabilitation goals and ESD principles set by government. The overarching objectives for rehabilitation at Ensham are to ensure safety hazards are not greater than those that exist in the surrounding landscape, and to establish a structurally stable, non-polluting landscape that maximises potential for a sustainable grazing land use. Reinstating the previous land use of grazing is fourth on the rehabilitation hierarchy, and this is the highest practicable level for rehabilitation at Ensham.

Table 4-2 Rehabilitation objectives for each domain

Domain	Description	Objectives based on goals			
		<i>Safe to humans and wildlife</i>	<i>Non-polluting</i>	<i>Stable</i>	<i>Able to sustain an agreed post-mining land use</i>
1A	Sustainable cattle grazing on overburden emplacement areas	Safety hazards in rehabilitation are similar to surrounding unmined landscapes ³ .	Surface runoff leaving domain is non-polluting to receiving waters (Nogoa River).	Landforms are both geo-technically and erosionally stable.	Rehabilitation is suitable for sustainable cattle grazing.
3A	Sustainable cattle grazing on mining infrastructure areas				
3E	Landholder retained infrastructure on mining infrastructure areas	Safety hazards accepted by landholder.		Landholder accepts the condition of infrastructure, including its structural integrity.	Landholder formally accepts infrastructure for his/her ongoing beneficial use.

² Guideline, Resource Activities, Rehabilitation requirements for mining resource activities, EM1122 Version 2, Department of Environment and Heritage Protection, 2014.

³ The surrounding landscape, particularly landform, has been comprehensively described in EIS, EMOS and EMP documentation.

Domain	Description	Objectives based on goals			
		<i>Safe to humans and wildlife</i>	<i>Non-polluting</i>	<i>Stable</i>	<i>Able to sustain an agreed post-mining land use</i>
4D	Watercourse bed, banks and riparian vegetation of the Boggy creek diversion	Safety hazards in rehabilitation are similar to surrounding unmined landscapes.		Landforms are both geo-technically and erosionally stable.	Riparian vegetation is suitable for conservation of rehabilitated creek diversion areas.
2(x ⁴)	Per condition G6, this information is to be provided by 31 March 2019.				

4.4 Design objectives for slope gradients and lengths

With respect to slope gradient and length, the basic design objective for all rehabilitation is to control erosion risk. So *et al* (1998) measured the rate of erosion-derived sediment delivery from 32 bare soils and overburdens in central Queensland at slope gradients from 5 to 30%. Unremarkably, sediment delivery rates increased linearly with slope (Figure 4-2) and also with slope length. The effect of increasing slope gradient from 5% to 30% was a 12-fold and 4-fold increase in sediment delivery rates for soils and spoils, respectively. Soils and spoils with 20-30% silt tended to form strong raindrop impact seals (hard surface crusts) under rainfall and consequently had very low erodibilities.

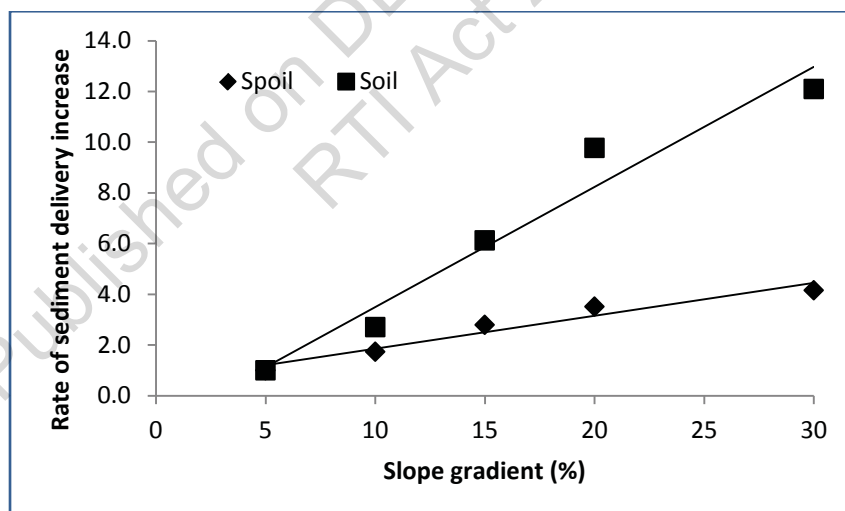


Figure 4-2 Effect of slope gradient on the rate of sediment delivery for central Queensland soils and overburdens (after So *et al* 1998)

There is no guideline that provides the optimal slope gradient and length combination for rehabilitation. Erosion is a function of not only slope gradient and length, but also of material properties, surface condition and groundcover, and rainfall. For example, the impact of vegetation on erosion from rehabilitated soils in central Queensland has been described as “enormous” (So *et al* 1998) and the single most important control on erosion (Grigg *et al* 2001).

⁴ To be determined and provided in accordance with EA condition G6 by 31 March 2019.

With consideration to material characteristics (see section 3) and more than 40 years of industry-led research and practice, Ensham has determined the following design objective for slopes.

1. Tertiary overburden slopes, regardless of soil type, will have:
 - Gradients $\leq 10\%$, and
 - Lengths $\leq 200\text{m}$, variable depending on the size of the contributing upper catchment.
2. Permian overburden slopes, regardless of soil type, will have:
 - Gradients $\leq 15\%$, and
 - Lengths $\leq 100\text{m}$, variable depending on the size of the contributing upper catchment.

4.5 Design objectives for aesthetics and sympathy to the surrounding landscape

The visual appeal and/or natural appearance of rehabilitation are not rehabilitation goals. The notion that form and function are closely linked and hence mining landscapes should be fashioned to look natural, as though they are the product of natural geomorphic processes, can not displace operational safety, cost and stability considerations in rehabilitation.

Mining is transformative in the landscape, and in central Queensland unconsolidated overburden emplacements are inherently more erodible than natural landforms. However, form (landscape attributes) and function (flow of energy, material and species) must be matched in rehabilitation too. This will likely be a fundamental characteristic of successful post-mining landscapes.

Ensham accepts that a 'natural appearance' may be important to some stakeholders and will endeavour to design landforms within the natural range of geometries of regional landforms. Natural landforms in the vicinity of Ensham are described as follows (Ensham Resources, 1996):

- Terrain in the northern half of the mine comprises mainly mildly dissected gently to moderately sloping and undulating lands, which form slopes and outwash plains flanking Boggy Creek. Erosion has occurred below the elevated plateau remnants that occur in the north. Plateau remnants feature steep escarpments, with slopes in the order of 33% to 66% gradient or more, with local relief up to 50 m between plateau crests and adjacent escarpment foot slopes.
- In the southern half, terrain is essentially gently sloping. This encompasses the extensive floodplain area of the Nogoa River.

Key post-mining landform design parameters for rehabilitation are within the natural range of geometries of local landforms, e.g. slope gradients and lengths.

5 TOPSOIL MANAGEMENT

Topsoil is salvaged in advance of mining disturbance and preserved for use in rehabilitation.

5.1 Topsoil quantity

Ensham currently holds about 3.5 million cubic metres (Mm³) of topsoil in stockpiles, preserved for use in future rehabilitation (Table 5-1).

Table 5-1 Location and volume of preserved topsoil

Location (pits)	Volume (m ³)
A and B	2,491,370
C, D and E	362,038
F	342,271
Y	474,635
TOTAL	3,670,332

If respread to create a 200mm soil layer for rehabilitation this quantity is sufficient to cover approximately 1,800ha. This highlights a topsoil deficit of around 3,000 ha. Ensham will manage this deficit by:

- Strategically using topsoil to promote rapid groundcover establishment and stabilisation of outer slopes that drain to the broader environment.
- Ameliorating Permian overburden to create a plant growth media or 'topsoil substitute', e.g. by additions of organic matter, gypsum and/or fertiliser.

6 REHABILITATION METHODS

Following is a summary of on-ground rehabilitation methods used at Ensham (Table 6-1).

Table 6-1 Rehabilitation methods for each domain

Domain	Rehabilitation methods
1A Sustainable cattle grazing on overburden emplacement areas	<ol style="list-style-type: none"> 1. Reshape to achieve post-mining landform design parameters using draglines, dozers or truck/shovel equipment; 2. Apply ameliorants such as gypsum, if needed; 3. Respread topsoil to 200mm depth (average); 4. Deep rip to 600mm on 2m centres using the 'Ensham ripper'; 5. Sow seed and spread fertiliser; 6. Spread hay mulch for immediate groundcover; 7. Monitor and maintain rehabilitation domains; 8. Erect fencing and supply stockwater then establish post-mining grazing land use.
3A Sustainable cattle grazing on mining infrastructure areas	<ol style="list-style-type: none"> 1. Remove infrastructure; 2. Complete contaminated land assessment and management; 3. Reshape to achieve post-mining landform design

Domain	Rehabilitation methods
	parameters, if required; 4. Apply ameliorants such as gypsum, if needed; 5. Respread topsoil to 200mm depth (average); 6. Deep rip to 600mm on 2m centres using the 'Ensham ripper'; 7. Sow seed and spread fertiliser; 8. Spread hay mulch for immediate groundcover; 9. Monitor and maintain rehabilitation domains; 10. Erect fencing and supply stockwater then establish post-mining grazing land use.
3E Landholder retained infrastructure on mining infrastructure areas	1. Remove unwanted infrastructure; 2. Complete contaminated land assessment and management; 3. Monitor and maintain rehabilitation domains.
4D Watercourse bed, banks and riparian vegetation of the Boggy Creek diversion	1. Reshape to achieve post-mining landform design parameters based on ACARP research; 2. Apply ameliorants such as gypsum, if needed; 3. Strategically respread topsoil to 200mm depth (average); 4. Where vegetation is to be established, i.e. banks, then <ol style="list-style-type: none"> Deep rip to 600mm on 2m centres using the 'Ensham ripper'; Sow seed and spread fertiliser; Spread hay mulch for immediate groundcover; 5. Monitor and maintain rehabilitation domains; 6. Erect fencing to exclude domestic stock for the protection of riparian vegetation.

7 NATIVE VEGETATION CORRIDORS

Much of the native vegetation surrounding Ensham has been extensively cleared for agricultural land development. Existing vegetation corridors mainly associated with the Nogoa River and its tributaries will remain in the post-mining landscape (Figure 7-1). As the most appropriate post-mining land use for Ensham is sustainable cattle grazing, no additional native vegetation corridors will be constructed in rehabilitation.



Figure 7-1 Native vegetation corridors

8 REFERENCE SITES

Since 2005, rehabilitation monitoring has included assessment and comparison of rehabilitation outcomes to reference sites. Reference sites are selected to provide 'target conditions' for rehabilitation and therefore, have should comparative:

- Soil, landform and land suitability;
- Vegetation form;
- Species assemblages;
- Land use.

However, it is difficult to select reference sites to compare rehabilitation due to the transformative impacts of mining on hydrology, topography and geology of the land. This may ultimately limit the usefulness of reference sites in benchmarking rehabilitation outcomes. For example, it is reasonably foreseeable that some rehabilitation may achieve the rehabilitation goals of safe, stable, non-polluting and sustainable land use, but remain '*different*' in form and function to unmined reference sites.

Despite recognised difficulties with this approach, a number of reference sites have been established and monitored at Ensham (Table 8-1). As an objective for most rehabilitation is sustainable cattle grazing land use, selection of reference sites has been skewed towards unmined areas used for pasture and/or grazing.

Table 8-1 Details of reference sites for rehabilitation monitoring (GDA 94, Zone 55)

Site ID	Description	Easting	Northing
DPREF1	Alluvial plain, ungrazed	650976	7402880
DPREF2	Alluvial plain, grazed	649302	7403072
ENREF1	Ungrazed grassland	654151	7408247
ENREF2	Grazed grassland	654063	7408087
Ironbark REF5	Open woodland	655590	7411002
Yapunyah REF6	Open woodland	650168	7406780

9 VALUES, INDICATORS AND COMPLETION CRITERIA

Rehabilitation goals and objectives (refer to section 4) and indicators and completion criteria are interdependent with environmental values. The following describes environmental values, identifies indicators and completion criteria, and outlines linkages between environmental values and rehabilitation indicators and completion criteria.

9.1 Environmental values

Ensham has previously identified environmental values (EVs) for air, groundwater, surface water, noise, ground vibration and air-blast overpressure, waste, land, community, nature conservation and cultural heritage (Hanson Bailey 2009). Some of these are not relevant to the post-mining landscape, e.g. noise, ground vibration and air-blast overpressure, and cultural heritage.

EVs relevant to rehabilitation are:

Air - In accordance with the *Environmental Protection (Air) Policy 2008 (EPP Air)*, the environmental values of the air environment to be enhanced or protected are the qualities of the air environment that are conducive to suitability for the life, health and wellbeing of humans.

Groundwater - The environmental values associated with groundwater resources that may potentially be affected by Ensham include the water level and water quality of the Nogoa River alluvial aquifer and the coal seam aquifer.

Surface water - The surface water environmental values which may potentially be affected by Ensham Mine include the following:

- Surface water quality, including the Nogoa River and tributary streams;
- The Nogoa Mackenzie Water Supply Scheme, which includes conveyance of allocated water supply flows via the reach of the Nogoa River traversing the mine site; and

Land - The environmental values to be protected or enhanced are the:

- The suitability of the project site for agricultural activities; and
- The aesthetic qualities of the landscape.

Community - The environmental values to be enhanced or protected are those that relate to the existing lifestyle of the surrounding community, including the general wealth, health, safety and wellbeing of the community.

The potential impacts of rehabilitation indicators and completion criteria on relevant EVs, the risks of those impacts and mitigation measures have been identified (Table 9-1). As indicators and criteria set the standards that rehabilitation must achieve, and these standards must ensure protection of the environment, these also constitute mitigation measures for EV risk management. The robust scientific bases of criteria are found in references provided as footnotes where each criterion appears for the first time in table text. Risk evaluation was performed in accordance with the Ensham Risk Matrix Tool (Appendix B).

Table 9-1 Environmental value linkages to rehabilitation indicators and completion criteria

EV	Potential impacts ⁵	Rehabilitation objective	Mitigation measures		Final risk ⁶
			Indicators	Completion criteria	
Air	Dust Odour	Landforms are both geotechnically and erosionally stable	Dust - Groundcover percentage Odour – none proposed	≥50%	L24 (low)
Groundwater	Deep drainage (seepage) of contaminants	Deep drainage (seepage) from domain is non-polluting to recognised groundwater resources	Contaminated land assessment	Zero contaminated sites	L25 (low)
			Per condition G6 of the EA		
Surface water	Runoff containing contaminants	Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River)	pH	7.5 – 8.3 ⁷	L21 (low)
			EC (salinity)	125 - 1250 µS/cm ⁸	L21 (low)
			TSS (sed. loss)	85 mg/L (max) ⁹	L21 (low)
			Sulphate	2.2-22.0 mg/L ¹⁰	L25 (low)

⁵ As relevant to each domain, refer to Table 9-2

⁶ Risk assessed in accord with Ensham risk matrix (Appendix B)

⁷ 10th and 90th Percentiles of pH from Government water sampling for Nogoa River upstream at Duckponds (141 samples, 1993-2015 period), see “*Water sample analysis summary report*”, available at <https://water-monitoring.information.qld.gov.au>. Values derived in accordance with Section 4.3 of Queensland Water Quality Guidelines 2009, DEHP, State of Queensland, 2013

⁸ 10th and 90th Percentiles of EC for the Nogoa Basin north of Emerald, highly disturbed system (regulated river), from Queensland Water Quality Guidelines 2009, DEHP, State of Queensland, 2013

⁹ Total suspended solids (TSS) post-construction phase, from Queensland Water Quality Guidelines 2009, DEHP, State of Queensland, 2013

¹⁰ 10th and 90th Percentiles of sulphate from Government water sampling for Nogoa River upstream at Duckponds (70 samples, 1993-2016 period), see “*Water sample analysis summary report*”, available at <https://water-monitoring.information.qld.gov.au>. Values derived in accordance with Section 4.3 of Queensland Water Quality Guidelines 2009, DEHP, State of Queensland, 2013

EV	Potential impacts ⁵	Rehabilitation objective	Mitigation measures		Final risk ⁶
			Indicators	Completion criteria	
		Riparian vegetation is suitable for conservation of rehabilitated creek diversion areas.	Index of diversion condition (IDC)	>10 ¹¹	L23 (low)
Land	Changes to land suitability Changes to land use	Rehabilitation is suitable for sustainable cattle grazing	Land suitability assessment	Land suitability classes 2-4 ¹²	L23 (low)
	Land contamination		Contaminated land assessment	Zero contaminated sites ¹³	L25 (low)
	Loss of aesthetic qualities	Landforms are erosionally stable	Groundcover	50% ¹⁴	L23 (low)
			Slope gradient	15% (max) ¹⁵	L25 (low)
Community	Additional safety hazards in the post-mining landscape.	Safety hazards in rehabilitation are similar to surrounding unmined landscapes.	Hazard assessment	No difference pre- and post-mining ¹⁶	L25 (low)
	Land instability	Landforms are geotechnically	Factor of safety	≥1.5 ¹⁷	L23 (low)

¹¹ White K, Moar D, Hardie R, Blackham D and Lucas R 2014, 'Criteria for functioning river landscape units in mining and post-mining landscapes', final report of ACARP Project number C20017, Australian Coal Research Limited, Brisbane.

¹² Guidelines for Agricultural Land Evaluation in Queensland, second edition, DNRm and DSITIA, State of Queensland 2013 (about 15 land and soil attributes are assessed to determine land suitability class)

¹³ In accordance with statutory requirements for the identification and management of contaminated land in Queensland

¹⁴ Many studies have demonstrated that with groundcover >50% erosional soil loss from rehabilitation is negligible, e.g. see Carroll, C and Tucker, A 2000, 'Effects of pasture cover on soil erosion and water quality on central Queensland coal mine rehabilitation', Tropical Grasslands, vol. 34, pp 254-262; Carroll C, Tucker A, Merton P, Burger P and Pink L 2001, 'Sustainability indicators for coal mine rehabilitation, ACARP Project Number C7006, Australian Coal Research Limited, Brisbane; Loch, R 2000, 'Effects of vegetation cover on runoff and erosion under simulated rain and overland flow on a rehabilitated site on the Meandu Mine, Tarong, Queensland'. *Australian Journal of Soil Research*, vol. 38, pp 299-312; So H, Sheridan G, Loch R, Carroll C, Willgoose G, Short M and Grabski A 1998, 'Post-mining landscape parameters for erosion and water quality control', final report of ACARP Project Numbers C1629 and C4011, Australian Coal Research Limited, Brisbane.

¹⁵ In accordance with the Ensham Rehabilitation Management Plan

¹⁶ Methodology in accordance with AS/NZS ISO 13000:2009 Risk Management (this standard is currently applied in risk management at Ensham)

EV	Potential impacts ⁵	Rehabilitation objective	Mitigation measures		Final risk ⁶
			Indicators	Completion criteria	
		stable			
	Landholders may benefit from retaining some mining infrastructure.	Landholder formally accepts rehabilitation for his/her ongoing beneficial use.	Legally binding agreement	Executed by each party	L25 (low)

9.2 Rehabilitation indicators and completion criteria

Ensham has identified meaningful indicators to provide robust and defensible measurements of progress towards rehabilitation objectives and protection of environmental values. Every domain has been assigned indicators (Table 9-2). Each indicator has a valid scientific basis and a practical and reliable method of measurement, and also reveals something important about the rehabilitation domain.

Criteria are the threshold limits or benchmarks against which indicators will be assessed to determine if rehabilitation objectives have been met. Every indicator has been allocated a relevant criterion or set of criteria. Importantly, criteria are numeric and will be measured to form a set of statistical metrics for on-going analysis during the period of rehabilitation monitoring and evaluation.

Table 1-2 Indicators and completion criteria

Mine domain	Rehabilitation feature name	Goals	Objective	Indicators	Completion criteria
1A	Sustainable cattle grazing on overburden emplacement areas	Safe	Safety hazards in rehabilitation are similar to surrounding unmined landscapes.	Hazard assessment	0 (zero) significant difference
		Non-polluting	Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River).	pH	7.5 – 8.3
				EC (salinity)	125 - 1250 µS/cm
				TSS (sed. loss)	85 mg/L (max)
				Sulphate	2.2-22.0 mg/L

¹⁷ Geotechnical slope stability, DME, State of Queensland 1995; Geotechnical considerations in open pit mines, guideline, version 1, DME, State of Western Australia 1999

Mine domain	Rehabilitation feature name	Goals	Objective	Indicators	Completion criteria
			Deep drainage (seepage) from domain is non-polluting to recognised groundwater resources	Per condition G6, this table is to be updated by 31 March 2019 to include indicators and criteria for any potential groundwater impacts, as this may be influenced by residual mining voids.	
		Stable	Landforms are both geo-technically and erosionally stable.	Factor of safety	≥1.5
				Slope gradient	15% (max)
				Groundcover	≥50%
		Land use	Rehabilitation is suitable for sustainable cattle grazing.	Land suitability assessment	Classes 2 to 4
2x	Remnant mining voids on mining pit areas	Per condition G6, this table is to be updated by 31 March 2019 to include indicators and criteria for residual mining voids.			
3A	Sustainable cattle grazing on mining infrastructure areas	Safe	Safety hazards in rehabilitation are similar to surrounding unmined landscapes.	Hazard assessment	0 (zero) significant difference
		Non-polluting	Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River).	pH	7.5 – 8.3
				EC (salinity)	125 - 1250 µS/cm
				TSS (sed. loss)	85 mg/L (max)
				Sulphate	2.2-22.0 mg/L
				Contaminated land assessment	0 (zero) contaminated sites
		Stable	Landforms are both geo-technically and erosionally stable.	Factor of safety	≥1.5
				Slope gradient	15% (max)
				Groundcover	≥50%
		Land use	Rehabilitation is suitable for sustainable cattle grazing.	Land suitability assessment	Classes 2 to 4

Mine domain	Rehabilitation feature name	Goals	Objective	Indicators	Completion criteria
3E	Landholder retained infrastructure on mining infrastructure areas	Safe	Safety hazards accepted by landholder.	Legally binding agreement	Executed by each party
		Non-polluting	Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River).	pH	7.5 – 8.3
				EC (salinity)	125 - 1250 µS/cm
				TSS (sed. loss)	85 mg/L (max)
				Sulphate	2.2-22.0 mg/L
				Contaminated land assessment	0 (zero) contaminated sites
		Stable	Landholder accepts the condition of infrastructure, including its structural integrity.	Legally binding agreement	Executed by each party
4D	Watercourse bed, banks and riparian vegetation of the Boggy creek diversion	Land use	Landholder formally accepts infrastructure for his/her ongoing beneficial use.	Legally binding agreement	Executed by each party
		Safe	Safety hazards in rehabilitation are similar to surrounding unmined landscapes.	Hazard assessment	0 (zero) significant difference
		Non-polluting	Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River).	pH	7.5 – 8.3
				EC (salinity)	125 - 1250 µS/cm
				TSS (sed. loss)	85 mg/L (max)
				Sulphate	2.2-22.0 mg/L
		Stable	Landforms are both geo-technically and erosionally stable.	Factor of safety	≥1.5
				Index of diversion condition	>10
		Land use	Riparian vegetation is suitable for conservation of rehabilitated creek diversion areas.	Index of diversion condition	>10

9.3 Land suitability class as an indicator for sustainable cattle grazing as a post-mining land use

The vast majority of rehabilitation at Ensham is focussed to establishing sustainable cattle grazing as a post-mining land use. Land Suitability Assessment has been identified as the best indicator to determine progress towards this rehabilitation objective. This will be of primary interest to stakeholders and is therefore, worthy of further explanation.

In Queensland, five land suitability classes are defined (DNR/DSITIA 2013a), with land suitability decreasing progressively from Class 1 to Class 5. These classes are used to describe an area of land in terms of suitability for a particular land use which allows optimum, sustainable production with current technology, while minimising degradation to the land resource in the short, medium or long-term. Land is considered less suitable as the severity of limitations affecting a particular land use increases, reflecting either:

- Reduced potential for production; and/or,
- Increased inputs required to achieve an acceptable level of production; and/or,
- Increased inputs required to prepare the land for successful production; and/or,
- Increased inputs required to prevent land degradation.

The five land suitability classes defined for Queensland are as follows.

Class 1 - Suitable land with negligible limitations – land that is well suited to a proposed use;

Class 2 - Suitable land with minor limitations – land that is suited to a proposed use but which may require minor changes in management to sustain the use;

Class 3 - Suitable land with moderate limitations – land that is moderately suited to a proposed use but which requires significant inputs to ensure sustainable use;

Class 4 - Marginally suitable land with severe limitations – land which is marginally suited for a proposed use and would require major inputs to ensure sustainability; often the inputs required may not be justified in terms of the benefits to be gained from using the land for a proposed use and the land is considered presently unsuitable for that use; and

Class 5 - Unsuitable land with extreme limitations – land that is unsuited and cannot be sustainably used for a proposed use.

Classes 1 to 3 are considered suitable for a specified land use because the benefits from using the land (for that particular use) outweigh the inputs required to initiate and maintain production.

Typically, the benefits from using Class 4 land are similar in magnitude to the level of inputs required to achieve production and its long-term suitability for the specified land use is doubtful. Class 4 is also used in situations where reducing the effect of a particular limitation may indicate production is possible, but additional studies are needed to determine the feasibility of such actions, e.g. fertilisation.

In contrast, there is no doubt regarding the long-term suitability of Class 1–3 lands or the unsuitability of Class 5 land. Class 5 land has limitations that in aggregate are so severe that the benefits do not justify the inputs required to initiate and maintain production. It would require a major change in economics, technology or management expertise before the land could be considered suitable for the land use being considered. Many Class 5 lands have physical characteristics that totally preclude any form of development, e.g. very steep slopes, and will always remain unsuitable for agriculture.

9.3.1 Suitability for grazing

The suitability classification for grazing evaluates soils in terms of the potential to graze and finish cattle on improved pastures (QDME 1995, Shields and Williams 1991). Typically, grazing systems in inland Central Queensland aim to produce young, finished, grassfed, export quality cattle without inputs other than pasture

development. Most production is based around improved grass-legume pastures. Improved pasture development in many areas is dominated by buffel grass, although Rhodes grass, introduced bluegrasses (Indian bluegrass, creeping bluegrass), purple pigeon grass and panic species all have a role in certain situations. Legume establishment and species vary significantly depending on soil characteristics and microclimates. Commonly used legumes include shrubby stylos species, Desmanthus species, Wynn cassia (sandy soils), butterfly pea (clay soils), siratro, medics and leucaena (cropping soils).

Class 1 and 2 land is considered suitable for grazing improved pastures and is capable of attaining maximum grazing productivity (QDME 1995, Shields and Williams 1991). In inland Central Queensland this can be defined as the production of young, finished, grassfed, export quality cattle in most seasons, and such country is termed 'fattening country'.

Class 3 land is suitable for grazing improved pastures but is generally less productive than Classes 1 and 2 and encompasses a range in productivity. Land in this class is often termed '*growing country*' and is defined as country on which younger cattle perform well but may be difficult to finish at a young age, depending on seasonal conditions, i.e. cattle on Class 3 land may take longer to achieve the desired weight class or finished grade than equivalent cattle on Classes 1 and 2 land.

Class 4 land is considered marginal for grazing improved pastures, but is generally considered suitable for grazing native pastures of varying quality all year round, depending on soil characteristics, (QDME 1995, Shields and Williams 1991). In inland Central Queensland such country is typically termed 'breeding country'. It encompasses a range in productivity from the lower end of Class 3 growing country through to the poorer end of Class 4 breeding country. Shields and Williams (1991) suggest 3 possible subclasses exist within Class 4:

- Land with native pasture of low productivity, which while physically capable of being developed to improved pasture, is subject to low soil fertility and doubtful long term productivity;
- Land with high quality native pasture (typically black soil downs) on which improved pasture establishment is marginal because of unfavourable soil characteristics and limited species; and
- Land with native pasture of low productivity, which has physical limitations that preclude fully improved pasture development, but allow over-sowing of legumes such as shrubby stylo.

Class 5 land is unsuitable for any form of pasture improvement and land use is limited to extensive grazing of native pastures of low productivity. In many cases, lands are of such poor quality they are considered marginal as breeding country and may be destocked in the winter/dry season, unless grazed in conjunction with better quality country. Land in this class is mostly used as breeding country during the summer/wet season when planes of nutrition are higher.

9.3.2 Land use requirements and limitations

Following DNR/DSITIA (2013a, 2013b), QDME (1995), and Shields and Williams (1991), a set of 15 land use requirements and associated limitations has been identified as important for sustainable grazing of land rehabilitated after mining in central Queensland (Table 9-2). Limitation subclass threshold limits have been defined (Appendix A).

Table 1-3 Land use requirements and limitations for sustainable grazing of rehabilitated land in central Queensland

Count	Land use requirement	Limitations	Code	Attributes to assess each limitation
1	Appropriate slope gradients for particular soil types	Surface soil erodibility	Ea	Slope, ESI, ESP, salinity
2		Subsoil erodibility	Eb	Slope, ESI, ESP, salinity

Count	Land use requirement	Limitations	Code	Attributes to assess each limitation
3	Adequate water supply	Soil water availability	M	PAWC, ERD, deep drainage losses, infiltration rate
4	Ease of pasture establishment	Surface condition	Ps	Soil structure, condition, texture
5	Rock free surface soils	Rockiness	R	Size and content of coarse fragments, % rock outcrop
6	Level land	Micro-relief	Tm	Size and frequency of micro-relief
7	Adequate soil aeration	Wetness	W	Soil drainage (field observation)
8	Not affected by AMD or acid sulphate soils	Acid drainage water hazard, real	Ar	Depth to buried PAF materials, water pH
9		Acid drainage water hazard, potential	Ap	Depth to buried PAF materials, water pH
10	Adequate nutrient supply	Nutrient deficiency	Nd	Levels of P (mg/kg) in surface soils (0-10cm)
11	Absence of elemental enrichment in surface soils	Element toxicity	Tx	pH (1:5 water) in surface soils (0-10cm)
12	Adequate soil depth to support vegetation	Soil depth	Sd	Measurement to rooting impediment
13	Salinity free root zone	Root zone salinity	Sa	EC, chloride level
14	Absence of undesirable vegetation	Vegetation	V	Vegetation type, regrowth potential
15	Practical land area available	Landscape complexity	Lc	Contiguous land area

10 CONTINUOUS IMPROVEMENT

Continuous improvement is an essential part of rehabilitation management at Ensham. The continuous improvement cycle has four interrelated phases, otherwise known as the Plan, Do, Check, Act cycle (Figure 10-1):

1. **PLAN** – establish the actions and resources necessary to implement the RMP.
2. **DO** – implement the RMP and allocate resources, including time.
3. **CHECK** – monitor, measure and report on rehabilitation outcomes, and compare and contrast these with 'completion criteria'.
4. **ACT** – incorporate actions for improvement into planning and/or execution to maximise rehabilitation success.

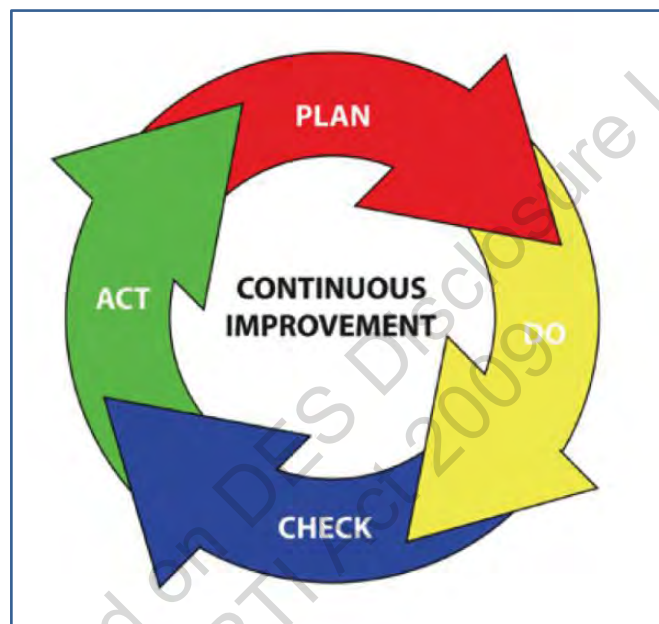


Figure 10-1 Continuous improvement cycle for rehabilitation

PLAN and DO are discussed elsewhere in this document. CHECK and ACT are detailed as follows.

10.1 Monitoring (check)

Monitoring will be required at various intervals for a range of indicators to ensure that completion criteria are met. It may take several years of monitoring to produce a statistically valid data set to do this. This relies on information being collected in a consistent manner to allow multi-year comparison of trends and assessment of outcomes against completion criteria and/or specific actions.

Monitoring methods and intervals for each indicator are provided (Table 10-1). This is considered the minimum data requirement and additional ad hoc monitoring may be performed. Some statistical analysis of monitoring data will be needed to determine if differences are significant or not. This will help to determine if management intervention is required to adjust performance trajectories. However, in most cases, data analysis will be simple and restricted to plotting of trends, calculation of averages, standard deviations and basic statistics.

Table 10-1 Monitoring methods and intervals for each indicator

Objective	Indicator	Completion criteria	Monitoring method	Monitoring frequency	By whom
Safety hazards in rehabilitation are similar to surrounding unmined landscapes.	Hazard assessment	Zero significant difference between rehabilitation and surrounding landscape	AS/NZS ISO 13000:2009 Risk Management	5 years	Appropriately qualified person ¹⁸
Safety hazard accepted by landholder	Legally binding agreement	Executed document	Qualitative (yes/no)	Once following cessation of mining	Legal document executed by EA holder and landholder/s
Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River).	pH	7.5 – 8.3	Water sampling of receiving waters upstream and downstream, and point of release from domains	Monthly and also at each rainfall runoff event	Sampling by technical personnel, data review and reporting by appropriately qualified person
	EC (salinity)	125 - 1250 µS/cm			
	TSS (sed. loss)	85 mg/L (max)			
	Sulphate	2.2-22.0 mg/L			
	Contaminated land assessment	Zero contaminated sites	Contaminated land assessment	Once following cessation of mining	Suitably qualified person ¹⁹
Landforms are both geo-technically and erosionally stable.	Factor of safety	≥1.5	Engineering calculation	5 years	Registered Professional Engineer Queensland (RPEQ) ²⁰
	Slope gradient	15% (max)	Remote sensing, e.g. LIDAR survey, or On-ground survey	As constructed	Registered Surveyor Queensland ²¹
	Groundcover	≥50%	Grass Check by NRM	2 years	Appropriately qualified person

¹⁸ “Appropriately qualified person” has the same meaning as in EHP Guideline EM1122

¹⁹ “Suitably qualified person” has the same meaning as in EHP Guideline ESR/2016/1938

²⁰ “RPEQ” by Board of Professional Engineers Queensland

²¹ “Registered Surveyor” by Surveyors Board Queensland

Objective	Indicator	Completion criteria	Monitoring method	Monitoring frequency	By whom
Landholder accepts the condition of infrastructure, including its structural integrity.	Legally binding agreement	Executed document	Qualitative (yes/no)	Once following cessation of mining	Legal document executed by EA holder and landholder/s
Landholder formally accepts infrastructure for his/her ongoing beneficial use.	Legally binding agreement	Executed document	Qualitative (yes/no)	Once following cessation of mining	Legal document executed by EA holder and landholder/s
Rehabilitation is suitable for sustainable grazing by cattle	Land suitability assessment	Classes 2 - 4	Land suitability assessment by NRM	Within 2 years of construction	Appropriately qualified person
Riparian vegetation is suitable for conservation of rehabilitated creek diversion areas.	Index of Diversion Condition (IDC)	IDC score >10	ACARP C9068 and C20017	Annually	Appropriately qualified person

10.2 Corrective actions (act)

Monitoring data will be used in conjunction with completion criteria to determine when and where corrective interventions are needed. This may include:

- Re-evaluation of monitoring data;
- Additional monitoring;
- Amendments to rehabilitation planning and/or execution; and/or
- Redoing rehabilitation earthworks or parts thereof.

11 PEOPLE, PLANET AND PROFIT

Assessing different rehabilitation options as part of the triple bottom line framework means giving consideration to the people (social), environmental (planet) and economic (profit) outcomes of the different options. This means that our rehabilitation will achieve outcomes that support a strong and viable post-mining land use, do not cause environmental harm and are feasible for Ensham to deliver. This approach has been developed based on best practice approaches in the literature and is considered fit for purpose (Figure 11-1).

ACCOUNTABILITY AND TRANSPARENCY

LEGISLATIVE NEED:

Environmental Protection Act 1994

PRACTICAL NEED:

Complex evidence base, facilitating understanding amongst stakeholders

TRIPLE BOTTOM LINE ASSESSMENT FRAMEWORK



Acceptable rehabilitation outcomes are based on comprehensive assessments of **economic, social** and **environmental** outcomes

Figure 11-1 The legislative and practical need for a triple bottom line framework, guided by an overarching principle of accountability and transparency

11.1 Legislative need

The object of the EP Act is to *protect Queensland's environment while allowing for development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends (ecologically sustainable development)* (Section 3). The act is implemented in several ways, including environmental strategies and integrating them into efficient resource management. The reasons for rehabilitation are to remedy potential impacts on environmental values and to minimise the potential for future environmental harm. Therefore, rehabilitation of land disturbed by resource activities assists to achieve the objectives of the EP Act.

11.2 Practical need

Setting rehabilitation indicators and completion criteria is a highly complex process that requires the specialised skill set of an appropriately qualified person. There are quantitative and qualitative outcomes of different options to compare across economic, social and environmental dimensions, as well as differing spatial and temporal settings. There is a large amount of information to weigh and process, and no definitive formula for the 'acceptable rehabilitation'. There are also multiple stakeholders to consider – government, community and us – with potentially conflicting views on what are acceptable outcomes.

11.3 Process steps

The steps in the triple bottom line assessment for rehabilitation at Ensham were:

1. **Goals:** confirm the appropriateness of rehabilitation goals.
2. **Domains:** decide rehabilitation domains, and their projected location and extent.
3. **Objectives:** set rehabilitation objectives.
4. **Indicators and completion criteria:** determine appropriate indicators and set threshold limits as completion criteria.
5. **Alternatives:** explore different combinations of completion criteria for rehabilitation.
6. **Triple bottom line assessment:** assess the evidence base to compare the economic, social and environmental outcomes for each alternative. Interpret information and evaluate outcomes.
7. **Propose amendment:** confirm rehabilitation indicators and completion criteria.

11.4 Assessment summary

Ensham is a mature mining operation and has a large and complex information base relating to rehabilitation. This information supported selection of indicators and associated completion criteria. The types of information used has been summarised (Figure 11-2).

	SUMMARY PAPERS		
	Economic	Social	Environment
Indicators	Cost to complete, land use economics	Qualitative narrative - perceptions of land use by agricultural sector, land suitability assessment	Per Table 9-1 in section 9 of this report
Detailed evidence	Rehabilitation cost modelling by Ensham, annual budgets, FA calculations	Stakeholder feedback, land suitability assessments, EIS documentation	ACARP reports, rehabilitation monitoring reports, various site specific technical studies

Figure 11-2 Summary of the detailed economic, social and environmental evidence base and overarching indicators used in the triple bottom line assessment

Process steps 1 through 4 have been defined in sections 4 and 9 of this report. A process summary table of relevant considerations for the triple bottom line assessment is provided (Table 11-1).

11.4.1 Conclusions

The triple bottom line assessment for rehabilitation followed sound principles in setting rehabilitation objectives, indicators and completion criteria. It enabled a complex evidence base to be logically and clearly understood. The development of indicators allowed for an iterative process of assessing alternatives and outcomes. Each scenario was considered against all others to ensure there was consistent deliberation. Selected indicators are meaningful and, when monitored and reported, will inform stakeholders about the rehabilitation and allow good decisions.

While the triple bottom line framework facilitated effective decision making, it did not remove the need for considered judgement in decision-making. This highlights the important and on-going role of appropriately qualified persons in the assessment, interpretation and communication of rehabilitation outcomes at Ensham and elsewhere.

Table 11-1 Qualitative process summary for rehabilitation indicators (TBL Assessment)

Objective	Indicator	Considerations		
		Economic	Social	Environmental
Safety hazards in rehabilitation are similar to surrounding unmined landscapes.	Hazard assessment	Indirect costs may apply if this delays closure.	Stakeholder expectations will be that hazards in the rehabilitation are no greater than those in the surrounding landscape. Use Australian Standard for risk management to ensure robust, valid process.	n/a
Safety hazard accepted by landholder	Legally binding agreement	Agreements for landholders to retain mining infrastructure may reduce rehabilitation costs.	Failure to reach agreement may cause reputational damage and unrest with other stakeholders.	n/a
Surface runoff leaving domain is non-polluting to receiving surface waters (Nogoa River).	pH	Water monitoring is a long-term cost associated with rehabilitation.	Stakeholder expectations will be that rehabilitation is free of contamination and not a source of environmental pollutants.	Use NRM provided upstream river water quality data and Queensland Water Quality Guidelines to determine completion criteria. Indicators should be consistent with EA conditions.
	EC (salinity)			
	TSS (sed. loss)			
	Sulphate			
	Contaminated land assessment	One off cost at end of mine life. Remediation may add significant costs if necessary.		Must comply with EP Act and requirements for contaminated land assessment and management in

Objective	Indicator	Considerations		
		Economic	Social	Environmental
				Queensland.
Landforms are both geotechnically and erosionally stable.	Factor of safety	Different FoS can require different volumes of materials to be moved and therefore, can add significantly to cost.	Stakeholder will expect rehabilitation is geotechnically stable.	Geotechnical stability is different to erosional stability, and rehabilitation must demonstrate both.
	Slope gradient	Different slope gradients require different volumes of materials to be moved and therefore, can add significantly to cost. Rehabilitation construction must be optimised to available equipment.	Slopes will need to be appropriate to proposed grazing land use, i.e. <20%.	Slope gradients (and lengths) need to recognise inherent material characteristics, e.g. propensity to dispersion and erosion.
	Groundcover	n/a	Stakeholders are aware of the role of groundcover in controlling erosion.	ACARP reports indicate minimum groundcover requirements for control of erosion.
Landholder accepts the condition of infrastructure, including its structural integrity.	Legally binding agreement	Agreements for landholders to retain mining infrastructure may reduce rehabilitation costs.	Failure to reach agreement may cause reputational damage and unrest with other stakeholders.	n/a
Landholder formally accepts infrastructure for his/her ongoing beneficial use.	Legally binding agreement	Agreements for landholders to retain mining infrastructure may reduce rehabilitation costs.	Failure to reach agreement may cause reputational damage and unrest with other stakeholders.	Must ensure this is non-polluting.
Rehabilitation is suitable for	Land suitability assessment	Rehabilitation must have an	Stakeholders are aware of	Rehabilitation will need to

Objective	Indicator	Considerations		
		Economic	Social	Environmental
sustainable grazing by cattle		appropriate land suitability class to have a post-mining land use, i.e. anthropic land use.	previous commitments to return rehabilitation to grazing land use.	meet a suite of land use limitations to achieve an appropriate land suitability class.
Riparian vegetation is suitable for conservation of rehabilitated creek diversion areas.	Index of Diversion Condition (IDC)	Rehabilitation of the Boggy Creek diversion will likely be the most costly rehabilitation on a 'per hectare' basis.	Stakeholders will expect the Boggy Creek diversion to function as though it were a natural watercourse.	ACARP C9068 and C20017 provide a sound technical basis for creek diversion rehabilitation, monitoring and assessment.

12 REFERENCES

- CMLR 2005, '*Ensham coal mine, rehabilitation resource survey*', Centre for Mined Land Rehabilitation, The University of Queensland, Brisbane.
- DNRM/DSITIA 2013a, '*Guidelines for agricultural land evaluation in Queensland*', second edition (draft), Department of Natural Resources and Mines and the Department of Science, Information Technology, Innovation and the Arts, Brisbane.
- DNRM/DSITIA 2013b, '*Regional land suitability frameworks for Queensland*', Department of Natural Resources and Mines and the Department of Science, Information Technology, Innovation and the Arts, Brisbane.
- Ensham Resources 1996, '*Environmental Management Overview Strategy*', Ensham Resources, Duckponds.
- Grigg, A, Emmerton, B and McCallum, N 2001, '*The development of draft completion criteria for ungrazed rehabilitation pastures after open-cut mining in central Queensland*', ACARP Project Number C8038, Australian Coal Research Limited, Brisbane.
- Hansen P 2006, '*Ensham Central Project – Terrain, soils and land capability assessment*', a report prepared for Ensham Resources by Hansen Environmental, Brisbane.
- Hansen Bailey 2009, '*Ensham Central Project – Supplementary Report, EMP*', a report prepared for Ensham Resources by Hansen Bailey, Brisbane.
- Loch R 2015, '*Assessment of stability of final void and landform shaping options, Ensham coal mine*', a report prepared for Idemitsu Australia Resources by LandLoch Pty Limited, Toowoomba.
- QDME 1995, '*Land suitability assessment techniques*', former Queensland Department of Mines and Energy, Brisbane.
- Shields P and Williams, B 1991, '*Land resource survey and evaluation of the Kilcummin area, Queensland*'. QDPI bulletin QV 91001.
- So H, Sheridan G, Loch R, Carroll C, Willgoose G, Short M and Grabski A 1998, '*Post-mining landscape parameters for erosion and water quality control*', final report of ACARP Project Numbers C1629 and C4011, Australian Coal Research Limited, Brisbane.
- URS 2005, '*Geochemical characterisation and assessment of overburden and potenal coal reject material at the Ensham Central Project*', a report prepared for Ensham Resources by URS Australia, Brisbane.
- URS 2015, '*Geochemical characterisation of overburden and potential rejects*', a report prepared for Ensham Resources by URS Australia, Brisbane.

APPENDIX A – LAND USE LIMITATION SUBCLASS THRESHOLD LIMITS

Limitation	Land suitability class				
	1	2	3	4	5
Surface soil erodibility, Ea	Moderately stable soils, <5% Non-cohesive soils, <5% Dispersive soils, <3% Highly erodible soils, <1%	Moderately stable soils, 5-10% Non-cohesive soils, 5-8% Dispersive soils, 3-5% Highly erodible soils, 1-3%	Moderately stable soils, 10-15% Non-cohesive soils, 8-10% Dispersive soils, 5-8% Highly erodible soils, 3-5%	Moderately stable soils, 15-20% Non-cohesive soils, 10-15% Dispersive soils, 8-10% Highly erodible soils, 5-8%	Moderately stable soils, >20% Non-cohesive soils, >15% Dispersive soils, >10% Highly erodible soils, >8%
Subsoil erodibility, Eb	Non-dispersive, <5%; Non-cohesive, <1%; Dispersive, <0.5%; Extremely dispersive, n/a	Non-dispersive, 5-10%; Non-cohesive, 1-5%; Dispersive, 0.5-1%; Extremely dispersive, <0.5%	Non-dispersive, 10-15%; Non-cohesive, 5-10%; Dispersive, 1-5%; Extremely dispersive, 0.5-3%	Non-dispersive, 15-20%; Non-cohesive, 10-15%; Dispersive, 5-10%; Extremely dispersive, 3-8%	Non-dispersive, >20%; Non-cohesive, >15%; Dispersive, >10%; Extremely dispersive, >8%
Soil water availability, M	PAWC >125mm/m	PAWC 100-125mm/m	PAWC 75-100mm/m	PAWC 50-75mm/m	PAWC <50mm/m
Surface condition, Ps	Soft or loose sandy to sandy loam; or Very fine self-mulching clays (peds less than 2mm)	Soils with soft, firm or only weakly had setting, sandy to loamy surface; or Fine self-mulching clays (peds 2-5mm) or Course self-mulching clays (peds >5-10mm)	Clay soils with hard setting, firm pedal or weakly self-mulching surface; or Very coarse self-mulching clays (peds >10mm)	Loamy, fine sand, silty or clayey surface, extremely hard setting, massive or crusting	
Rockiness, R	<20% pebbles <60mm and rock outcrop	20-50% pebbles <60mm and rock outcrop	>50% pebbles <60mm; or 20-50% cobbles 60-200mm	>50% cobbles 60-200mm; or 20-50% stone >200mm	>50% stone or rock outcrop
Micro-relief, Tm	Normal linear gilgai, 0.1-0.3m), <30% surface area	Shallow melonhole gilgai, 0.3-0.6m, 30-70% surface area	Strong, deep melonhole gilgai, 0.6-1.5m, <30% surface area	Strong, deep melonhole gilgai (0.6-1.5m), 30-70% of land surface	Strong, deep melonhole gilgai (0.6-1.5m), >70% of land surface

Limitation	Land suitability class				
	1	2	3	4	5
Wetness, W	Rapid draining to moderately well drained and slowly permeable	Imperfectly drained and highly permeable	Imperfectly drained and moderately permeable	Imperfectly drained and slowly permeable	Poorly to very poorly drained
Acid drainage water hazard, actual, Ar	AASS (pH<4) not present or present at depths >2m	AASS present at depths 1-2m	AASS present at depths 0.5-1m	AASS present <0.5m	
Acid drainage water hazard, potential, Ap	PASS (%S > action threshold) not present or at depths >3m	PASS present at depths 1-2m	PASS present at depths 0.5-1m	PASS present <0.5m	
Nutrient deficiency, Nd	P >20mg/kg	P 10-20mg/kg	P 5-10mg/kg	P <5mg/kg	
Element toxicity, Tx	pH 6.6-7.3	pH 6.0-6.5	pH 5.1-5.5 or pH 7.4-8.4	pH <5 or pH>8.5	
Soil depth, Sd	>0.75m	0.5-0.75m	0.25-0.5m	<0.25m	
Salinity, Sa	ECe <2dS/m	ECe 2-4dS/m	ECe 4-8dS/m	ECe >8dS/m	
Vegetation, V	Improved pastures (grass and legumes) with Eucalypt dominated overstory on non-gilgai forming soils	Improved pastures (grass and legumes) with or without overstory species on non-gilgai forming soils	Native pastures with or without Acacia dominated overstory on non-gilgai forming soils	Native pastures with Acacia dominated overstory on gilgai forming soils	None
Landscape complexity, Lc	>10ha	5-10ha	2.5-5ha	<2.5ha	

APPENDIX B – ENSHAM RISK MATRIX TOOL

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RTI Act 2009

Consequence / Severity Descriptions

Rating	Consequence					
	Note: Consequence may consist of a single event or may represent a cumulative impact over a period of 12 months					
	Personal Injury (PI)	Impact to Annual Business Plan (EBIT)	Business Interruption (BI)	Legal (L)	Reputation/ Community (R)	Environment (E)
1. Catastrophic	Multiple fatalities / Irreversible health impacts >50 workers	>\$50m	> 2 months production	Prolonged litigation, heavy fines, potential jail term	Extended negative national media coverage. Socially irresponsible image	Serious environmental harm that is irreversible. Legal / regulatory impact.
2. Major	Single fatality and/or severe irreversible disability (>30%) to one or more workers	\$10m - \$50m	1 to 2 months production	Major breach/ major litigation	Longer term State wide and national negative media coverage > 1 week (State)	Material environmental harm –that requires extensive time & resources to remediate)
3. Moderate	Lost Time Injury / Illness / moderate irreversible disability (<30%) to one or more workers	\$5m - \$10m	1 week to 1 month production	Serious breach of regulation. prosecution/ fine	Short term State wide or extensive negative media coverage < 1 week.	Moderate (reversible) environmental effects – remedial in LOM
4. Minor	Medical Treatment Injury / Illness. Reversible disability / impairment	\$1m - \$5m	1 day to 1 week production	Non-compliance, breaches in regulation	Series of articles in local press, including radio or other media.	Minor damage to physical environment – contained and remedial in short term
5. Insignificant	First Aid injury. No medical treatment	<\$1m	< 1 day production	Low level compliance issue	Local complaints / no real impact on Community	Negligible environmental harm. Can be immediately cleaned up.

Likelihood Description

Likelihood	(2) Description	(1) Frequency
A Certain	The event is expected to occur in most circumstances	Multiple / 12 months
B Likely	The event will probably occur in most circumstances	Once 1-5 years
C Possible	The event may occur at some time	Once 5 – 10 years
D Unlikely	The event has not occurred in our company, but has occurred within the industry as a whole on a number of occasions	Once 10 - 50 years
E Rare	Event has not been known to occur in our organisation, but has been known to occur infrequently within the industry and is only likely to occur in exceptional circumstances.	Once / > 50 years

Consequence	Likelihood				
	A	B	C	D	E
	Certain	Likely	Possible	Unlikely	Rare
	"Common" Once or greater per annum	"Has Happened but infrequently" Could happen in 1-5 years	"Could Happen once between 5 – 10 years"	"Not Likely – but has happened in industry" May occur within 10–50 years	"May occur once > 50 years"
1	C1	C2	C4	C6	H11
2	C3	C5	C7	H12	M16
3	H8	H9	H13	M17	M20
4	H10	M14	M18	L21	L23
5	M15	M19	L22	L24	L25

Risk Tolerability Levels

Risk Rating	Risk Category		Tolerance	Generic Management Actions
1 to 7	C	Critical	Intolerable	Immediate intervention required from senior management to eliminate or reduce this risk
9 to 13	H	High	ALARA	Imperative to eliminate or reduce risk to a lower level by the introduction of control measures. Management planning required
14 to 20	M	Medium	ALARA	Corrective action required, management attention needed to eliminate or reduce risk
21 to 25	L	Low	Tolerable	Monitor and manage by corrective action where practicable,



THE MINE REHABILITATION SPECIALISTS
highlandsenvironmental.com.au

FINAL REPORT

**SOIL AND LAND RESOURCE SUITABILITY ASSESSMENT
FOR SUSTAINABLE CATTLE GRAZING OF
REHABILITATION AT ENSHAM MINE**

16 December 2017

Prepared for Ensham Resources

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IMPORTANT INFORMATION ABOUT THIS REPORT

DEFINITIONS

In this section:

“Client” means the organisation or individual that engaged Highlands Environmental to perform the work described in this report.

“Highlands Environmental” means La Tierra Pty Limited trading as Highlands Environmental, and its subcontractors.

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EXECUTIVE SUMMARY

Rehabilitation that is suitable for sustainable cattle grazing is a statutory objective for most rehabilitation at Ensham mine, central Queensland. This document reports an evaluation of soil and land resources across approximately 1,000 hectares of rehabilitation and determines the suitability of that rehabilitation for sustainable cattle grazing using standard government-defined criteria. It also provides some recommendations for land and grazing management.

Of the 20 discrete areas of rehabilitation assessed, 17 of these are land suitability class 4 and three of these are land suitability class 5. Land suitability class 4 rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. Land suitability class 5 rehabilitation has extreme limitations that preclude grazing of the land for most of the year.

Primary limitations to sustainable grazing in rehabilitation are: erosion risk; strong to very strong alkalinity in topsoils and mine overburdens (now subsoils in rehabilitation); poor soil water retention capacity; and, low soil fertility. Most of these limitations are inherent to the constructed post-mining landscape and are enduring characteristics of the rehabilitation. However, limitations like these are not unique to mine rehabilitation and are common limitations in unmined grazing lands across central Queensland.

Recommendations are provided for the mitigation of particular limitations, e.g. strong alkalinity in soils, in existing and future rehabilitation, and also for future grazing systems in rehabilitation. The appropriate grazing production model for rehabilitation is a *store weaner production* model. In this system the main products are store weaners for sale or growing on better country, which is not rehabilitation.

1 INTRODUCTION

A post-mining land use of sustainable cattle grazing is an important objective for most rehabilitation at Ensham mine. In 2017 this objective was formalised in Environmental Authority (EA) EPML00732813 and applies to most rehabilitation domains at the mine (see EA condition G5 and Appendix 4). Rehabilitation that comprises soil and land resources that are suitable for sustainable cattle grazing is a critical measure of rehabilitation success at Ensham.

This document reports an evaluation of soil and land resources in rehabilitation and determines the suitability of that rehabilitation for sustainable cattle grazing using standard government-defined criteria. Highlands Environmental Pty Limited completed this work in September - November 2017.

1.1 Study area

This study evaluated soil and land resources across approximately 1,000 hectares (ha) of rehabilitation at Ensham mine. In 2017 existing rehabilitation had been stratified into 21 'rehabilitation polygons' for monitoring and mapping. Polygons were based on core rehabilitation attributes, e.g. age, spoil type, topsoil and vegetation. Each polygon represents an area of rehabilitation that is more-or-less homogeneous. None of the existing rehabilitation pre-dates 2004.

1.2 Previous land resource studies

Several studies have assessed land resources in the pre-mining landscape at Ensham mine. Some of these studies have also proposed possible post-mining outcomes, however none have actually assessed land resources following open-cut mining and rehabilitation. These studies form a record of pre-mining conditions, and also a benchmark against which post-mining outcomes can be gauged.

1.2.1 Regional assessments

The Queensland Government and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have undertaken regional-scale mapping of land resources and soils throughout much of Queensland, including the study area. Relevant studies, which assessed pre-mining land resources, are summarised as follows.

Lands of the Nogoa-Belyando Area, Queensland (Galloway *et al.* 1967 for CSIRO).

This early study mapped soils across most of the Central Highlands region comprising the former shires of Bauhinia, Emerald, Peak Downs and part of Jericho, an area of 9 million hectares (ha). The landscape was assessed using the reconnaissance survey method that mapped and described the area in terms of 43 land systems, and arranged soils into seven major groups with 34 families (all via a now superseded classification scheme). Although this work excluded the study area (the boundary was Crinum Creek), because of its close proximity it does provide a preliminary indication of soil types that can be expected.

Land Units of the Fitzroy Region, Queensland (Nix and Gunn, 1977 for CSIRO)

This was the last report of its type by CSIRO and reflects considerable methodology changes compared to earlier reports, though these too are now superseded. This report consolidates and restructures information from three earlier reports covering the same area, almost 20 million ha and including the study area. It identified 142 simple land units with associated lithology, soils and vegetation, and also land capability.

Soils in the study area are mapped as alluvial clay soils near to the Nogoa River (land units 39-53 and 123-142), and skeletal soils to the north and adjacent to Boggy Creek (land units 54-56). Probable specific land units within these mapping groups have been interpreted from mapping (Table 1-1).

Table 1-1 Land unit descriptions within the study area (after Nix and Gunn, 1977)

Study area	Land unit	Lithology	Terrain	Soil	Vegetation	Land capability
South-side of Nogoa River	127	Alluvium, medium to fine texture	Level to very gently sloping	Deep texture contrast soils	Brigalow open forest	V
North-side of Nogoa River	41	Tertiary clay	Level to gently undulating	Deep cracking clay soils	Brigalow open forest	III
Along northern part of Boggy Creek	55	Quartz sandstone	Mountainous to hilly	Skeletal, shallow	Sandstone open forest	VII-VIII

Land capability is the inherent physical capacity of the land to sustain a range of land uses and management practices in the long term without degradation to soil, land, air and water resources. Although detail of the assessment conducted in this study is not known, contemporary general definitions used in land and soil capability assessment provide a sound guide and approximation to the outcomes of this study, viz.

Land and soil capability classes (LSCC) I, II and III – Land capable of a wide variety of land uses (cropping, grazing, horticulture, forestry, nature conservation) with few to moderate limitations.

LSCC IV and V – Land capable of a variety of land uses (cropping with restricted cultivation, pasture cropping, grazing, some horticulture, forestry, nature conservation) but Class V land should not be cultivated.

LSCC VI – Land capable for a limited set of land uses (grazing, forestry and nature conservation, some horticulture) with moderate limitations.

LSCC VII and VIII – Land generally incapable of agricultural land use (selective forestry and nature conservation) (from State of NSW and Office of Environment and Heritage, 2012 and Queensland Government, 2017a)

Lands Resource Survey and Evaluation of the Kilcummin Area, central Queensland (Shields and Williams, 1991).

This report provides a practical application of land resource assessment techniques. These techniques have been used to supplement contemporaneous guidance materials issued by Government.

Understanding and Managing Soils of the Central Highlands (Bourne and Tuck, 1993).

This landmark report underpins most modern land resource assessments in central Queensland. This study identified six broad land resource areas (LRAs) that cover the central Highlands and within these, 18 agricultural management units (AMUs) (Table 1-2). Mapping units within the study area have been interpreted and reveal five LRAs could have been present pre-mining (Table 1-3).

Table 1-2 Relationship of LRAs to AMUs (from Bourne and Tuck, 1993)

LRA	AMUs	
	Major occurrence	Minor occurrence
Alluvial plains	Adelong, Moramana, College	Dooruna, Isaac, Lascelles, Lonsome, Rolleston, Turkey Creek
Undulating scrub plains	Rolleston, Picardy, Springton, Turkey Creek, Glengallan, Glen Idol	Adelong, Lonsome
Eucalypt duplex plains	Lascelles, Duckponds	Glengallan, Turkey Creek, Glen Idol
Undulating downs	Orion, Jimbaroo	Kia-Ora, Glen Idol, Moramana

LRA	AMUs	
	Major occurrence	Minor occurrence
Plateaus	Duckponds	Glen Idol, Highlands, Lascelles
Ranges	Highlands	Lascelles, Glen Idol

Table 1-3 LRA descriptions within the study area (after Bourne and Tuck, 1993)

LRA	Landform	Soils	Vegetation	Land use
Alluvial plains	Level plains on Quaternary alluvium	Alluvial clays	Eucalypt woodland	Rainfed and irrigated cropping, grazing
Undulating scrub plains	Undulating plains on sedimentary rocks, Tertiary basalt and unconsolidated sediments	Cracking clays	Brigalow	Rainfed cropping, grazing
Eucalypt duplex plains	Gentle plains to low hills	Mainly solodic soils	Poplar box woodlands	Grazing
Undulating downs	Gentle plains on Tertiary basalt	Cracking clays	Dense grasslands	Rainfed cropping and grazing
Ranges	Hills to very steep hills	Stony lithosols, minor earths	Ironbark, bendee, Acacia spp.	Grazing native pastures

1.2.2 Local assessments

Ensham Central Project EIS, Terrain, Soil and Land Capability Assessment Study (Hansen Bailey, 2006)

Hollingsworth, Dames and Moore (1991) mapped soils for the Ensham mine in the late 1980s, identifying six major soil units. Later, Hansen Bailey (2006) supplemented this work with further field investigation for a subsequent mining approval. Although the latter study focussed only on land immediately adjacent to the Nogoa River, much of the information is relevant to the study area. For example the geological regime, which is summarised as follows.

- Quaternary Alluvium; River and Floodplain Deposits – clay, silt, sand, gravel.
- Cainozoic Soil Cover including Older Alluvial and Colluvial Deposits – soil, sand, siliceous and ferruginous gravel and reworked laterite.
- Tertiary Emerald Formation – argillaceous sandstone, lateritised sediments, laterite, claystone, siltstone, sandstone and pebbly sandstone.
- Permian Undifferentiated Blackwater Group which includes the Rangal Coal Measures, Burngrove Formation and Fairhill Formation which comprise carbonaceous mudstone, thinly interbedded mudstone and fine sandstone, siliceous siltstone, lithic calcareous and feldspathic sandstone, tuff and coal seams.

Each of these materials is readily identifiable in rehabilitation at Ensham where it may or may not be covered with soil.

Hansen Bailey (2006) adopted the major soil groups identified by Hollingsworth, Dames and Moore (1991). These groups were:

1. Shallow rocky (skeletal) soils - Rudosols
2. Moderately shallow gravelly sands, loams and clay soils – Rudosols and Tenosols
3. Gradational red and yellow earths – Tenosols, Kandosols and Ferrosols
4. Duplex soils - Sodosols
5. Uniform, fine textured, non-cracking clays - Dermosols
6. Cracking clay soils - Vertosols

In terms of land suitability for sustainable cattle grazing, Hansen Bailey (2006), using QDME (1995), found that pre-mining the land was a mix of Class 1 to Class 5 land, and forecast that post-mining the rehabilitation would be a mix of Class 2, 4 and 5 land for grazing land use.

1.3 Cattle grazing trials in coal mine rehabilitation

Cattle grazing productivity metrics are not a component of soil and land resource suitability assessment for sustainable grazing in Queensland. However, 'grazing trials' do provide good and useful supplementary information about what happens to soil and land condition, and also pasture and cattle condition, when cattle graze rehabilitation.

1.3.1 Industry trials

Land Use – Liddell Grazing Trial (GCAA, undated)

This paper summarises a recent cattle grazing trial at Liddell coal mine in the Hunter Valley, NSW. The trial consisted of 70 ha each of rehabilitation (3 to 10 years old) and unmined land, and Charbray steers at a stocking rate of one beast per 2.4 ha. Cattle were grazed for 18 months and key results for soil, pasture and cattle are summarised as:

- Soil – soils in rehabilitation had elevated salinity and sodicity;
- Pasture – groundcover was maintained above 70% throughout the trial;
- Cattle – cattle in rehabilitation gained more weight over the period, though testing showed blood copper deficiency.

Sustainable Grazing on Rehabilitated Lands in the Bowen Basin – Stages 1 and 2 (Grigg *et al.* 2006)

This Australian Coal Association Research Program (ACARP) sponsored research by The University of Queensland considered several grazing regimes in small areas at Goonyella Riverside, Norwich Park and Blackwater coal mines in central Queensland. Conclusions from this study are:

- Pasture-based coal mine rehabilitation has the capacity to support cattle grazing;
- Estimated sustainable stocking rates on rehabilitation are 2.2 to 5.6 ha/head;
- High productivity pasture at Norwich Park coal mine can sustain a stocking rate of 3 ha/head, and this is comparable to rates on better improved pastures on unmined land in the region.

1.3.2 Local trials

Yongala Grazing Trial and Assessment, 2016 Report (CHRRUP, 2016)

This study assessed soil and pasture condition pre- and post-grazing in rehabilitation at Y Pit, in the northern most area of the mine. Grazing consisted of 110 cows with calves at foot on 94 ha of rehabilitation, plus minor other areas and unmined land summing to 115 ha total. Cattle were grazed for a period of 142 days between December and April 2016. Key results of this trial were:

- Grazing removed about 50% of the pasture (standing dry matter);
- Groundcover was reduced only slightly from 94% to 89%;
- Grazing did not affect soil condition;
- Cows held their condition and this was unexpected by the cattle owner because the condition of his lactating cows typically declines.

Nogoa Pastoral Company grazing trial 2017 (unpublished)

In 2017 Nogoa Pastoral Company introduced cattle to an area at A Pit, in the southern part of the mine, which included 92 ha of rehabilitation, plus minor areas of other disturbance and unmined land. Approximately 83 head of 18-24 month old Santa Gertrudis steers were grazed for 240 days. The weight of each beast was recorded on the first and last day of the grazing period. Although there was some variation within the herd, the average daily weight gain per beast was 0.335 kg/head/day.

2 METHODS

The methodologies used in this assessment are detailed as follows.

2.1 Applying recognised standards

In this land resource assessment, Highlands Environmental has applied the following suite of recognised industry standards and guidelines.

Soil and landscape field assessment

National Committee on Soil and Terrain (2009) *Australian Soil and Land Survey Field Handbook*, Third Edition, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Soil survey specifications

McKenzie N, Grundy M, Webster R and Ringrose-Voase A (2008) *Guidelines for Surveying Soil and Land Resources*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Soil classification

Isbell RF (1996) *The Australian Soil Classification*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Field vegetation assessment

Hnatiuk R, Thackway R and Walker J (2009) *Vegetation*, In: Australian Soil and Land Survey Field Handbook, Third Edition, Australian Soil and Land Survey Handbook Series, National Committee on Soil and Terrain, CSIRO Publishing, Melbourne.

Soil chemistry

Rayment G and Lyons D (2011) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Soil physics

Mckenzie N, Coughlan K and Cresswell H (2002) *Soil Physical Measurement and Interpretation for Land Evaluation*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Land suitability for sustainable grazing

DNRM/DSITIA (2013a) *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition, Queensland Government, Brisbane.

DNRM/DSITIA (2013b) *Regional Land Suitability Frameworks for Queensland, Chapter 10 - Suitability framework for the Inland Fitzroy and Southern Burdekin area*, Queensland Government, Brisbane.

QDME (1995) *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*. Queensland Department of Mines and Energy, Brisbane.

2.2 Mapping scale and sampling intensity

The mine had previously identified 21 'rehabilitation polygons' summing to approximately 1,000 ha of existing rehabilitation. Polygon boundaries were defined by the core rehabilitation attributes of year sown, spoil type, topsoil and vegetation, to group areas of like rehabilitation. Adopting these rehabilitation polygons as a basis for fieldwork, and with consideration to the degree of landscape complexity this accounted for, a final mapping scale of 1:50,000 is considered appropriate.

According to Queensland Government (2017b) mapping at this scale requires an investigation density of 1 site per 20-100 ha. As rehabilitation polygon boundaries were untested, it was decided to target a site density

of 1 per 25 ha, knowing that this would also allow mapping at moderately high intensity scale of 1:25,000 if required in future. This equates to 47 sites across the study area.

McKenzie *et al.* (2008) recommend at least 5% of sites should include soil profile description with laboratory analysis, 35% sites should include soil profile description only, and 60% of sites should be observational only. However, to ensure that each of the previously identified polygons could be mapped with certainty, a constraint of at least one detailed soil profile description with laboratory testing per polygon was applied. In addition, other recent soil sampling data was also incorporated to provide a total of 59 sites, and a very high level of detail in the investigation (Table 2-1).

Table 2-1 Recommended and actual site densities within the study area

Site density	Detailed	Check	Observation	Total
Recommended	2	17	28	47
Actual	33	24	2	59

The location of each site within polygons across the rehabilitated landscape is provided (Appendix A).

2.3 Fieldwork

Fieldwork was completed in August and September 2017. Within polygon constraints, fieldwork used 'free survey' techniques (McKenzie *et al.* 2008) to collect site information. All field descriptions were collected in accordance with standards outlined by the Soil and Terrain (2009), Hnatiuk *et al.* (2009) and Isbell (1996). Soil profiles were excavated by hand auger to a depth of 900mm or refusal on rock or impenetrable gravel. Soil profiles were described, photographed and sampled for laboratory testing in the field. Depending on total hole depth, soil samples were taken from the following depth increments: 0-100mm, 200-300mm, 400-500mm, 600-700mm and 800-900mm.

2.4 Laboratory analyses

Soil samples were analysed at Incitec Pivot Limited's Nutrient Advantage Laboratory Services in Werribee, Victoria. This facility holds the following accreditations:

- NATA Accredited Laboratory (Accreditation No. 11958), demonstrating technical competence to operate in accordance with ISO/IEC 17025 for chemical testing;
- ASPAC (Australian Soil and Plant Analysis Council Inc.), certifying the laboratory meets proficiency criteria to conduct analysis in accordance with Rayment and Lyons (2010); and,
- FERTCARE, by AgSafe, accredited advisor.

The following laboratory analyses were performed.

1. For all surface soil fractions, a full soil fertility suite
Ammonium, nitrate, phosphorus (P) (Colwell), phosphorus buffer index (PBI), sulphur (MCP), exchangeable cations (calcium, magnesium, potassium, sodium and aluminium), pH (water) and pH (CaCl₂), chloride, electrical conductivity (water and saturated), organic carbon, colour, and texture, and copper, iron, manganese, zinc and boron
2. For other depth fractions, a limited salinity based suite
pH (water) and pH (CaCl₂), electrical conductivity (water and saturated), exchangeable cations (calcium, magnesium, potassium, sodium and aluminium), calcium/magnesium ratio, exchangeable sodium percentage, colour and texture

2.5 Land suitability framework

2.5.1 Land classes

Five land suitability classes are defined for use in Queensland (DNR/DSITIA 2013a), with land suitability decreasing progressively from Class 1 to Class 5. These classes are used to describe an area of land in terms of suitability for a particular land use which allows optimum, sustainable production with current technology, while minimising degradation to the land resource in the short, medium or long-term. Land is considered less suitable as the severity of limitations affecting a particular land use increases, reflecting either:

- Reduced potential for production; and/or,
- Increased inputs required to achieve an acceptable level of production; and/or,
- Increased inputs required to prepare the land for successful production; and/or,
- Increased inputs required to prevent land degradation.

The five land suitability classes defined for Queensland are described (Table 2-2).

Table 2-2 Land suitability classes (adapted from DNR/DSITIA, 2013a and QDME, 1995)

Class	Suitability	Limitations	Description
1	Suitable	Negligible	Highly productive land that is well suited to the proposed use
2	Suitable	Minor	Land with limitations that either constrain production, or require more than the simple management practices of class 1 land to maintain sustainable production
3	Suitable	Moderate	Land with limitations that either further constrain production, or require significant inputs to ensure sustainable use
4	Marginally suitable	Severe	Land which is marginally suited for a proposed use and would require major inputs to ensure sustainability; often the inputs required may not be justified in terms of the benefits to be gained from using the land for a proposed use and the land is considered presently unsuitable for that use
5	Unsuitable	Extreme	Land with extreme limitations that preclude any possibility of successful sustained use of the land in the proposed manner

Classes 1 to 3 are considered suitable for a specified land use because the benefits from using the land (for that particular use) outweigh the inputs required to initiate and maintain production.

Typically, the benefits from using Class 4 land are similar in magnitude to the level of inputs required to achieve production and its long-term suitability for the specified land use is doubtful. Class 4 is also used in situations where reducing the effect of a particular limitation may indicate production is possible, but additional studies are needed to determine the feasibility of such actions, e.g. fertilisation.

In contrast, there is no doubt regarding the long-term suitability of Class 1–3 lands or the unsuitability of Class 5 land. Class 5 land has limitations that in aggregate are so severe that the benefits do not justify the inputs required to initiate and maintain production. It would require a major change in economics, technology or management expertise before the land could be considered suitable for the land use being considered. Many Class 5 lands have physical characteristics that totally preclude any form of development, e.g. mountains, and will always remain unsuitable for agriculture.

2.5.2 Land suitability for sustainable beef cattle grazing

The suitability classification for grazing evaluates soils in terms of the potential to graze and finish cattle on improved pastures (QDME 1995, Shields and Williams 1991). Typically, grazing systems in inland central Queensland aim to produce young, finished, grassfed, export quality cattle without inputs other than pasture development. Most production is based around improved grass-legume pastures. Improved pasture development in many areas is dominated by buffel grass, although Rhodes grass, introduced bluegrasses (Indian bluegrass, creeping bluegrass), purple pigeon grass and panic species all have a role in certain situations. Legume establishment and species vary significantly depending on soil characteristics and

microclimates. Commonly used legumes include shrubby stylos species, Desmanthus species, Wynn cassia (sandy soils), butterfly pea (clay soils), siratro, medics and leucaena (cropping soils).

Class 1 and 2 land is considered suitable for grazing improved pastures and is capable of attaining maximum grazing productivity (QDME 1995, Shields and Williams 1991). In inland central Queensland this can be defined as the production of young, finished, grassfed, export quality cattle in most seasons, and such country is termed 'fattening country'.

Class 3 land is suitable for grazing improved pastures but is generally less productive than Classes 1 and 2 and encompasses a range in productivity. Land in this class is often termed 'growing country' and is defined as country on which younger cattle perform well but may be difficult to finish at a young age, depending on seasonal conditions, i.e. cattle on Class 3 land may take longer to achieve the desired weight class or finished grade than equivalent cattle on Classes 1 and 2 land.

Class 4 land is considered marginal for grazing improved pastures, but is generally considered suitable for grazing native pastures of varying quality all year round, depending on soil characteristics, (QDME 1995, Shields and Williams 1991). In inland Central Queensland such country is typically termed 'breeding country'. It encompasses a range in productivity from the lower end of Class 3 growing country through to the poorer end of Class 4 breeding country. Shields and Williams (1991) suggest 3 possible subclasses exist within Class 4:

- Land with native pasture of low productivity, which while physically capable of being developed to improved pasture, is subject to low soil fertility and doubtful long term productivity;
- Land with high quality native pasture (typically black soil downs) on which improved pasture establishment is marginal because of unfavourable soil characteristics and limited species; and
- Land with native pasture of low productivity, which has physical limitations that preclude fully improved pasture development, but allow over-sowing of legumes such as shrubby stylo.

For coal mine rehabilitation that is Class 4 breeding country, the appropriate production system is a store weaner production model. In this model herds will consist mostly of cows (>2 years of age) with or without calves at foot, replacement heifers (<2 years of age) and a low percentage of bulls (≤3%). The primary product is store weaners for sale or growing on better country, with surplus heifers and empty cows as secondary products.

Class 5 land is unsuitable for any form of pasture improvement and land use is limited to extensive grazing of native pastures of low productivity. In many cases, lands are of such poor quality they are considered marginal as breeding country and may be destocked in the winter/dry season, unless grazed in conjunction with better quality country. Land in this class is mostly used as breeding country during the summer/wet season when planes of nutrition are higher.

2.5.3 Land use requirements and limitations

Following DNR/DSITIA (2013a, 2013b), QDME (1995), and Shields and Williams (1991), a set of 15 land use requirements and associated limitations has been identified as important for sustainable grazing of land rehabilitated after mining in central Queensland (Table 2-3).

Table 2-3 Land use requirements & limitations for sustainable cattle grazing on rehabilitation

Land use requirement	Limitation	Criteria	Subclass code
Slope gradients appropriate to soil types.	Surface soil erodability	Moderately stable soils, <5%; non-cohesive soils, <5%; dispersive soils, <3%; highly erodible soils, <1%.	Ea1
		Moderately stable soils, 5-10%; non-cohesive soils, 5-8%; dispersive soils, 3-5%; highly erodible soils, 1-3%.	Ea2
		Moderately stable soils, 10- 15%; non-cohesive soils, 8-10%; dispersive soils, 5-8%; highly erodible soils, 3-5%.	Ea3
		Moderately stable soils, 15- 20%; non-cohesive soils, 10-15%; dispersive soils, 8-10%; highly erodible soils, 5-8%.	Ea4
		Moderately stable soils, >20%; non-cohesive soils, >15%; dispersive soils, >10%; highly erodible soils, >8%.	Ea5

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

Land use requirement	Limitation	Criteria	Subclass code
	Subsoil erodability	Non-dispersive, <5%; Non-cohesive, <1%; Dispersive, <0.5%; Extremely dispersive, n/a.	Eb1
		Non-dispersive, 5-10%; Non-cohesive, 1- 5%; Dispersive, 0.5-3%; Extremely dispersive, <0.5%.	Eb2
		Non-dispersive, 10-15%; Non-cohesive, 5-10%; Dispersive, 3-10%; Extremely dispersive, 0.5- 3%.	Eb3
		Non-dispersive, 15-20%; Non-cohesive, 10-15%; Dispersive, 5-10%; Extremely dispersive, 3- 8%.	Eb4
		Non- dispersive, >20%; Non-cohesive, >15%; Dispersive, >10%; Extremely dispersive, >8%.	Eb5
Adequate water supply. Soil has capacity to hold rainfall and make it available to pasture species at a later time.	Soil water availability	PAWC >125mm PAWC 100-125mm PAWC 75-100mm PAWC 50-75mm PAWC ≤50mm Estimated via method described in QDME (1995).	M1 M2 M3 M4 M5
Seedbed for seed germination.	Surface condition	Soft or loose sandy to sandy loam; or very fine self-mulching clays (peds less than 2mm). Soils with soft, firm or only weakly had setting, sandy to loamy surface; or fine self-mulching clays (peds 2-5mm) or coarse self- mulching clays (peds >5-10mm). Clay soils with hard setting, firm pedal or weakly self-mulching surface; or very coarse self-mulching clays (peds >10mm). Loamy, fine sand, silty or clayey surface, extremely hard setting, massive or crusting.	Ps1 Ps2 Ps3 Ps4
Rock-free surface soils	Rockiness	<20% pebbles <60mm and rock outcrop. 20-50% pebbles <60mm and rock outcrop. >50% pebbles <60mm; or 20-50% cobbles 60-200mm. >50% cobbles 60-200mm; or 20-50% stone >200mm. >50% stone or rock outcrop.	R1 R2 R3 R4 R5
Accessible land	Micro-relief	Nil. Shallow melonhole gilgai, 0.3-0.6m, 30- 70% surface area. Normal linear gilgai, 0.1-0.3m), <30% surface area. Strong, deep melonhole gilgai, 0.6-1.5m, <30% surface area. Normal linear gilgai, 0.1-0.3m), 30-50% surface area. Strong, deep melonhole gilgai (0.6-1.5m), 30- 70% of land surface. Normal linear gilgai, 0.1-0.3m), >50% surface area. Strong, deep melonhole gilgai (0.6- 1.5m), >70% of land surface	Tm1 Tm2 Tm3 Tm4 Tm5
Aerobic soil conditions (soil drainage conditions)	Wetness	Rapid draining to moderately well drained and slowly permeable. Imperfectly drained and highly permeable. Imperfectly drained and moderately permeable. Imperfectly drained and slowly permeable. Poorly to very poorly drained.	W1 W2 W3 W4 W5
Not affected by AMD or acid-sulphate soils	Acid drainage, real	pH<4 not present or present at depths >2m pH4 present at depths 1-2m pH4 present at depths 0-0.5m pH4 present at in surface soils	Ar2 Ar3 Ar4 Ar5
	Acid drainage, potential	%S > action threshold not present %S > action threshold at depths >1.5m %S > action threshold at depths >1-1.5m %S > action threshold at depths >0.5m %S > action threshold in surface soils	Ap1 Ap2 Ap3 Ap4 Ap5
Adequate nutrient supply	Nutrient deficiency	P >20mg/kg P 10-20mg/kg P 5-10mg/kg	Nd1 Nd2 Nd3 Nd4

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

Land use requirement	Limitation	Criteria	Subclass code
		P <5mg/kg	
Nutrient imbalance	Nutrient imbalance	pH 6.6 – 7.3 pH 6.0 – 6.5 pH 5.1 – 5.5 or pH 7.4 – 8.4 pH 4.1-5.0 or pH 8.5 to 9.9 pH ≥10 or ≤4	Tx1 Tx2 Tx3 Tx4 Tx5
Adequate soil depth to support vegetation	Soil depth	>750mm 500 – 750mm 250 – 500mm <250mm	Sd1 Sd2 Sd3 Sd4
Salinity free root zone	Root zone salinity, in 0-60cm fraction (QDME, 1995)	ECe <2dS/m ECe 2-4dS/m ECe 4-8dS/m ECe 8-16dS/m ECe >16	Sa1 Sa2 Sa3 Sa4 Sa5
Absence of undesirable vegetation	Vegetation	Improved pastures (grass and legumes) with Eucalypt dominated overstory on non- gilgai forming soils. Improved pastures (grass and legumes) with or without overstory species on non-gilgai forming soils. Native pastures with or without Acacia dominated overstory on non-gilgai forming soils. Native pastures with Acacia dominated overstory on gilgai forming soils.	V1 V2 V3 V4
Practical land area available	Landscape complexity	>10ha 5-10ha 2.5-5ha <2.5ha	Lc1 Lc2 Lc3 Lc4

The overall objective of land suitability classification is to allocate a final suitability class for a specific land use, in this case sustainable cattle grazing. The suitability subclasses for all limitations must be considered and these function as a set of rules to determine overall suitability classes. In this assessment there are 71 rules (see Table 2-3), developed from literature review and local experience. As in all land suitability assessments, the limitation with the lowest subclass ranking score determines the overall suitability score.

3 RESULTS

This section provides a comprehensive summary of field descriptions, analytical data, interpreted attributes of soils and land suitability within rehabilitation. Traditionally, results of land suitability assessments are presented on a soil mapping unit basis. For the reasons outlined in the previous section, and because most soil profiles in rehabilitation are Anthrosols, the following results are presented on a rehabilitation polygon basis.

Anthrosols are soils resulting from human activities which have led to profound modification, truncation or burial of the original soil horizons, or the creation of new soil parent materials by a variety of mechanical means (Isbell, 1996). These soils are different from all others and it may or may not be possible to understand their origin using pedogenic attributes. For example, it may not be possible to say that a particular Anthrosol was derived from stripping and replacing the surface fraction of a Dermosol or Sodosol in the mining process. In this section only key analytical data is presented and original laboratory reporting sheets are also provided (Appendix B).

3.1 Rehabilitation Polygon 1

Rehabilitation Polygon 1 has a total area of 61.6ha and is located in A Pit, south of the Nogoa River. The current land use is grazing and cattle were present on the land during fieldwork. Rehabilitation works were conducted in 2009.

3.1.1 Sites

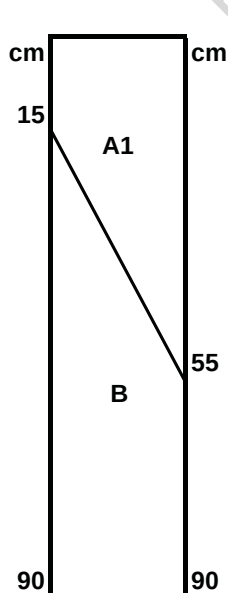
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
1	0649555,7396129	Detail	Top of landform	<2%	Rhodes grass, minor Buffel grass, minor Stylo spp.	25cm	Tertiary	90cm
2	0649419,7395462	Detail	Upper slope	10%	Rhodes grass, minor Stylo spp.	15cm	Permian	90cm
3	0649388,7395246	Check	Lower slope	10%	Rhodes grass	25cm	Permian	90cm
4	0649864,7396146	Check	Lower slope	10%	Buffel grass	n/a	n/a	20cm
5	0649670,7397045	Check	Upper slope	<5%	Rhodes and Buffel grasses	55cm	n/a	55cm
6	0649760,7396947	Obs.	Upper slope	10%	Rhodes and Buffel grasses	25cm	n/a	25cm

3.1.2 Representative photographs



Surface and vegetation conditions at Site 1 (left), Site 2 (middle) and Site 5 (right)

3.1.3 Soil profile description



The **topsoil (A1)** is a brown (7.5YR4/3, Site 1) to dark red brown (2.5YR3/4, Site 2), yellow red (5YR4/6, Site 3) and brown (7.5YR4/1, Site 5) colour, sandy loam to sandy clay, with a granular (free draining) structure. Soil can be stoney (Site 4). Field pH was neutral to alkaline, ranging from 6.5 (Site 1) to 8.0 (Site 5). Clear change to:

Subsoil (B) is mine overburden, mostly of Permian age by field observation. Texture is sandy clay to clay, and structure is blocky to massive with some mottling (45cm, Site 3) indicating low permeability. Gravel and rock is present. Subsoil is alkaline, ranging from 8.0 (Sites 1 and 2) to 8.5 (Site 3) and 9.0 (Site 5).

Profile photo is Site 2.



3.1.4 Laboratory analyses

Site 1

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.4	0.4	3.09	2.3	0.26	0.54	<0.02	<1.0	4.3	8
20-30	8.5	0.5	6.52	4.6	0.18	1.5	0.26	4	3.1	-
40-50	9.3	1.2	18.7	10	0.21	6.4	1.7	8.9	1.6	-
60-70	9.2	2	24.5	14	0.23	7.2	2.5	10	1.9	-
80-90	8.8	3	23.7	12	0.32	8.2	3.2	14	1.5	-

Site 2

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.3	0.3	7.39	5.4	0.35	1.6	0.04	0.6	3.4	5
20-30	9.1	0.7	27.3	19	0.32	7.8	0.51	1.9	2.4	-
40-50	9.4	1	30	19	0.36	9.7	1.5	4.9	2	-
60-70	9.5	1.4	31.2	18	0.39	10	2.5	8	1.8	-
80-90	9.5	1.9	30.8	18	0.34	9.4	3.1	10	1.9	-

Site 4

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	5.83	4.3	0.54	0.98	0.03	0.5	4.4	15

Soil pH is neutral to alkaline in surface soils and very strongly alkaline at depth (pH>9). Saturated EC levels indicate low salinity to only slight salinity at depth (3dS/m). Surface CEC is very low (3.09-7.39 Meq/100g), reflecting the sandy texture of topsoils and an inherent low capacity to retain plant nutrients. CEC increases with depth and increasing clay content of subsoils to high levels (>30 Meq/100g). ESP indicates surface soils are non-sodic (<0.6%) and not prone to dispersion when wet. Subsoils are sodic to moderately sodic (≤14%) and although relatively benign in central Queensland coal mining terms, will be prone to dispersion and accelerated erosion if uncovered.

3.1.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	1	1	2	2	1	1	3	3	1	2	2	1

Rehabilitation Polygon 1 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitation/s making it marginally suited for cattle grazing and will require major inputs to ensure

sustainability and prevent land degradation. The key limitation/s to sustainable cattle grazing in this rehabilitation are: subsoil erosion risk (Eb4).

3.2 Rehabilitation Polygon 2

Rehabilitation Polygon 2 has a total area of 30.3ha and is located in A Pit, south of the Nogoia River. It was rehabilitated in three stages in 2004, 2006 and 2009, and the current land use is cattle grazing.

3.2.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
7	0649876,7397049	Detail	Upper slope	7%	Buffel grass	25cm	Tertiary	90cm
8	0650157,7396932	Check	Lower slope	10%	Buffel grass	35cm	Tertiary	45cm

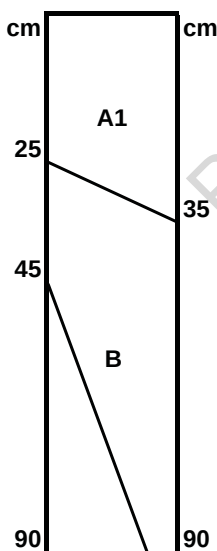
3.2.2 Representative photographs



Surface and vegetation condition at Site 7 (left and right)

3.2.3 Soil profile description

Profile photo is Site 7.



The **topsoil (A1)** is a brown (7.5YR4/4, Site 7) to black (7.5YR/2.5/1, Site 8) colour, sandy clay with a fine blocky/granular (free draining) structure; field pH 7.5 (Site 7) to 8.0 (Site 8). Clear change to:

The **subsoil (B)** is mine overburden of Tertiary age. Colour is variable from yellow brown (10YR5/4, 55cm depth, Site 7) to red brown (2.5YR5/4, 90cm depth, Site 7). Texture is sandy clay to clay, and structure is massive. Subsoil is alkaline, pH 8.0 (75cm depth, Site 7). Some gravel is present throughout and rock prohibited hand augering at Site 8 at 45cm. Where present, abrupt change to:

Substrate rock (B/C) is present from 45cm depth.



3.2.4 Laboratory analyses

Site 7

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.3	0.6	13.2	11	0.68	1.9	0.03	0.2	5.8	42
20-30	8.9	0.9	17.5	12	0.31	3.8	0.86	4.9	3.2	-
40-50	9.6	2.2	26.7	14	0.21	8.3	4	15	1.7	-
60-70	9.6	2.7	26.5	14	0.21	7.8	5	19	1.8	-
80-90	9.5	3.5	25.7	11	0.25	8.9	5.6	22	1.2	-

Site 8

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.8	31.1	25	0.65	5.5	0.08	0.3	4.5	15

Soil pH is alkaline to very strongly alkaline at depth (pH>9.5). Soil salinity is low to slightly saline at depth (3.5dS/m). Surface CEC is moderate to high throughout due to clay content, indicating soil has sufficient capacity to retain plant nutrients. Surface soil is non-dispersive but ESP increases with depth (22% at 80-90cm depth), indicating subsoil is highly dispersive and will be prone to excessive erosion if uncovered. Calcium levels are sufficient in surface soil but decline with depth. Magnesium levels increase with depth and this will exacerbate subsoil dispersion risk.

3.2.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	2	1	2	2	2	1	2	4	3	2	2	1

Rehabilitation Polygon 2 has a land suitability class of 4 for sustainable beef cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: subsoil erosion risk (Eb4) and strong soil alkalinity (Tx4).

3.3 Rehabilitation Polygon 3

Rehabilitation Polygon 3 has a total area of 26.25ha and was rehabilitated in three stages in 2004, 2007 and 2009. No post-mining land use has been established on this polygon. The following soils data was collected at an intense scale in 2017 for the verification of remote sensing vegetation data and has been repurposed here.

3.3.1 Sites

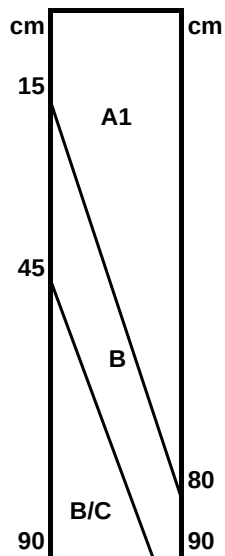
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
A1	650364,7397429	Detail	Upper slope	10%	Rhodes grass	15cm	Tertiary	90cm
A2	650388,7397439	Detail	Upper slope	10%	Rhodes grass	70cm	Permian	90cm
B1	650371,7397355	Detail	Upper slope	10%	Buffel grasses	60cm	Tertiary	60cm
B2	650343,7397344	Detail	Upper slope	10%	Buffel grasses	50cm	Tertiary	50cm
B3	650362,7397345	Detail	Upper slope	10%	Rhodes and buffel grasses	80cm	Tertiary	90cm
C1	650524,7397321	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Permian	45cm
C2	650532,7397329	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Tertiary	90cm
C3	650534,7397337	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Tertiary	50cm
D1	650476,7397274	Detail	Lower slope	10%	Buffel grass, Stylo spp.	20cm	Permian	45cm
D2	650466,7397284	Detail	Lower slope	10%	Buffel grass, minor legume	20cm	Permian	90cm
D3	650461,7397294	Detail	Lower slope	10%	Buffel grass, minor legume	15cm	Permian	90cm

3.3.2 Representative photographs



Surface and vegetation conditions at Sites A (left), Site B (centre) and Site D (right)

3.3.3 Soil profile description



The **topsoil (A1)** is a grey or brown colour sandy loam / clay loam, with weak blocky structure. No field pH was measured. Clear change to:

The **subsoil (B)** is either Permian or Tertiary age mine overburden. Texture is generally clay, and structure is blocky to massive. Where present, abrupt change to:

Substrate rock (B/C) is present from 45cm depth.

Profile photo is Site D2.



3.3.4 Laboratory analyses

Representative soil profile analyses follow.

Site A1

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.6	10.6	8.1	0.6	1.9	0.05	0.5	4.3	10
20-30	8.9	0.7	16	11	0.29	4	0.31	2	2.8	-
40-50	8.9	0.9	14.7	11	0.22	3.1	0.37	2.5	3.5	-
60-70	9.7	1.6	22.4	12	0.23	7.8	2.5	11	1.5	-
80-90	9.7	2.4	28	12	0.29	11	4.8	17	1.1	-

Site C2

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8	0.5	4.88	3	0.6	1.3	<0.02	<1.0	2.3	20
20-30	9.4	0.9	22.3	12	0.22	8.9	0.83	3.7	1.3	-
40-50	10.1	2.9	25	11	0.31	8.9	5.3	21	1.2	-
60-70	10.1	2.5	24.3	9.4	0.27	9.9	4.7	19	1	-
80-90	10.1	3	27	11	0.34	9.4	6.3	23	1.2	-

Site D2

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	5.68	4	0.63	1	<0.02	<1.0	4	25
20-30	8.6	0.6	11.5	8.7	0.28	2.4	0.12	1	3.6	-
40-50	9.7	1.5	25	11	0.29	11	2.3	9.3	1	-

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Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
60-70	10.1	2.9	26.2	10	0.34	10	5.7	22	1	-
80-90	10.1	3.1	25.7	11	0.32	9.1	5.6	22	1.2	-

Soil pH is alkaline to strongly alkaline at depth (pH>10). Saturated EC levels indicate low salinity to only slight salinity at depth (3.1dS/m). Topsoil CEC is low to very low (4.8-10.6Meq/100g) but increase to high levels in the clayey subsoil (>25Meq/100g). ESP indicates surface soil is non-sodic but subsoils are highly sodic and prone to dispersion and excessive erosion if uncovered. Calcium is deficient. Magnesium levels increase with depth exacerbating the subsoil erosion risk.

3.3.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	3	1	2	3	2	1	2	4	3	2	3	1

Rehabilitation Polygon 3 has a land suitability class of 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: subsoil erosion risk (Eb4) and very strong alkalinity (Tx4).

3.4 Rehabilitation Polygon 4

Rehabilitation Polygon 4 has a total area of 44.7ha and is located in A Pit, south of the Nogoia River. It was rehabilitated in 2017, and vegetation is in the establishment phase.

3.4.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
11	0650777,7397796	Detail	Upper slope	14%	Establishing pasture	15cm	Tertiary	90cm
14	0651062,7397406	Check	Lower slope	<14%	Establishing pasture	45cm	Tertiary	45cm
15	0651954,7397923	Check	Lower slope	5%	Establishing pasture	15cm	Permian	50cm

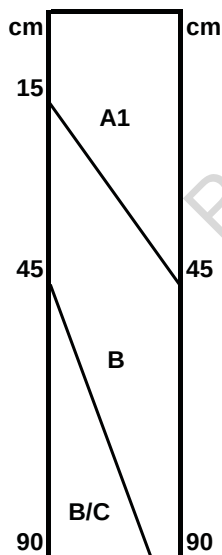
3.4.2 Representative photographs



Surface and vegetation condition at Site 11 (left) and Site 14 (right)

3.4.3 Soil profile description

Profile photo is Site 11.



The **topsoil (A1)** is a brown (7.5YR4/2, Site 11), very dark greyish brown (10YR3/2, Site 14) and dusky red (2.5YR3/2, Site 15), sandy loam to sandy clay, with a weakly blocky structure (highly permeable); field pH 8.0 (all sites). Clear change to:

The **subsoil (B)** is mine overburden, both Tertiary and Permian age. Texture is clay. Gravel is a feature throughout. Field pH is neutral (7.0, Site 11). Where present, abrupt change to:

Substrate rock (B/C) is present from 45cm depth.



3.4.4 Laboratory analyses

Site 11

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.8	1.4	26.5	18	0.61	6.1	1.6	6.1	3	10
20-30	8.7	1.6	16.7	12	0.38	3.7	1	6.2	3.2	-
40-50	8.7	2.2	16.5	9.3	0.3	5.4	1.5	9	1.7	-
60-70	8.3	2.4	13.5	6.7	0.22	5.3	1.3	9.5	1.3	-
80-90	8.3	2.2	13.5	6.7	0.26	5.3	1.2	9	1.3	-

Site 14

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.5	1.1	20.2	16	0.42	3	0.44	2.2	5.3	15

Site 15

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	1.1	29.8	21	0.78	7.3	0.68	2.3	2.9	27

Soil pH is strongly alkaline (8.5-8.8) to the extent that nutrient availability is reduced, e.g. phosphorus and trace elements. Soils are non-saline (<2.5dS/m). ESP indicates a propensity to dispersion when wet (>6, Site 11) but this is variable. CEC is moderate (20-26) in surface soils. The ratio of calcium to magnesium is low.

3.4.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	3	3	3	3	2	3	2	1	2	4	2	2	2	1

Rehabilitation Polygon 4 has a land suitability class of 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: topsoil erosion risk (Ea4); and, strong soil alkalinity (Tx4).

3.5 Rehabilitation Polygon 5

Rehabilitation Polygon 5 has a total area of 44.2ha and is located in A Pit, south of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010. Current land use is mine site rehabilitation.

3.5.1 Sites

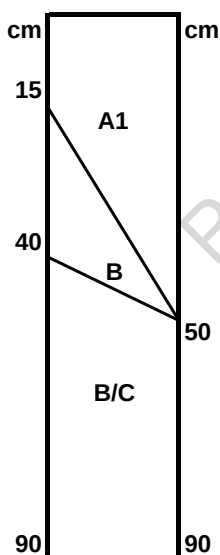
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
9	0650883,7397849	Check	Upper slope	<5%	Rhodes grass, Stylo spp.	50cm	Tertiary	50cm
10	0650789,7397929	Check	Upper slope	>10%	Rhodes grass, Stylo spp.	15cm	Tertiary	50cm
13	0651758,7398281	Check	Lower slope	<10%	Rhodes grass	20cm	Tertiary	40cm

3.5.2 Representative photographs



Surface and vegetation conditions at Site 9 (left), Site 10 (middle) and Site 13 (right)

3.5.3 Soil profile description



Profile photo is Site 10.

The **topsoil (A1)** is a yellowish brown (10YR5/6, Site 9), brown (7.5YR4/4, Site 10) to very dark grey (5YR3/1, Site 13), sandy clay with a weak blocky structure (free draining); field pH 7.5 (Sites 9 and 10) and 8.0 (Site 13). Clear change to:

The **subsoil (B)** is mine overburden of Tertiary age. Gravel throughout. Abrupt change to:

Substrate rock (B/C) is present from 40cm depth.



3.5.4 Laboratory analyses

Site 9

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.6	21.8	15	0.74	6.4	0.06	0.3	2.3	11

Site 10

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.7	0.7	16.4	14	0.32	2.2	0.1	0.6	6.4	8

Site 13

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.7	0.9	26.5	18	0.83	7.2	0.71	2.7	2.5	61

Topsoil pH is strongly alkaline (8.6-8.7) to the extent that nutrient availability is reduced, e.g. phosphorus and trace elements. Soil is non-saline and non-sodic. CEC is moderate to high indicating adequate capacity to hold nutrients, and the exchange surface is dominated by calcium. Soil phosphorus levels are adequate.

3.5.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	3	4	3	2	2	2	2	1	2	4	2	1	2	1

Rehabilitation Polygon 5 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: poor soil water holding capacity (M4); and, strong soil alkalinity (Tx4).

3.6 Rehabilitation Polygon 6

Rehabilitation Polygon 6 has a total area of 53.9ha and is located in B Pit, south of the Nogoia River. It was rehabilitated in 2017. This rehabilitation polygon was not assessed in this study.

3.7 Rehabilitation Polygon 7

Rehabilitation Polygon 7 is a 38.6ha area of rehabilitation in B Pit, south of the Nogoia River. Rehabilitation works were conducted in 2003 and no post-mining land use has been established to date.

3.7.1 Sites

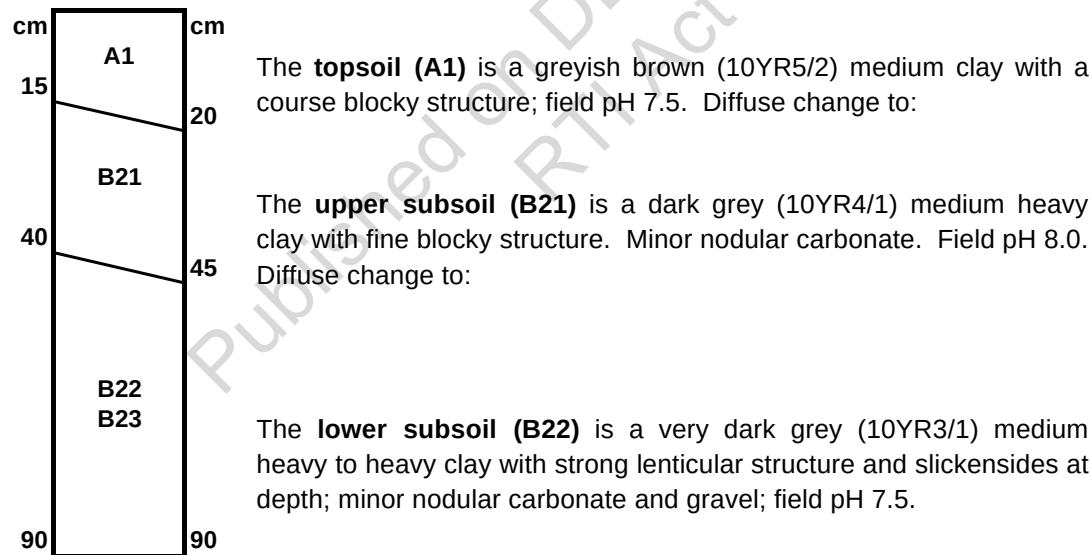
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
19	0652453,7398431	Detail	Flat	<2%	Eucalypt and Acacia over storey with mixed grass groundcover	15cm	None	90cm

3.7.2 Representative photographs



Surface and vegetation condition at Site 19

3.7.3 Soil profile description



This soil profile has not been disturbed by mining, at least not in any significant way. This soil is a Vertosol (Isbell, 1996) and likely a variant of the Adelong AMU as described by Bourne and Tuck (1993) with the following characteristics:

- Alluvial plains with slopes <1%
- Low to very high P
- Surface pH 7.5 tending alkaline at depth
- Saline and sodic at depth

- Very high PAWC and imperfectly drained

3.7.4 Laboratory analyses

Site 19

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.9	1.1	33.8	20	0.84	11	2	6	1.8	21
20-30	8.8	2.1	35.2	17	0.74	13	5.1	14	1.3	-
40-50	8.5	6.6	39.8	20	0.77	13	6.6	17	1.5	-
60-70	8.5	7.7	39	21	0.64	12	6.3	16	1.8	-
80-90	8.3	8.6	38.4	21	0.66	11	5.8	15	1.9	-

Soil pH is strongly alkaline throughout (8.3-8.9) to the extent that nutrient availability is reduced, e.g. phosphorus and trace elements. Salinity is moderate to high (>8dS/m) at depth, which will restrict rooting depth of some plant species. CEC is high (>25). Topsoil (A1) is marginally sodic but below 20cm depth subsoils are highly sodic. This soil is prone to dispersion and erosion. Phosphorus level is adequate.

3.7.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	1	3	1	2	1	2	3	2	1	1	4	1	3	2	1

Rehabilitation Polygon 7 is land suitability class 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: strongly alkaline soil conditions (Tx4).

3.8 Rehabilitation Polygon 8

Rehabilitation Polygon 8 has a total area of 64.45ha and is located in B Pit, south of the Nogoa River. It was rehabilitated in two stages in 2009 and 2010, and the current land use is mine rehabilitation.

3.8.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
18	0652132,7398684	Detail	Lower slope	<1%	Rhodes grass, Stylo spp.	50cm	Permian	90cm
20	0652867,7399723	Detail	Lower slope	<2%	Mixed grass spp., Acacia salicina	20cm	None	90cm
21	0652569,7400034	Detail	Lower slope	<5%	Rhodes and Buffel grass	40cm	Tertiary	90cm

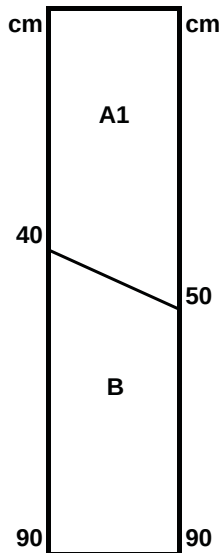
Site 20 is an intact soil profile that has not been disturbed by mining. It is not representative of the rehabilitation polygon, which is predominantly an elevated overburden emplacement, and for that reason it is not included in the assessment following.

3.8.2 Representative photographs



Surface and vegetation conditions at Site 18 (left) and Site 21 (right)

3.8.3 Soil profile description



Profile photo is Site 21.

The **topsoil (A1)** is a yellowish brown (10YR5/4) to dark brown (10YR3/3) light clay with a fine blocky structure; field pH 6.5 to 8.0. Clear change to:

The **subsoil (B)** is mine overburden of Permian and Tertiary age. It is a grey (5YR6/1, Site 21) gravelling clay to a dark grey gravel (Site 18).



3.8.4 Laboratory analyses

Site 18

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9	0.7	20.2	11	0.49	7.5	0.91	4.5	1.5	12
20-30	9.4	1.6	21.3	10	0.39	7.7	2.9	14	1.3	-
40-50	9.2	3.2	22.3	9.7	0.38	8	4.1	18	1.2	-
60-70	8.6	6.6	27	14	0.45	8.5	4.2	15	1.6	-
80-90	8.7	5.5	24.9	13	0.42	8.2	3.6	14	1.6	-

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Site 21

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.9	1.4	37.5	23	0.66	11	2.1	5.6	2.1	18
20-30	8.9	1.9	33.2	19	0.57	10	2.8	8.4	1.9	-
40-50	8.8	2.9	26.9	14	0.46	9.9	2.3	8.7	1.4	-
60-70	9.3	3.3	29.9	13	0.36	14	2.7	9	0.9	-
80-90	9.2	3.2	29	13	0.41	13	2.5	8.7	1	-

The topsoil (A1) is strongly alkaline (8.9-9.4) to the extent that the availability of plant nutrients is significantly affected. At pH 9, the availability of nitrogen, phosphorus, base cations and micronutrients to plants is limited. Topsoil is non-saline and extremely sodic (18%) in the lower fraction of the horizon. Dispersion and accelerated erosion is a risk. The subsoil (B) is similarly highly alkaline, non-saline and highly sodic, and has a similar dispersion and erosion risk.

3.8.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	3	3	3	3	2	2	3	2	1	2	4	3	2	2	1

Rehabilitation Polygon 8 is land suitability class 4 for sustainable beef cattle production. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: strongly alkaline soil conditions (Tx4).

3.9 Rehabilitation Polygon 9

Rehabilitation Polygon 9 has a total area of 28.1ha and is located in B Pit, south of the Nogo River. It was rehabilitated in 2009, and the current land use is mine rehabilitation.

3.9.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Soil depth	Spoil type	Hole depth
16	0651711,7399071	Check	Top of dump	<2%	Rhodes and Buffel grass, Aacia Salicina	25cm	Tertiary	25cm
17	0651854,7398899	Detail	Top of dump	5%	Rhodes and Buffel grass, Stylo spp.	10cm	Quaternary	50cm

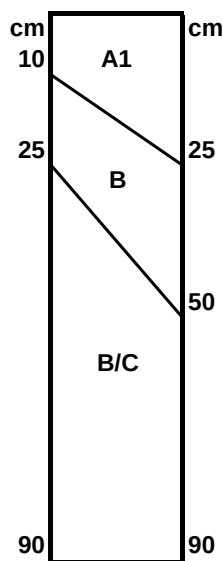
3.9.2 Representative photographs



Vegetation and surface conditions at Site 16 (left) and Site 17 (right)

3.9.3 Soil profile description

Profile photo is Site 17.



The **topsoil (A1)** is a brown (7.5YR4/3, Site 16) to very dark grey (10YR3/1) coloured, fine blocky structured light clay; field pH 7.5 (both). Clear change to:

The **subsoil (B)** is Tertiary age mine overburden. Texture is sand. Gravel and rock is present.

Substrate rock (B/C) is present from 25cm depth.



3.9.4 Laboratory analyses

Site 16

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.1	1.1	36.5	23	0.8	11	2	5.5	2.1	13

Site 17

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	1.6	36.3	22	1.1	12	1	2.8	1.8	23
20-30	9.5	1.1	7.86	4.5	0.14	2.7	0.48	6.1	1.7	-
40-50	9.5	1.0	6.67	3.7	0.11	2.4	0.43	6.4	1.5	-

The topsoil is strongly to very strongly alkaline (pH8.6-9.1) to the extent that the availability of plant nutrients is significantly affected. At pH 9, the availability of nitrogen, phosphorus, base cations and micronutrients is limited. Soil is non-saline (<2dS/m) throughout and only slightly sodic at depth. CEC in topsoil is high but low in subsoil due to its sandy texture. Calcium is deficient and phosphorus levels are adequate.

3.9.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	2	4	3	2	1	1	2	1	2	4	3	1	2	1

Rehabilitation Polygon 9 is land suitability class 4 for sustainable beef cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: poor soil water holding capacity (M4) and strongly alkaline soil conditions (Tx4).

3.10 Rehabilitation Polygon 10

Rehabilitation Polygon 10 has a total area of 40.3ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in 2007, and the current land use is mine rehabilitation.

3.10.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
49	0653259,7403419	Detail	Lower slope	5%	Buffel grass	10cm	Tertiary	55cm

3.10.2 Representative photographs



Surface and vegetation condition at Site 49

3.10.3 Soil profile description

cm 10	A1	cm 10	The topsoil (A1) is very dark greyish brown (10YR3/2), medium clay with a fine blocky structure; field pH is 8.0. Diffuse change to:
	A2		The subsurface layer (A2) is conspicuously bleached, grey or light brown, gravelly coarse sand with massive or single grain structure. Abrupt change to:
30	B	30	The subsoil (B) is grey, gravelly coarse sandy clay; massive. Abrupt change to:
55	B/C	55	Substrate rock (B/C) is present from 55cm depth.
90		90	



3.10.4 Laboratory analyses

Site 49

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.9	1.1	22.2	9.6	0.86	9.6	2.2	9.9	1	12
20-30	9.3	0.6	16.4	3	0.26	9.1	4	24	0.3	-
40-50	9.3	1.4	17	3.1	0.27	9.2	4.5	26	0.3	-

This soil is strongly to very strongly alkaline (pH8.9-9.3). CEC levels decline with depth reflecting the clay content of the material. Soil is non-saline but ESP is high to extremely high and reflects the dominance of sodium and magnesium on the exchange, and calcium deficiency. Phosphorus level is adequate, albeit unavailable to plants at this pH.

3.10.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	4	4	3	2	2	2	1	2	4	3	1	2	1

Rehabilitation Polygon 10 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: high topsoil and subsoil erosion risk (Ea4 and Eb4); poor soil water holding capacity (M4); hardsetting and massive soil surface conditions (Ps4); and, strongly alkaline soil conditions (Tx4).

3.11 Rehabilitation Polygon 11

Rehabilitation Polygon 11 has a total area of 54.6ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in 2007, and the current land use mine rehabilitation. Cattle have never grazed this rehabilitation.

3.11.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
30	0652872,7403840	Check	Upper slope	<10%	Buffel grass	n/a	Tertiary	20cm
31	0653158,7404778	Detail	Upper slope	<10%	Buffel and Rhodes grasses	20cm	Tertiary	60cm

3.11.2 Representative photographs



Surface and vegetation condition at Site 31

3.11.3 Soil profile description

cm		cm	
	A1		
20		20	The topsoil (A1) is brown (7.5YR4/3) medium clay with fine blocky structure; gravelly; field pH 7.5-8.0. Abrupt change to:
	B		
60		60	The subsoil (B) is gravelly, coarse sanding clay; massive; field pH8. Abrupt change to:
	B/C		
90		90	Substrate rock (B/C) is present from 60cm depth.

Profile photo is Site 31.



3.11.4 Laboratory analyses

Site 30

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.7	17.2	11	1.5	4.8	0.09	0.5	2.3	61

Site 31

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.4	1.0	31.6	23	0.85	7.1	0.27	0.9	3.2	13
20-30	8.7	1.1	28.8	21	0.49	6.6	1	3.5	3.2	
40-50	9.1	1.5	31.4	21	0.42	7.9	2.4	7.7	2.7	

pH in topsoil is alkaline and subsoil is very strongly alkaline. EC indicates low salinity to 50cm depth. CEC is moderate (17.2) to high (>28.8), indicating the capacity of the soil to hold and exchange cations important in

plant fertility. Calcium is low with a Ca/Mg ratio less than 4. Topsoil is non-sodic but subsoil is weak to moderately sodic. Phosphorus levels are adequate for pasture nutrition.

3.11.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	3	4	3	3	2	2	2	1	2	3	3	1	2	1

Rehabilitation Polygon 11 is land suitability class 4 for sustainable beef cattle grazing. This rehabilitation has moderate limitation/s that will require significant inputs to ensure sustainability and prevent land degradation following instatement of grazing land use. The key limitation/s to sustainable cattle grazing in this rehabilitation are: poor soil water holding capacity (M4).

3.12 Rehabilitation Polygon 12

Rehabilitation Polygon 12 has a total area of 46ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in 2010, and the current land use is mine rehabilitation.

3.12.1 Sites

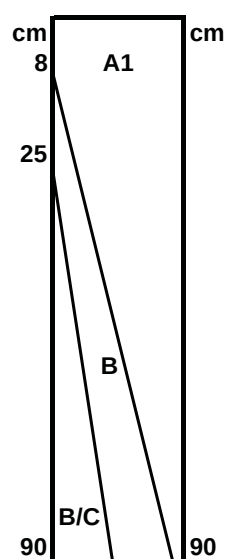
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
27	0652384,7404515	Check	Top of landform	<2%	Rhodes grass	n/a	n/a	35cm
28	0652543,7403871	Check	Top of landform	<2%	Buffel and Rhodes grasses, A. salicina	8cm	Permian	25cm
29	0652762,7403838	Detail	Top of landform	≈2%	Buffel and Rhodes grasses, A. salicina	90cm	None	90cm

3.12.2 Representative photographs



Surface and vegetation conditions at Site 28 (left) and Site 29 (right)

3.12.3 Soil profile description



Profile photo is Site 28.

The **topsoil (A1)** is grey (7.5YR5/1, Site 28) to brown (7.5YR4/2, Sites 27 and 29) clay with a fine blocky structure (lenticular at depth, Site 29); field pH 8.0-8.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian age; gravelly clay; contains rocks. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.



3.12.4 Laboratory analyses

Site 27

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.1	1.3	34.7	22	0.79	9.8	2.4	6.9	2.2	18
20-30	9.4	1.2	26.8	16	0.57	8.3	2.4	9	1.9	-

Site 28

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.8	1.4	29.7	18	0.7	8.4	2.1	7	2.1	17

Site 29

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.0	2.7	35.4	20	0.73	10	4.2	12	2.0	22
20-30	8.2	12.2	42.1	23	0.7	11	7	17	2.1	-
40-50	8	20.7	52.8	29	0.75	13	10	19	2.2	-
60-70	8.1	17.2	49.2	23	0.84	14	11	23	1.6	-
80-90	8	17.9	49.4	24	0.77	14	11	22	1.7	-

Surface soil pH is strongly to very strongly alkaline throughout and nutrient availability is limited at these levels (pH>8.5). EC analysis indicates low levels of soluble salts (<3dS/m) in surface fractions, but extreme salinity (>16dS/m) below this. Extreme salinity (Site 29) and rockiness (Sites 27 and 28) restricts the effective root zone and soil water holding capacity. CEC is high throughout due to high clay content. ESP indicates sodicity throughout, increasing to extreme sodicity at depth, meaning this high clay soil will be prone to dispersion when wet and accelerated erosion. Calcium levels are low. Phosphorus levels are adequate, however unavailable to plants are these high pH levels. Plant nutrient deficiency is likely.

3.12.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	5	3	3	2	3	2	1	2	4	3	4	2	1

Rehabilitation Polygon 12 is land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that make it unsuitable to sustained cattle grazing. The key limitation to sustainable cattle grazing in this rehabilitation is: soil water holding capacity (M5) due to near surface extreme salinity.

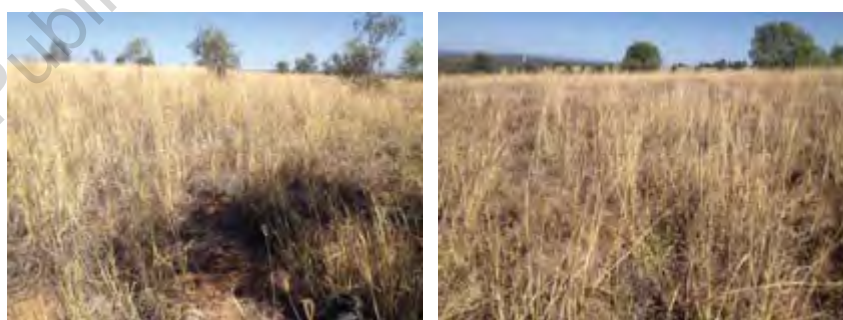
3.13 Rehabilitation Polygon 13

Rehabilitation Polygon 13 has a total area of 50.6ha and is located in C Pit, north of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010, and the current land use is mine rehabilitation.

3.13.1 Sites

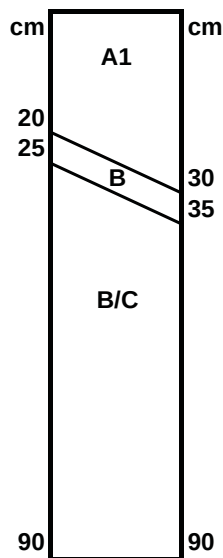
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
23	0652477,7405571	Check	Top of landform	<5%	Rhodes and Buffel grasses	20cm	n/a	25cm
24	0652610,7405563	Detail	Upper slope	5%	Rhodes and Buffel grasses	30cm	Permian	35cm
25	0652776,7404885	Check	Upper slope	<10%	Rhodes and Buffel grasses; Acacia salicina	n/a	n/a	20cm
26	0652961,7404888	Check	Lower slope	10%	Rhodes and Buffel grasses	n/a	n/a	20cm

3.13.2 Representative photographs



Surface and vegetation condition at Site 23 (left) and Site 24 (right)

3.13.3 Soil profile description



Profile photo is Site 24.

The **topsoil (A1)** is brown (7.5YR5/4) to reddish brown (5YR4/4) light clay with a weak sub-angular blocky to massive structure; field pH is 8.0-8.5. Clear change to:

The **subsoil (B)**, where present, is mine overburden of Permian age; gravelly clay with rock present; massive. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.



3.13.4 Laboratory analyses

Site 23

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.3	1.5	29.8	18	0.34	8.6	2.7	8.9	2.1	6

Site 24

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	0.7	25.7	21	0.51	3.8	0.16	0.6	5.5	<5
10-20	8.7	0.8	19.3	14	0.36	4.2	0.48	2.5	3.3	-

Site 25

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	9.0	1.2	32.4	21	0.68	9.2	1.6	5.1	2.3	10

Site 26

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.5	0.9	24.7	16	1.1	7.1	0.46	1.9	2.3	38

Soil is strongly alkaline (8.5) to very strongly alkaline (pH>9) and nutrient availability is limited at these levels. Soil is non-saline and generally non-sodic, though Site 23 is moderately sodic. CEC is moderate to high indicating an adequate capability to hold and exchange cations important in plant nutrition. Soil phosphorus levels are generally below that required for productive and resilient grazing pastures. Effective rooting depth is shallow (each <35cm) due to rock and this will severely limit soil water storage capacity.

3.13.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	3	4	4	3	2	3	2	1	4	4	3	2	2	1

Rehabilitation Polygon 13 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: low soil water storage (M4); hardsetting massive topsoil (Ps4); low soil nutrients (Nd4); and very strong alkalinity leading to elemental imbalance (Tx4).

3.14 Rehabilitation Polygon 14

Rehabilitation Polygon 14 has a total area of 97ha and is located in D Pit, north of the Nogoia River. It was rehabilitated in two stages in 2007 and 2010, and the current land use is mine rehabilitation.

3.14.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
32	0652940,7406713	Check	Mid slope	10%	Rhodes and Buffel grass	30cm	n/a	30cm
33	0652966,7406710	Check	Mid slope	10%	Rhodes and Buffel grass	30cm	n/a	30cm
34	0653015,7406321	Check	Lower slope	10%	Rhodes and Buffel grass	10cm	n/a	10cm
34b	0652725,7407118	Detail	Top of landform	<10%	Rhodes and Buffel grass	5cm	Tertiary	50cm

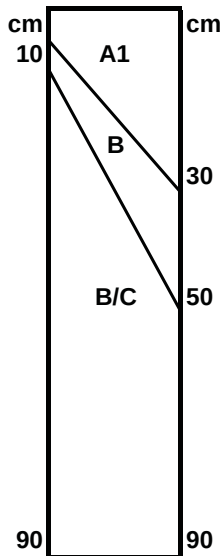
3.14.2 Representative photographs



Surface and vegetation conditions at Site 32 (left), Site 33 (middle) and Site 34b (right)

3.14.3 Soil profile description

Profile photo is Site 34b.



The **topsoil (A)** is a brown (7.5YR4/3, 7.5YR4/4) to dark brown (7.5YR3/3), clay loam with a sub-angular blocky to massive structure; field pH is 7.0 to 8.5. Clear change to:

The **subsoil (B)**, where present, is mine overburden of Tertiary age; very gravelly clay with rock present, massive. Abrupt change to:

Substrate rock (B/C) is present from 10cm depth.

Profiles varied in depth from 10cm to 50cm, with each limited by rock.



3.14.4 Laboratory analyses

Site 32

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	16.3	11	1.2	4.3	0.09	0.5	2.6	59
20-30	8.1	0.6	16.6	11	0.56	4.3	0.25	1.5	2.6	-

Site 33

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.4	0.6	15.5	8.3	0.72	5.8	0.65	4.2	1.4	18
20-30	8.6	0.7	16.1	8.4	0.56	5.8	1.3	8.0	1.4	-

Site 34

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.9	0.5	16.0	9.5	0.81	5.3	0.38	2.4	1.8	25

Site 34b

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.5	0.9	30.5	23	0.79	6.3	0.32	1.1	3.7	14
20-30	9.5	1.5	32.8	18	0.35	12	2.9	8.7	1.5	-
40-50	9.7	1.9	33.7	17	0.35	12	4.4	13	1.4	-

The topsoil (A1) is alkaline and beneath this the subsoil (B) is very strongly alkaline. Nutrient availability is limited at these levels. Profiles are non-saline but sodic at depth (ESP>8). CEC is moderate to high,

indicating a capacity to hold and exchange cations important for plant nutrition. Calcium levels are low but phosphorus levels are adequate.

3.14.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	3	4	4	4	3	2	3	2	1	2	4	3	1	2	1

Rehabilitation Polygon 14 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: high subsoil erosion risk (Eb4); low soil water holding capacity (M4); hardsetting, crusting and massive topsoils (Ps4); and, very strongly alkaline conditions (Tx4).

3.15 Rehabilitation Polygon 15

Rehabilitation Polygon 15 has a total area of 11ha and is located in F Pit, north of the Nogoia River. It was rehabilitated in two stages in 2009 and 2010, and the current land use mine rehabilitation.

3.15.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
35	0654145,7408677	Detail	Lower slope	<10%	Buffel and Rhodes grasses	25cm	Permian	90cm
36	0653880,7408450	Check	Lower slope	<10%	Buffel and Rhodes grasses	35cm	n/a	35cm

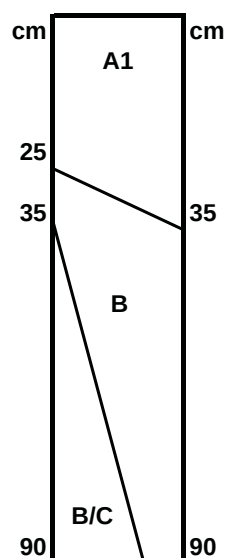
3.15.2 Representative photographs



Surface and vegetation condition at Site 35 (left) and Site 36 (right)

3.15.3 Soil profile description

Profile photo is Site 35.



The **topsoil (A1)** is a reddish brown (5RY4/3) to dark reddish brown (5YR3/2) colour, sandy loam with a sub-angular blocky structure; minor gravel; field pH is 7.0 to 7.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian age; bluish grey (GLE2 6/10B) colour; field pH 8.5. Abrupt change to:

Substrate rock (B/C) is present from 35cm depth.



3.15.4 Laboratory analyses

Site 35

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	8.6	1	29.3	23	0.65	5.4	0.58	2	4.3	6
20-30	9.4	2	29.1	17	0.43	8.1	3.5	12	2.1	-
40-50	9.8	3.7	22.3	8.1	0.37	7.4	6.5	29	1.1	-
60-70	9.7	4.1	23.7	9.2	0.44	7.1	6.9	29	1.3	-
80-90	9.7	5.2	22.9	8.1	0.4	7	7.4	32	1.2	-

Site 36

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.1	0.7	15.2	7.6	1.2	6	0.35	2.3	1.3	35

The topsoil (A1) is neutral to strongly alkaline (7.1-8.6) and subsoil (B) is very strongly alkaline (9.4-9.8). Nutrient availability is limited at these levels. ECe shows topsoil is non-saline and subsoil grades with depth from slightly (2dS/m) to moderately saline (5.2dS/m). CEC indicates a moderate capacity to hold and exchange cations important for plant nutrition. Topsoil is non-sodic but subsoil is extremely sodic and will be prone to dispersion when wet and accelerated erosion if uncovered. Calcium levels are low, particularly in subsoils. Phosphorus levels are variable, low to high.

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

3.15.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	3	4	4	4	3	2	3	2	1	3	4	3	3	2	1

Rehabilitation Polygon 15 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: high subsoil erosion risk (Eb4); low soil water holding capacity (M4); hardsetting, crusting and massive topsoils (Ps4); and, very strongly alkaline conditions (Tx4).

3.16 Rehabilitation Polygon 16

Rehabilitation Polygon 16 has a total area of 27ha and is located in F Pit, north of the Nogoia River. It was rehabilitated in 2013, and the current land use is mine rehabilitation.

3.16.1 Sites

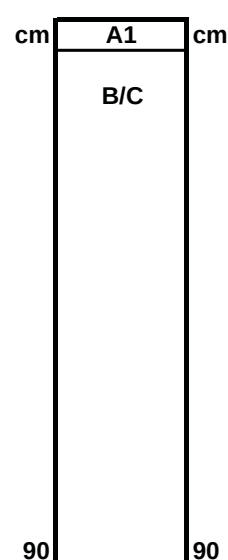
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
37	06514018,7409028	Check	Elevated	<10%	Buffel grass and woody regrowth	n/a	n/a	15cm

3.16.2 Representative photographs



Surface and vegetation condition at Site 37

3.16.3 Soil profile description



Profile photo is Site 37.

The **topsoil (A1)** is a brown (7.5YR5/3) loamy sand (medium to coarse sand fraction) with massive single grain fabric; field pH is 6.0.

Hole could not be hand augered deeper than 15cm due to gravelly stones at this depth.



3.16.4 Laboratory analyses

Site 37

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.3	0.2	4.81	3.3	0.32	1	0.04	0.7	3.3	6

Topsoil (A1) is slightly acid, non-saline and non-sodic. CEC is low due to sand fraction. Ca and P are deficient. Profile has a very shallow rooting depth and very low soil water holding capacity.

3.16.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	2	4	4	4	2	2	2	1	3	2	4	1	3	1

Rehabilitation Polygon 16 is land suitability class 4 for sustainable beef cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: low soil water holding capacity (M4); hardsetting, crusting and massive topsoil (Ps4); high stone content (R4); and, very shallow soil (Sd4).

3.17 Rehabilitation Polygon 17

Rehabilitation Polygon 17 has a total area of 39ha and is located in Y Pit, north of the Nogo River. It was rehabilitated in two stages in 2007 and 2009, and the current land use is mine rehabilitation.

3.17.1 Sites

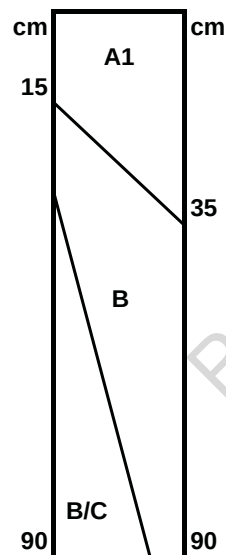
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
38	0654511,7413018	Check	Upper slope	<10%	Rhodes grass	30cm	n/a	30cm
39	0654538,7413113	Detail	Upper slope	<10%	Rhodes grass, Acacia salicina	35cm	Permian	90cm
40	0654964,7415367	Detail	Lower slope	<10%	Rhodes grass	15cm	Tertiary	90cm

3.17.2 Representative photographs



Surface and vegetation condition at Site 38 (left), Site 39 (middle) and Site 40 (right)

3.17.3 Soil profile description



The **topsoil (A1)** is a brown (7.5YR4/3, 7.5YR4/4, 10YR4/3) sandy loam with a fine subangular blocky structure; field pH is 7.0-7.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian age; bluish grey (GLE Y2 6/10B) colour; mudstone/shale fragments present; field pH 8.5. Abrupt change to:

Substrate rock (B/C) is present from 35cm depth.

Profile photo is Site 39.



3.17.4 Laboratory analyses

Site 38

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.2	0.6	10.3	6	1.2	2.9	0.23	2.3	2.1	20
20-30	7.5	0.5	12.2	7.3	0.56	3.9	0.46	3.8	1.9	-

SUITABILITY OF REHABILITATION FOR SUSTAINABLE CATTLE GRAZING

Site 39

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	7.8	0.6	11.6	7.5	0.77	2.9	0.43	3.7	2.6	23
20-30	8.2	0.6	10.4	6.6	0.29	2.7	0.86	8.2	2.4	-
40-50	9.2	2	18.7	8.1	0.27	7.2	3.1	17	1.1	-
60-70	9.5	3.6	26.7	12	0.4	10	4.9	18	1.2	-
80-90	9.6	3.5	19.1	4.1	0.46	9.7	4.8	25	0.4	-

Site 40

Depth	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.8	0.6	8.34	4.3	0.66	2.7	0.62	7.4	1.6	5
20-30	8.8	1.8	16.1	7.9	0.37	5.9	2	12	1.3	-
40-50	9.4	3.1	19.8	8.7	0.35	6.9	3.9	20	1.3	-
60-70	9.1	3.6	13.1	4.7	0.22	4.5	3.7	28	1	-
80-90	7.6	3	5.63	0.5	0.09	2.5	2.6	46	0.2	-

The topsoil (A1) is neutral (6.8) to alkaline (8.2) and is non-saline (0.6dS/m). CEC is low indicating a low capacity to hold and exchange cations important in plant nutrition. ESP indicates topsoil is non-sodic to sodic (7.4%). Calcium is low. Levels of phosphorus are variable from deficient (5mg/kg) to adequate (20-23mg/kg).

The subsoil (B) is strongly to very strongly alkaline, slightly saline and extremely dispersive (ESP 46%). The dominance of magnesium on the CEC at depth will add to the dispersion risk. This material will be prone to dispersion when wet and excessive erosion is uncovered.

3.17.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	3	3	3	2	3	2	1	3	3	3	2	2	1

Rehabilitation Polygon 17 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitation/s to sustainable cattle grazing in this rehabilitation is: subsoil erosion risk (Eb4).

3.18 Rehabilitation Polygon 18

Rehabilitation Polygon 18 has a total area of 94ha and is located in Y Pit, north of the Nogo River. It was rehabilitated in two stages in 2007 and 2009, and the current land use is cattle grazing.

3.18.1 Sites

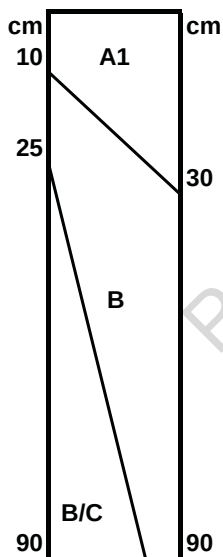
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
41	654825,7415673	Detail	Upper slope	<10%	Rhodes grass	30cm	Permian	90cm
42	654822,7416618	Detail	Upper slope	<10%	Rhodes grass	25cm	Tertiary	90cm
47	0654373,7417118	Check	Mid slope	<10%	Rhodes grass, Acacia spp.	25cm	n/a	25cm
48	0653259,7403419	Check	Lower slope	<5%	Buffel grass, Acacia spp.	10cm	Tertiary	35cm

3.18.2 Representative photographs



Surface and vegetation conditions at Site 41 (left), Site 47 (middle) and Site 48 (right)

3.18.3 Soil profile description



The **topsoil (A1)** is a reddish brown (5YR4/3, 5YR4/4) to strong brown (7.5YR4/6) loamy sand with a fine sub-angular blocky structure; field pH is 6.0-6.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian or Tertiary age; rock is present; mottles below 70cm; field pH 7.0-7.5. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.

Profile photo is Site 42.



3.18.4 Laboratory analyses

Site 41

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	2.4	6.71	2.7	0.53	2.4	0.97	14	1.1	<5
20-30	5.7	2.4	7.24	2.1	0.25	3.6	1.2	17	0.6	
40-50	7	3.7	14.7	3	0.45	8.6	2.6	17	0.4	
60-70	7.8	4.7	14	2.9	0.47	7.9	2.6	19	0.4	
80-90	7.6	4.2	13.6	2.7	0.48	7.9	2.4	18	0.3	

Site 42

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	1.4	5.35	2	0.75	1.6	0.77	14	1.3	<5
20-30	5.5	1.4	5.02	1.1	0.28	2.1	1.2	23	0.5	
40-50	6.9	2	6.93	1.3	0.16	3.7	1.8	26	0.4	
60-70	7	2.6	12.4	2.2	0.3	6.9	3.1	25	0.3	
80-90	7.2	2.3	11.1	2.3	0.22	5.9	2.7	24	0.4	

Site 47

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.7	0.4	4.69	1.9	0.63	1.7	0.19	4.1	1.1	<5

Site 48

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.9	1.1	5.19	1.6	0.26	2.2	1	20	0.7	9

Soil pH is moderately acid (5.5) grading to neutral and mildly alkaline at depth (7.8). Topsoil is non-saline but subsoil can be moderately saline (4.7dS/m). CEC low to very low, indicating the capacity of the soil to hold and exchange cations important in plant nutrition. ESP shows topsoil is non-sodic to extremely sodic (20%) and subsoil is extremely sodic (26%), meaning soil is prone to dispersion when wet and excessive erosion. Low calcium and a prevalence of magnesium on the exchange surfaces will exacerbate dispersion and erosion risk. Phosphorus is deficient in this soil.

3.18.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	4	3	3	2	3	2	1	4	3	3	2	2	1

Rehabilitation Polygon 18 is land suitability class 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: topsoil and subsoil erosion risk (Ea4 and Eb4), poor soil water holding capacity (M4); and nutrient deficiency (Nd4).

3.19 Rehabilitation Polygon 19

Rehabilitation Polygon 19 has a total area of 17ha and is located in Y Pit, north of the Nogoia River. It was rehabilitated in 2011, and the current land use is mine rehabilitation.

3.19.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
44	0653980,7416682	Detail	Slope	<5%	Rhodes grass	25cm	Permian Tertiary	90cm

3.19.2 Representative photographs



Surface and vegetation condition at Site 44

3.19.3 Soil profile description

Profile photo is Site 44.

cm	A1	cm	
25		25	The topsoil (A1) is reddish brown (5YR4/3) sandy loam with a massive/single grain fabric; field pH is 6.0. Clear change to:
40	B1	40	The upper subsoil (B1) is mine overburden of Permian age; gravelly, light clay loam with a massive or weak blocky structure; field pH is 6.0. Clear change to:
	B2		The lower subsoil (B2) is mine overburden of Tertiary age; sandy clay with a strongly blocky structure; field pH is 7.0.
90		90	



3.19.4 Laboratory analyses

Site 44

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.4	1.2	5.79	2.4	0.55	1.9	0.67	12	1.3	6
20-30	5.3	3	6.64	1.5	0.28	2.7	2	30	0.6	-
40-50	5.7	4.6	10.6	0.98	0.32	5	4.3	40	0.2	-
60-70	6.6	5	12.3	1.1	0.41	5.7	5	41	0.2	-
80-90	6.9	5.3	13.1	1.1	0.41	6.1	5.4	41	0.2	-

The topsoil (A1) is strongly acid (pH5.3-5.4). This pH is suboptimal for pasture growth and aluminium toxicity may be a problem for some species. The profile is moderately saline below 40cm. This will affect the growth of some species by limiting rooting depth. CEC indicates soil has a low capacity to hold and exchange cations important in plant nutrition. Soil is highly sodic to extremely sodic (ESP 41%) at depth and will be prone to dispersion when wet and excessive erosion. Magnesium dominates the exchange and this will add to the dispersion and erosion risk. Calcium and phosphorus are deficient.

3.19.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	4	5	4	2	2	3	2	1	3	3	3	3	2	1

Rehabilitation Polygon 19 is land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that make it unsuitable to sustained cattle grazing. The key limitation to sustainable cattle grazing in this rehabilitation is: soil water holding capacity (M5) due to near surface extreme sodicity.

3.20 Rehabilitation Polygon 20

Rehabilitation Polygon 20 has a total area of 25.3ha and is located in Y Pit, north of the Nogoia River. It was rehabilitated in 2015, and the current land use is mine rehabilitation. Cattle have never grazed this rehabilitation.

3.20.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
43	0653995,7416598	Detail	Natural surface	<10%	Rhodes grass, Acacia spp.	10cm	n/a	90cm
46	0654038,7417373	Obs.	Natural surface	<5%	Very little groundcover	n/a	n/a	n/a

3.20.2 Representative photographs



Surface and vegetation conditions at Site 43

3.20.3 Soil profile description

cm		cm
10	A1	10
	B1	
30		30
	B2	
90		90

Profile photo is Site 43.

The **topsoil (A1)** is a reddish brown (5YR4/4) sandy loam to sandy clay loam with a massive structure; field pH 6.5. Clear change to:

The **upper subsoil (B1)** is a light brown (7.5YR7/4 - 7.5YR6/4) sandy clay loam with a massive structure; field pH 6.0. Diffuse change to:

The **lower subsoil (B2)** is a light brown (7.5YR6/4) sandy clay loam with massive structure.

According to the Australian Soil Classification (Isbell, 1996) this soil is a Brown Kandosol.



3.20.4 Laboratory analyses

Site 43

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	10.9	13.7	2.6	0.48	4.5	6	44	0.6	<5
20-30	4.7	3.9	5.96	0.45	0.14	2.5	2.7	45	0.2	
40-50	4.5	4.4	7	0.28	0.17	2.9	3.3	48	0.1	
60-70	4.6	4.4	7.41	0.29	0.17	3.1	3.5	47	0.1	
80-90	4.7	4	7.32	0.29	0.18	3.1	3.3	46	0.1	

This soil is strongly acid to very strongly acid at depth. Topsoil is highly saline while subsoil is moderately saline. CEC is low and the exchange is dominated by sodium (ESP >40) and magnesium. This soil is inherently highly dispersive when wet and prone to excessive erosion if disturbed. Calcium and phosphorus are deficient.

3.20.5 Land suitability class

Limitation	Surface soil erodability	Subsoil erodability	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	5	4	2	2	3	2	1	4	4	1	4	2	1

Rehabilitation Polygon 20 is land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that make it unsuitable to sustained cattle grazing. The key limitation to sustainable cattle grazing in this rehabilitation is: soil water holding capacity (M5) due to near surface extreme salinity and sodicity.

3.21 Rehabilitation Polygon 21

Rehabilitation Polygon 21 has a total area of 13ha and is located in Y Pit, north of the Nogoia River. It was rehabilitated in 2010, and the current land use mine rehabilitation. Cattle have never grazed this rehabilitation.

3.21.1 Sites

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
45	0653459,7416891	Detail	Slope	<5%	Rhodes grass, Acacia spp.	10cm	n/a	55cm

3.21.2 Representative photographs



Surface and vegetation conditions at Site 45

3.21.3 Soil profile description

Profile photo is Site 45.

cm	10	A1	cm	10
		B1		
	35	B2		35
	55	B2/C		55
	90			90

The **topsoil (A1)** is a brown (7.5YR4/4) sandy loam with a massive/single grain fabric; field pH is 6.0. Diffuse change to:

The **upper subsoil (B1)** is a sandy loam with a massive/single grain fabric. Diffuse change to:

The **lower subsoil (B2)** is a dark red (2.5YR3/6) sandy loam with a massive/single grain fabric; field pH 6.5. Abrupt change to rock.

According to the Australian Soil Classification (Isbell, 1996) this soil is a Red Kandosol.



3.21.4 Laboratory analyses

Site 45

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.9	0.3	5.11	2.5	0.93	1.5	0.05	1	1.7	<5
20-30	6.1	0.2	3.75	2	0.13	1.4	0.09	2.3	1.4	-
40-50	5.7	0.2	4.54	2.2	0.35	1.5	0.1	2.1	1.5	-

This soil is moderately acid throughout and non-saline. CEC is very low, indicating the capacity of the soil to hold and exchange cations important in plant nutrition. Calcium is deficient but the soil is non-sodic. Phosphorus is deficient.

3.21.5 Land suitability class

Limitation	Surface soil erodibility	Subsoil erodibility	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	2	2	4	4	3	2	3	2	1	4	3	2	1	2	1

Rehabilitation Polygon 21 is land suitability 4 for sustainable cattle grazing. This rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: low soil water holding capacity (M4); hardsetting, massive topsoil (Ps4); and, nutrient deficiency (Nd4).

3.22 Summary of results

The land suitability class and primary limitations for each of the 21 rehabilitation polygons have been summarised (Table 3-1).

Table 3-1 Land suitability summary for each rehabilitation polygon

#	Limitation subclasses	Limitation description	Class
1	Eb4	Subsoil erosion risk	4
2	Eb4, Tx4	Subsoil erosion risk; high soil pH	4
3	Eb4, Tx4	Subsoil erosion risk; high soil pH	4
4	Eb4, Tx4	Subsoil erosion risk; high soil pH	4
5	M4, Tx4	Poor water holding capacity; high soil pH	4
6	n/a	--	--
7	Tx4	High soil pH	4
8	Tx4	High soil pH	4
9	M4	Poor water holding capacity	4
10	M4, Tx4	Poor water holding capacity; high soil pH	4
11	M4	Poor water holding capacity	4
12	M5	Very poor water holding capacity	5
13	M4, Ps4, Nd4, Tx4	Poor water holding capacity; hardsetting soil; low P; high soil pH	4
14	Eb4, M4, Ps4, Tx4	Subsoil erosion risk; poor water holding capacity; hardsetting soil; high soil pH	4
15	Eb4, M4, Ps4, Tx4	Subsoil erosion risk; poor water holding capacity; hardsetting soil; high soil pH	4
16	M4, Ps4, R4, Sd4	Poor water holding capacity; hardsetting soil; rockiness; shallow soil	4
17	Eb4	Subsoil erosion risk	4
18	Ea4, Eb4, Nd4	Topsoil and subsoil erosion risk; low P	4
19	M5	Very poor water holding capacity	5
20	M5	Very poor water holding capacity	5
21	M4, Ps4, Nd	Poor water holding capacity; hardsetting soil; low P	4

4 DISCUSSION OF RESULTS

4.1 Land use limitations

A range of limitations affects the suitability of rehabilitation for sustainable cattle grazing. Most of these limitations are inherent to the constructed post-mining landscape and are enduring characteristics of the rehabilitation. Common limitations at Ensham include soil erosion risk, high soil pH, low soil water holding capacity, hardsetting topsoils and low soil fertility. In a regional context, land use limitations like these are not uncommon for grazing land in central Queensland (DPI&F, 2007).

Most rehabilitation at Ensham is land suitability class 4, breeding country, for sustainable cattle grazing. This land is marginally suited for sustainable cattle grazing but requires significant inputs to ensure sustainability and prevent land degradation. Those significant inputs might relate to managing total grazing pressure, using appropriate pasture utilisation rates, types of grazing systems and herd management strategies, strategic supplementation, forage budgeting strategies, utilising climate and seasonal forecasting resources, managing fire, fencing, distance to water and monitoring of pastures, amongst others.

It may be possible in certain instances to mitigate a limitation and by doing so, reduce the nature of inputs required to prevent land degradation and possibly improve land suitability class ranking. For example, much of the rehabilitation in the southern part of the mine has strong to very strong soil alkalinity, pH >8 and approaching 10. This is a serious limitation to sustainable grazing because high soil alkalinity affects the speciation and solubility of some essential plant nutrients, changing the amount of those nutrients that are available to plants. This will have knock-on effects in pasture productivity, pasture health and resilience to grazing, and ultimately feed intake quality, and cattle nutrition, health and productivity.

At pH >8 the availability of copper and zinc decreases; at pH >8.5 the availability of phosphorus decreases; and at pH >9.5 the availability of nitrogen, calcium, magnesium and a suite of micronutrients decreases (Hazelton and Murphy, 2007). This will occur regardless of fertiliser application of those nutrients, and the pasture and grazing cattle will be deficient.

There are two possible ways to address this limitation to ensure sustainability and prevent land degradation, viz. (i) cattle mineral supplementation via injection, water infusion or lick (block or liquid), or (ii) soil pH amendment via application of elemental sulphur to reduce the soil alkalinity by at least 1 pH unit (x100 reduction). Only the latter reduces management inputs and can potential improve land suitability class ranking. The feasibility of this action in existing rehabilitation should be examined. For future rehabilitation, pH correction should be a routine requirement when strongly alkaline materials are identified.

Three rehabilitation polygons are land suitability class 5 for sustainable cattle grazing. This rehabilitation has extreme limitations that usually preclude sustainable grazing. Grazing of this rehabilitation may only be possible sometimes, when summer rainfall promotes pasture growth and even then, probably only if it can be used in conjunction with other better quality land. Class 5 rehabilitation should be destocked seasonally to prevent excessive utilisation and land degradation.

4.2 Broad recommendations for grazing trials

Grazing trials should employ a production system matched to the land suitability of rehabilitation – Class 4 breeding country. Following are some broad recommendations for rehabilitation grazing management.

The appropriate production model for rehabilitation is a *store weaner production* model. In this system the main products are store weaners for sale or growing on better country, which is not rehabilitation. Surplus weaner heifers (not needed for replacements) and cull cows (empty) are secondary products.

In rehabilitation particular attention should be given to utilisation rates. Utilisation rate is the proportion of annual pasture growth (from July to June) that is consumed by grazing animals. Excessive utilisation adversely affects the capacity of the pasture to convert water and nutrients into growth, thereby having

detrimental impacts on sustainability (Chilcott *et al.* 2005). Impacts of over utilisation include tussock size reduction, loss of groundcover and accelerated erosion, and weed invasion. According to DPI&F (2007) utilisation rates in central Queensland vary depending on the fertility of the land but are typically 15% to 30% of annual pasture production. Although a low utilisation rate may appear to 'waste' feed, it is actually allowing pasture to recover from stress, set seed, and maintain groundcover and soil health. For these reasons, an appropriately low utilisation rate is critical to the sustainable grazing of rehabilitation.

Other important management considerations to ensure sustainability and prevent land degradation in rehabilitation include:

- Short-term forage budgeting strategies, i.e. using Stocktake Plus.
- Fencing according to land types.
- Managing distance to water and supplementation points to encourage paddock utilisation.

If possible, the store weaner production model in rehabilitation should be mimicked on unmined land of the same land suitability class ranking to allow direct comparison of system performance metrics. These metrics should include:

- The seasonal condition of cattle (live weights), particularly pregnant and lactating cows that can lose condition rapidly.
- Pregnancy, calving and weaning rates.
- Weaner age and live weight at turn off.
- Pasture and soil condition.

Modern grazing systems that promote rapid rumen development in calves and early weaning should also be considered, e.g. creep feeding. If achieved, early weaning will reduce the maintenance feed intake requirements for lactating cows, which in turn reduces the pressure on pastures.

5 REFERENCES

Bourne G and Tuck G (1993) *Understanding and managing soils in the Central Highlands*, Land Management Manual Project, Training Series QE93002, Department of Primary Industries, Brisbane.

Chilcott C, Sandral C, Aisthorpe J, Paton C, and McCallum B (2005). *Grazing Land Management- Fitzroy Basin Version*, Meat and Livestock Australia Limited, Australia.

CHRRUP (2016) *Ensham Resources, Yongala Grazing Trial and Assessment, 2016 Report*, Central Highlands Regional Resources Use Planning Cooperative Ltd, Emerald.

DNRM/DSITIA (2013a) *Guidelines for Agricultural Land Evaluation in Queensland*, Second edition, Queensland Government, Brisbane.

DNRM/DSITIA (2013b) *Regional Land Suitability Frameworks for Queensland, Chapter 10 - Suitability framework for the Inland Fitzroy and Southern Burdekin area*, Queensland Government, Brisbane.

DPI&F (2007) *The economics of beef in central Queensland, Gross margins and production notes*. Department of Primary Industries and Fisheries, Brisbane.

GCAA (undated) *Fact Sheet, Land Use – Liddell Grazing Trial*, Glencore Coal Assets Australia, viewed on 13 November 2017 at <http://www.glencore.com.au/en/publications/fact-sheets/FactsheetsGCAA/Land-Use-Liddell-Grazing-Trial.pdf>

Grigg A, Mullen B, Bing So H, Shelton M, Bisrat S, Horn P and Yatapange K (2006) Sustainable grazing on rehabilitated lands in the Bowen Basin – Stages 1 and 2, ACARP Project No C9038, Australian Coal Research Limited, Brisbane.

Gunn R, Galloway R, Pedley L and Fitzpatrick E (1967) *Lands of the Nogoa-Belyando Area, Queensland*, Land Research Series No. 18, Commonwealth Scientific and Industrial Research Organisation, Melbourne.

Gunn R and Nix H (1977) *Land units of the Fitzroy region, Queensland*, Land Research Series No. 39, Commonwealth Scientific and Industrial Research Organisation, Melbourne.

Hollingsworth Dames and Moore (1991) *Ensham Coal Project Final Impact Assessment Study*.

Hnatiuk R, Thackway R and Walker J (2009) *Vegetation*, In: Australian Soil and Land Survey Field Handbook, Third Edition, Australian Soil and Land Survey Handbook Series, National Committee on Soil and Terrain, CSIRO Publishing, Melbourne.

Isbell RF (1996) *The Australian Soil Classification*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Mckenzie N, Coughlan K and Cresswell H (2002) *Soil Physical Measurement and Interpretation for Land Evaluation*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

McKenzie N, Grundy M, Webster R and Ringrose-Voase A (2008) *Guidelines for Surveying Soil and Land Resources*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

National Committee on Soil and Terrain (2009) *Australian Soil and Land Survey Field Handbook*, Third Edition, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Northcote K and Skene J (1972) Australian soils with saline and sodic properties, CSIRO Soil Publication 27.

QDME (1995) *Technical guidelines for Environmental Management of Exploration and Mining in Queensland*, Queensland Department of Mines and Energy, Brisbane.

Queensland Government (2017a) *Land evaluation schemes*, viewed on 13 November 2017 at <https://www.qld.gov.au/environment/land/soil/soil-data/land-evaluation>

Queensland Government (2017b) *Interpreting data, map scales and site density*, viewed on 10 July 2017 at <https://www.qld.gov.au/environment/land/soil/soil-data/interpreting/>

Rayment G and Lyons D (2011) *Soil Chemical Methods – Australasia*, Australian Soil and Land Survey Handbook Series, CSIRO Publishing, Melbourne.

Shields P and Williams P (1991) *Soils and land suitability for the Kilcummin area, central Queensland*, Department of Primary Industries, Brisbane.

State of NSW and Office of Environment and Heritage Protection (2012) *The land capability assessment scheme, second approximation: A general rural land evaluation scheme for New South Wales*, NSW Government, Sydney.

6 GLOSSARY OF TERMS

Cations – a ion with a net positive electrical charge.

Cation exchange capacity (CEC) – capacity of soil to hold and exchange cations.

Dispersion – occurs when clay particles separate from one another when wet, causing soil aggregates to break down, a loss of soil structure and an increased risk of erosion.

Electrical conductivity – a measure of soil salinity.

Electrochemical stability index - the ratio of the electrical conductivity (EC1:5 in dS/m) and the exchangeable sodium percentage (ESP = the sodium proportion of the cation exchange capacity, CEC) in a soil sample. An indication of a soils propensity to disperse when wet.

pH – a measure of soil acidity or basicity defined as the negative logarithm (base 10) of the activity of hydrogen ions in soil solution.

Horizon – distinctive layer of a soil profile.

Imperfectly drained – water is removed only slowly in relation to supply causing some horizons to be mottled and/or have orange or rusty linings of root channels, and are wet for several weeks following rainfall.

Massive – without structure, appearing as a solid mass devoid of peds.

Mottles – refers to secondary soil colours not associated with compositional properties and typically a sign of anaerobic conditions, i.e. imperfect drainage.

Ped – an individual soil aggregate.

Profile – vertical section that depicts soil horizons.

Salinity – the accumulation of water soluble salts, mainly sodium but also potassium, calcium and magnesium, which may be chlorides, sulphates or carbonates.

Sodicity – a measure of exchangeable sodium in relation to other exchangeable cations in soil and expressed Exchangeable Sodium Percentage (ESP). A soil with an ESP greater than 6 is generally regarded as being a sodic soil in Australia (Northcote and Skene, 1972).

Subsoil – horizon immediately below the surface soil or topsoil.

Texture – the proportion of sand, loam and clay sized particles that make up the mineral fraction of soil.

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APPENDIX A

The location of rehabilitation polygons and assessment sites

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APPENDIX B

Original laboratory reporting sheets

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R E S O U R C E S

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RESOURCES
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The Ensham Coal Project
is a joint venture of the
following companies which
are liable severally in the
following proportions:

Bligh Coal Limited
ABN 20 010 186 393
47.5%

Idemitsu Australia
Resources Pty Ltd
ABN 45 010 236 272
37.5%

Bowen Investment
(Australia) Pty Ltd
ABN 12 002 806 831
15.0%

PROGRESSIVE REHABILITATION REPORT

To support an application for certification of progressive
rehabilitation at Ensham coal mine

27 August 2018

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1 Introduction

This progressive rehabilitation report supports an application for certification of an area of progressive rehabilitation at the Ensham coal mine near Comet in central Queensland.

The mine uses conventional open-cut and underground mining methods to extract coal from the late Permian-age Rangal coal measures. Mining commenced in 1993 and has disturbed an area of approximately 4,590 hectares (ha) to date. By the end of 2018 the mine aims to have progressively rehabilitated more than 1,400 ha of that disturbance. Most rehabilitation at Ensham has a target post-mining land use of cattle grazing.

1.1 Purpose of this report

This progressive rehabilitation report has been prepared in accordance with the following.

- *Environmental Protection Act 1994* (EP Act) Section 318ZF (including requirements of Section 264)
- *Report, Environmental Protection Act 1994, Rehabilitation Report*, EM872 (Part 1), version 1.3 (DES 2018a)
- *Application Form, Environmental Protection Act 1994, Application for the certification of progressive rehabilitation*, EM891, version 2 (DES 2018b).

The purpose of this report is to describe the subject rehabilitation in sufficient detail to demonstrate that the conditions of the environmental authority have been complied with and the land has been satisfactorily rehabilitated. Satisfactory rehabilitation is safe, stable, non-polluting and able to sustain an agreed post-mining land use. In addition to demonstrating compliance and rehabilitation success, this report also describes on-going environmental management requirements and presents a detailed assessment of environmental risks associated with the rehabilitation.

1.1.1 Report structure

This report is structured as follows.

Section 1 – Introductory context, compliance checklist and description of the land

Section 2 – Nature and extent of disturbance, time-lapse imagery

Section 3 – Extent to which rehabilitation satisfies agreed completion criteria

Section 4 - Extent to which rehabilitation satisfies conditions of the environmental authority

Section 5 – Stakeholder consultation

Section 6 – Contaminated land

Section 7 – Environmental risk assessment and consideration of residual risk to government

1.1.2 Addressing requirements of the EP Act

To make straightforward the assessment of compliance with the EP Act, this report explicitly addresses the relevant clauses in Section 318ZF and 264 (Table 1).

Table 1-1 – EP Act requirement checklist

Section	Requirement	Where addressed
264(1)(a)	A final rehabilitation report must— be in the approved form; and	Form attached
264(1)(b)(i)	include enough information to allow the administering authority to decide whether— the conditions of the environmental authority have been complied with; and	Section 4
264(1)(b)(ii)	the land on which each relevant activity for the environmental authority has been carried out has been satisfactorily rehabilitated; and	Section 3
264(1)(c)	describe any ongoing environmental management needs for the land; and	Section 7
264(1)(d)(i)(A)	for an environmental authority for a resource activity— state details of— the monitoring program and the results of monitoring rehabilitation indicators required under any condition of the environmental authority; and	Section 3
264(1)(d)(i)(B)	any consultation with affected owners and occupiers, members of the public, community groups, government agencies and other bodies about any completion criteria for rehabilitation stated in the environmental authority; and	Section 5
264(1)(d)(ii)	state an environmental risk assessment of the land; and	Section 7
264(1)(d)(iii)	propose the residual risks associated with the rehabilitation of the land, worked out under a guideline or other document publicly available from the administering authority; and	Section 7
264(1)(e)	include another matter prescribed under a regulation.	Not relevant
264(2)(a)	The environmental risk assessment must— use a methodology agreed to by the administering authority; and	Section 7
264(2)(b)	show any part of the land that is likely to change or fail to the extent that monitoring, maintenance, reconstruction or other remedial action may be necessary.	Section 7
318ZD(1)(a)	The application must be— in the approved form; and	Form provided
318ZD(1)(b)	supported by enough information to enable the administering authority to decide the application; and	This report
318ZD(1)(c)(i)	accompanied by— a progressive rehabilitation report for the environmental authority that complies with section 318ZF; and	This report
318ZD(1)(c)(ii)	a compliance statement for the report; and	Application form Appendix A
318ZD(1)(c)(iii)	the fee prescribed under a regulation.	Not relevant
318ZD(2)(a)	The compliance statement must— be made for the environmental authority holder; and	Application form Appendix A
318ZD(2)(b)(i)	state— the extent to which activities carried out under the environmental authority relating to the proposed certified rehabilitated area for the	Application form Appendix A

	relevant tenure have complied with the conditions of the environmental authority; and	
318ZD(2)(b)(ii)	the extent to which the progressive rehabilitation report is accurate.	Application form Appendix A
318ZF(1)(a)	The progressive rehabilitation report must— contain the information required under section 264 for a final rehabilitation report, as if a reference in that section to the land were a reference to the proposed certified rehabilitated area; and	As above
318ZF(1)(b)(i)	include— a map of an appropriate scale that shows the proposed certified rehabilitated area; and	Figures throughout
318ZF(1)(b)(ii)	relevant information to locate the proposed certified rehabilitated area, including, for example, GPS information or a survey; and	Figure 6
318ZF(1)(b)(iii)	an environmental risk assessment for the proposed certified rehabilitated area; and	Section 7
318ZF(1)(c)(i)	if progressive certification has previously been given for a relevant tenure for the environmental authority— state when the certification was given; and	Not relevant
318ZF(1)(c)(ii)	identify the certified rehabilitated area the subject of the certification.	Not relevant
318ZF(2)(a)	The environmental risk assessment must— comply with a methodology published by the administering authority; and	Not relevant
318ZF(2)(b)	identify all credible risks for the proposed certified rehabilitated area; and	Section 7
318ZF(2)(c)	evaluate the likelihood and effects of events that reach a threshold of significance published by the administering authority.	Section 7

1.2 Ensham coal mine

Ensham coal mine is located about 50 kilometres (km) east of Emerald, near the township of Comet in central Queensland. It is a modern, efficient mine that currently produces around 6 million tonnes per annum (mtpa) of quality thermal coal by traditional open-cut strip and underground bord-and-pillar mining methods.

1.2.1 Environmental authority holders

The latest Environmental authority EPML00732813 (the EA) took effect on 28 May 2018. The Ensham joint venture partners are the EA holders.

Ensham is a joint venture between Idemitsu Australia Resources Pty Limited (IAR) (47.5%), Bligh Coal Limited (37.5%) and Bowen Investment (Australia) Pty Limited (15%). Ensham Resources Pty Limited, a wholly owned subsidiary of IAR, operates the mine on behalf of the joint venture partners.

1.2.2 Mining activities

Open-cut mining commenced in 1993 at Yongala (Y Pit) and later progressed to Ensham (Pits A, B, C, D, E and F) (Figure 1). Underground mining commenced in 2010 with first coal in September 2011. Mining tenements and affected land areas and background landholders are listed (Table 2).



Figure 1 – Ensham coal mine tenements and mining activities

Table 1-2 – Mining tenements, affected lands and landholders

Mining tenement	Area (ha)	Lot on plan	Landholders
ML7459	6,154	Lot 31 CP864573 Lot 32 RP908643 Lot 30 CP864574 Lot 33 RP864576	Bligh Coal Ltd (47.5%) Idemitsu Australia Resources Pty Ltd (37.5%) Bowen Investment (Australia) Pty Ltd (15%)
ML7460	774	Lot 31 CP864573 Lot 32 RP908643	Bligh Coal Ltd (47.5%) Idemitsu Australia Resources Pty Ltd (37.5%) Bowen Investment (Australia) Pty Ltd (15%)
ML70049 [#]	1,648	Lot 3 CP911009 Lot 2 SP165518	MD, ME, EM, JD & SM Shaw RH & RJ Simmons
ML70326	26	Lot 31 CP864573	Bligh Coal Ltd (47.5%) Idemitsu Australia Resources Pty Ltd (37.5%) Bowen Investment (Australia) Pty Ltd (15%)
ML70365	2,763	Lot 31 CP864573 Lot 32 RP908643	Bligh Coal Ltd (47.5%) Idemitsu Australia Resources Pty Ltd (37.5%) Bowen Investment (Australia) Pty Ltd (15%)
ML70366	254	Lot 30 CP864574	Bligh Coal Ltd (47.5%) Idemitsu Australia Resources Pty Ltd (37.5%) Bowen Investment (Australia) Pty Ltd (15%)
ML70367	1,003	Lot 31 CP864573 Lot 32 RP908643	Bligh Coal Ltd (47.5%) Idemitsu Australia Resources Pty Ltd (37.5%) Bowen Investment (Australia) Pty Ltd (15%)
TOTAL	12,622		

[#] tenement containing rehabilitation that is subject of this report

1.2.3 Description of the subject land

The subject land is a 97 ha area of progressive rehabilitation within ML70049 at Y Pit (Yongala) that was rehabilitated in 2007 and 2009. The application area is a single polygon. The following land and rehabilitation descriptors are provided.

- Rehabilitation area (Figure 1-2)
- Cadastre (Figure 1-3)
- Boundary points (GDA94) (Figure 1-4)
- Final topography (Figure 1-5)
- Catchment limits (Figure 1-6)

- Monitoring locations (Figure 1-7)
- Sequence of rehabilitation (Figure 1-8)

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Figure 2 Rehabilitation area



Figure 3 Cadastre boundaries



Figure 4 Rehabilitation boundary points

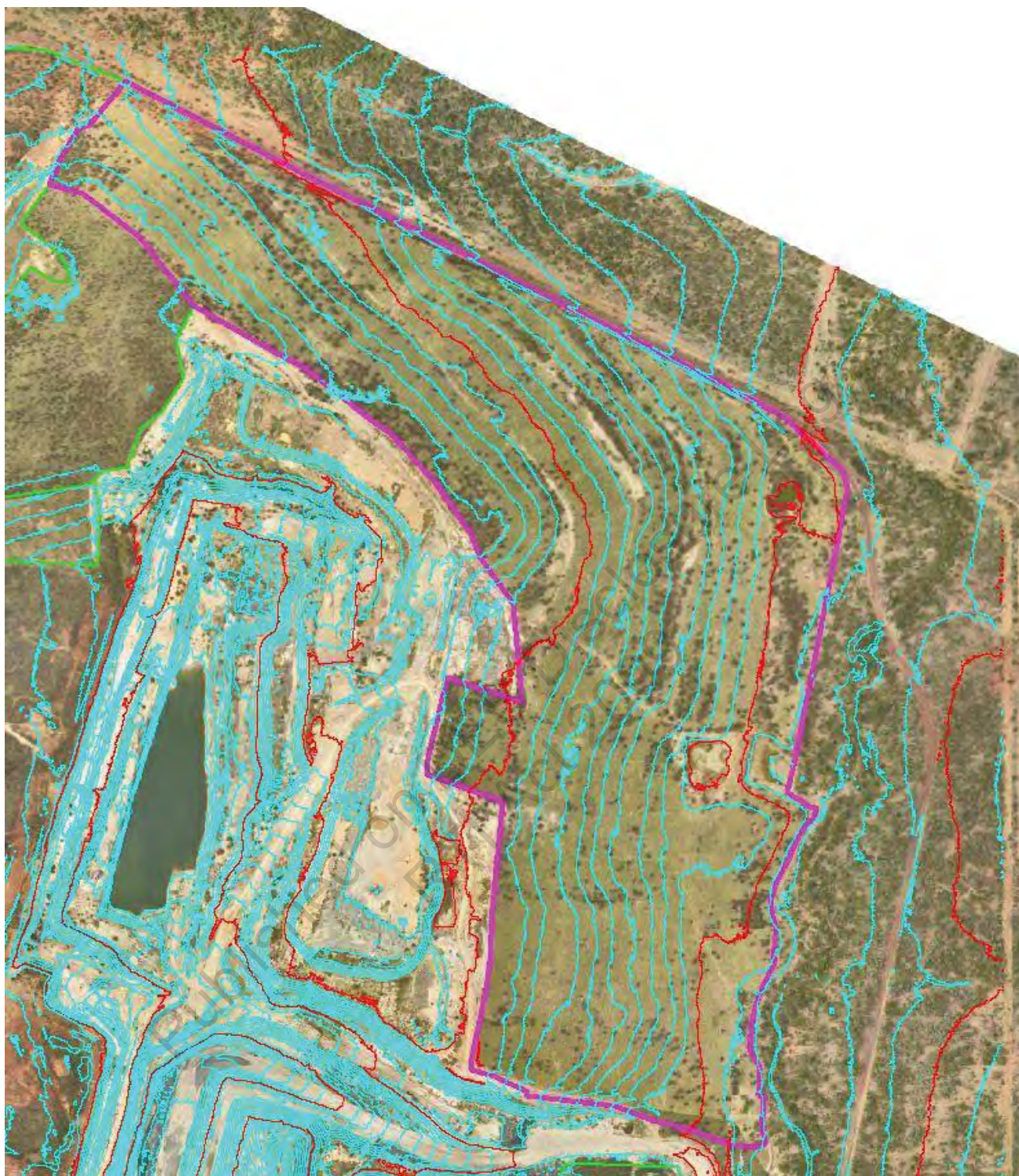


Figure 5 Rehabilitation final topography



Figure 6 Rehabilitation catchment limits



Figure 7 Monitoring locations



Figure 8 Sequence of rehabilitation

2 Nature and extent of disturbance

2.1 Pre-mining land condition

Prior to mining, the "Yongala" property was used for cattle grazing. The 1992 Environmental Management Overview Strategy (EMOS by Hollingsworth, Dames and Moore, 1992) notes:

"The only current land use within the study area is beef cattle grazing on predominantly native pasture of low to moderate productivity with some small areas of introduced pasture species – mainly buffel grass."

That EMOS also assessed land suitable for cattle grazing, adopting the scheme by Shields and Williams (1991). According to that assessment, the subject land was a mix of Class 3 and Class 4 suitable, and Class 5 unsuitable land for sustainable cattle grazing (Figure 2-1). Class 3 and Class 4 lands are suitable with moderate and severe limitations, respectively. Class 5 land has limitations that are so extreme that cattle grazing is not recommended.

Regarding the pre-mining land condition of the Yongalla property, the EMOS found:

"Overall, the Yongala property, which comprises the major part of the study area, is currently in a moderately to in places severely degraded condition.....those areas which are potential susceptible to degradation due to landform, soil type and drainage conditions, already reflect a substantial level of degradation.

In places, very deep erosion gullies have developed in many of the depressional drainageways within the property...The size and severity of gullying is attributable to the generally dispersive nature of the soils and substrate materials within those land units and uncontrolled surface water runoff."

Much of the unmined land at Yongala is simply not suitable for agricultural improvement, i.e. clearing and sowing with improved pastures, and extensive remnant native vegetation exists.

2.2 Mining activities

The subject land has been transformed by open-cut coal mining. The general sequence, timing and nature of mining disturbance is as follows.

- Pre-mining land condition, 1966 (Figure 2-2)
- Mining underway, 1993 (Figure 2-3)
- Rehabilitation underway, 2007 (Figure 2-4)
- Rehabilitation in monitoring and assessment phase, 2018 (Figure 2-5)



Figure 9 Pre-mining land suitability classes



Figure 10 Pre-mining land condition (1966)



Figure 11 Mining underway (1993)



Figure 12 Rehabilitation underway (2007)



Figure 13 Rehabilitation in monitoring and assessment phase (2018)

3 Status of rehabilitation

This section outlines the status of the rehabilitation and the degree to which it satisfies agreed completion criteria.

3.1 Completion criteria

In 2017, Ensham and the then Department of Environment and Heritage Protection (DEHP) each developed rehabilitation completion criteria, which were set in the EA. For sustainable cattle grazing on overburden emplacement areas, the relevant completion criteria are as follows (Table 3-1).

Table 3-1 – Rehabilitation completion criteria

Goals	Objective	Indicators	Completion Criteria
Safe	Safety hazards in rehabilitation are similar to surrounding unmined landscapes	Hazard assessment by a suitably qualified and experienced person	0 (zero) significant difference as defined in <i>AS/NZS ISO 13000:2009 Risk Management</i>
Stable	Landforms are both geotechnically and erosionally stable	Factor of safety	≥ 1.5 as defined in <i>Guideline Geotechnical considerations in open pit mines (State of Western Australia 1999)</i> .
		Slope gradient	Maximum 15% slope
		Groundcover	≥ 50% established and persistent groundcover that is not significantly different from non-mining affected land that is or will be used for a similar purpose
Non-polluting	Surface runoff leaving domain is non-polluting to receiving waters	pH	7.5 – 8.3 as developed in accordance with section 4.3 the <i>Queensland Water Quality Guideline 2009 (see Rehabilitation Management Plan for dataset)</i>
		EC (salinity)	130 – 510µs/cm as per Fitzroy Central zone Rateable 10 th to 90 th percentile of Table G.4 of the <i>Queensland Water Quality Guidelines (2009)</i> .
		Total Suspended Solids (TSS) (sediment loss)	<10mg/L as per <i>Nogoa River Sub-basin EPP Water (2009) Environmental Values and Water Quality Objectives Basin No. 130 (part), including all waters of the Nogoa River Sub-basin (2011)</i> .
		Sulphate (SO ₄ ²⁺)	2.2 – 22.0mg/L as developed in accordance with section 4.3 the <i>Queensland Water Quality Guideline 2009</i>

			(see <i>Rehabilitation Management Plan for dataset</i>)
		Groundcover	≥ 50% established and persistent groundcover that is not significantly different from non-mining affected land that is or will be used for a similar purpose.
	Deep drainage (seepage) from domain is non-polluting to recognised groundwater resources	Per condition G6, this table is to be updated by 31 March 2019 to include indicators and criteria for any potential groundwater impacts, as this may be influenced by residual mining voids	
Land use	Rehabilitation is suitable for sustainable cattle grazing	Land suitability assessment by a suitably qualified person	Class 2 to 4 as defined in the <i>Guidelines for Agricultural Land Evaluation in Queensland (State Department of Queensland 2013)</i> .

Comprehensive rehabilitation monitoring has occurred since the rehabilitation was completed, and much of the following analysis relies on that monitoring data as cited.

3.2 Safe to humans and wildlife

Objectives, indicators and completion criteria for 'safe to humans and wildlife' have been identified (Table 3-1). Safety hazards for people and wildlife accessing and using the rehabilitation have been compared with hazards for the same activities in surrounding unmined lands (Table 4). In this hazard analysis, the standard *IAR Risk Matrix and Risk Acceptance Threshold Model* has been used, including likelihood and consequence tables, and quantitative risk matrix (Appendix B). This IAR tool recognises *AS/NZS ISO 31000:2009 Risk Management*, Queensland safety and health legislation and recognised standards. The types of activities assessed are those typically associated with the final land use of cattle grazing.

3.3 Stable

There are three facets of 'stable' to consider, i.e. engineering factor of safety, maximum slope gradient and groundcover percentage. Factor of safety is a civil engineering calculation of theoretical load-bearing mass stability, while slope gradient and groundcover are surrogate indicators for mass stability and erosional stability, respectively.

3.3.1 Factor of safety

Geotechnical slope stability at Ensham has been investigated in detail (Douglas Partners 2009a and 2009b) for overburden slopes as part of B and C Pits flood protection levee design works. Results showed that slopes of 75 % (37°) to 100 % (45°) were marginally stable and slopes formed to 25 % (14°) or less will readily achieve a safety factor greater than the minimum acceptable long-term safety factor of 1.5. The rehabilitation subject to this application features a very conservative

maximum slope gradient of 10 % (5.7°) and is therefore, according to previous geotechnical assessments, fundamentally stable regarding risk of mass material movement.

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Table 3-2 – Safety hazards in rehabilitation compared to unmined land

Activity	Hazard	Rehabilitation			Unmined land			Comments
		Likelihood	Consequence	Score	Likelihood	Consequence	Score	
Human access / egress on foot	Slips, trips and falls	3 possible	2 minor	8 moderate	3 possible	2 minor	8 moderate	<p>Hazards are comparable in rehabilitation and unmined land, because:</p> <ul style="list-style-type: none"> • Uneven ground is common to rehabilitation and unmined adjacent land. • Sloping land is common to rehabilitation and unmined adjacent land. • Rehabilitation features slopes of <12% and humans can readily transit slopes of this gradient and more.
Human access / egress on vehicle	Bumps, humps and jarring	2 unlikely	2 minor	5 low	2 unlikely	2 minor	5 low	<p>Hazards are comparable in rehabilitation and unmined land, because:</p> <ul style="list-style-type: none"> • Uneven ground is common to rehabilitation and unmined adjacent land. • Sloping land is common to rehabilitation and unmined adjacent land. • Rehabilitation features slopes of <12% and vehicles can readily transit slopes of this gradient with due care and attention.

Animal access / egress on foot	Slips, trips and falls	1 rare	1 insignificant	1 low	1 rare	1 insignificant	1 low	<p>Hazards are comparable in rehabilitation and unmined land, because:</p> <ul style="list-style-type: none"> • Uneven ground is common to rehabilitation and unmined adjacent land. • Sloping land is common to rehabilitation and unmined adjacent land. • Rehabilitation features slopes of <12% and animals, including cattle and other domestic animals, can readily transit slopes of this gradient and more.
Wildlife and cattle drink retained water	Contaminants in waters above guideline levels	2 unlikely	2 minor	5 low	1 rare	2 minor	3 low	<p>Hazards are comparable in rehabilitation and unmined land, because:</p> <ul style="list-style-type: none"> • There is no acid and metalliferous drainage (AMD) on site. • Monitoring shows dam water in the rehabilitation area has suitable quality for cattle drinking. • Cattle have been grazing the rehabilitation and drinking the dam water for several years with no discernible adverse effects.

3.3.2 Maximum slope gradient

Aerial survey data (Figure 14) shows that:

- 100 % of the certification area complies with the maximum slope criterion of 15 % (8.5°).
- The landform features slope gradients of 10 % (5.7°) maximum and is less than that overall due to the incorporation of benches in the landform design.

3.3.3 Groundcover percentage

Groundcover has been assessed annually in rehabilitation monitoring (Table 3-3). Like most pasture-based rehabilitation, groundcover was low initially but rapidly increased thereafter (Figure 3-1). Groundcover percentages have remained high even following the introduction of grazing and compare favourably to unmined reference sites. The certification area complies with the minimum groundcover percentage criterion of ≥ 50 %.

Table 3-3 Groundcover percentages

Year	Groundcover (%)			
	Rehabilitation	Ref Site 1	Ref site 2	F-pit ref site
2007	3	61	45	43
2008	95	88	61	77
2009	99	63	97	n/a
2010	96	95	74	n/a
2014	100	100	100	n/a
2015 before grazing	99	n/a	n/a	n/a
2016 after grazing	92	n/a	n/a	n/a
March 2018	82			
June 2018	74			

In 2015/16 a grazing trial was conducted on the rehabilitation. A total of 110 breeder units (cows with calves at foot) grazed the rehabilitation for a 142-day period. This very high stocking rate of 1 unit/ha was possible due to the large volume of standing forage, assessed at almost 7,000 kg/ha pre-grazing. Results show that when intensively grazed for a long duration, a very high groundcover percentage is maintained. Since that time the rehabilitation has continued to be rotationally grazed at the sole discretion of the background landholder.

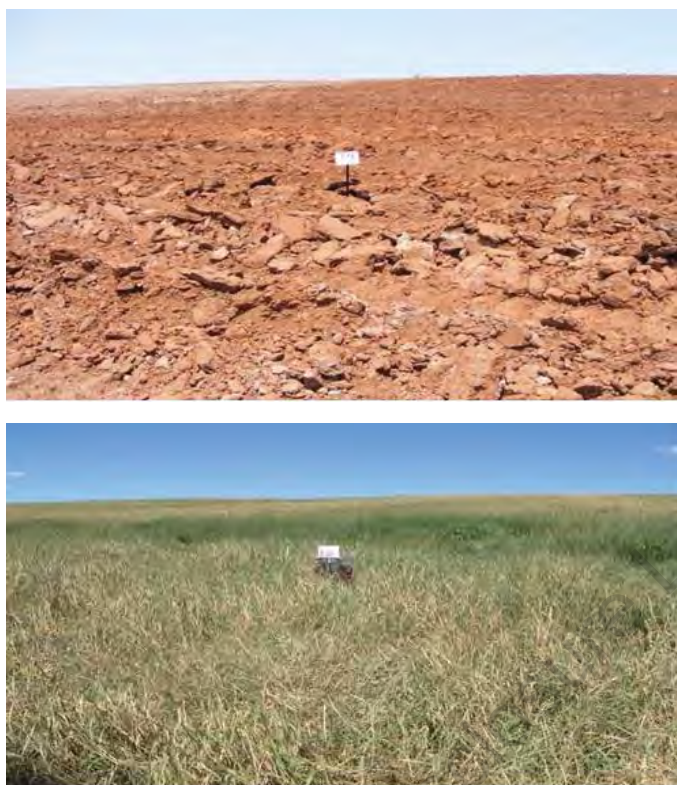


Figure 14 Rapid establishment of persistent groundcover (2007 top and 2008 bottom)

3.4 Non-polluting

'Non-polluting' is assessed as the quality of water that leaves the rehabilitation polygon. For this indicator, the quality of surface water runoff from the rehabilitation is not significantly different to that from upstream, unmined locations. Groundwater is not an aspect for consideration in certification of progressive rehabilitation. Groundwater impacts will be considered at mine closure, prior to surrender of the EA and mining tenements.

In late 2017 and 2018, nine samples of runoff water from the rehabilitation area were collected (Table 3-4). None of this was runoff leaving the rehabilitation polygon as none did during this period. Rather samples were taken of rainfall runoff within the rehabilitation itself where preferential flow paths could be identified.

Samples A to E were taken on bare ground, immediately up-catchment from the dam located within the rehabilitation. This skewed results, particularly for TSS, and these amounts of suspended solids are not representative of water quality leaving the rehabilitation. Samples F to I were taken from more typical areas with high groundcover percentages.

If runoff were to leave the rehabilitation it would enter Boggy Creek, a tributary of the Nogoa River. Monitoring of Boggy Creek immediately upstream of the rehabilitation shows a median TSS of 4,742 mg/L in four flow events. This result reflects the ephemeral nature of flows in Boggy Creek, the inherent erosivity of soils within the Boggy Creek catchment, and the high intensity-duration of rainfall events required to cause a flow in Boggy Creek. The receiving waters for runoff from the rehabilitation have a very high sediment load.

Table 3-4 Runoff water quality

Sample	pH	EC μS/cm	TSS mg/L	SO ₄ mg/L
A	7.49	219	56	21
B	7.01	64	36	3
C	6.95	120	5510	9
D	6.61	109	415	2
E	6.1	326	3950	4
F	6.69	138	154	2
G	6.35	330	80	8
H	6.93	482	96	4
I	7.0	114	93	3
Median	6.79	211.33	1154.44	6.22

The completion criteria threshold limit of < 10mg/L as per *Nogoa River Sub-basin EPP Water (2009) Environmental Values and Water Quality Objectives Basin No. 130 (part)*, including all waters of the *Nogoa River Sub-basin (2011)*, as inserted by DEHP in 2017, is not reflective of local receiving waters.

The median soil pH value of 6.79 is reflective of the moderately acid to neutral surface soil conditions in the rehabilitation (discuss in detail in Section 3.5).

3.5 Land use

The ability of the rehabilitation to sustain an agreed post-mining land use is assessed as Land Suitability according the Queensland Government's guidelines for agricultural land evaluation (DNR/DSITIA 2013). In late 2017, Highlands Environmental conducted an on-ground land suitability assessment of the rehabilitation, using a methodology and rule-set adapted from Shields and Williams (1991). Four sites were assessed (Table 3-5) in the rehabilitation (Figure 3-2).

Table 3-5 Sites assessed in the rehabilitation

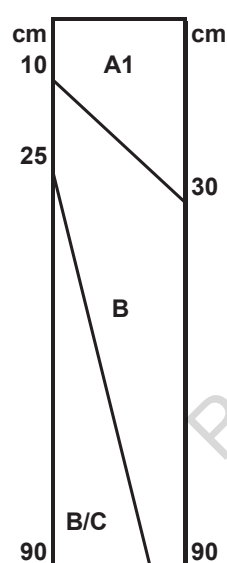
#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
41	654825,7415673	Detail	Upper slope	<10%	Rhodes grass	30cm	Permian	90cm
42	654822,7416618	Detail	Upper slope	<10%	Rhodes grass	25cm	Tertiary	90cm

#	Coordinates	Type	Landform	Slope	Vegetation	Topsoil depth	Spoil type	Hole depth
47	0654373,7417118	Check	Mid slope	<10%	Rhodes grass, Acacia spp.	25cm	n/a	25cm
48	0653259,7403419	Check	Lower slope	<5%	Buffel grass, Acacia spp.	10cm	Tertiary	35cm



Figure 15 Surface and vegetation conditions at Site 41 (left), Site 47 (middle) and Site 48 (right)

Soils profiles were described as follows:



The **topsoil (A1)** is a reddish brown (5YR4/3, 5YR4/4) to strong brown (7.5YR4/6) loamy sand with a fine sub-angular blocky structure; field pH is 6.0-6.5. Clear change to:

The **subsoil (B)** is mine overburden of Permian or Tertiary age; rock is present; mottles below 70cm; field pH 7.0-7.5. Abrupt change to:

Substrate rock (B/C) is present from 25cm depth.

Profile photo is Site 42.



Soils were sampled and sent to a testing laboratory for analysis. Soil chemical properties were comprehensively described (Table 3-6).

Table 3-6 Soil chemical properties

Site 41

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	2.4	6.71	2.7	0.53	2.4	0.97	14	1.1	<5
20-30	5.7	2.4	7.24	2.1	0.25	3.6	1.2	17	0.6	
40-50	7	3.7	14.7	3	0.45	8.6	2.6	17	0.4	
60-70	7.8	4.7	14	2.9	0.47	7.9	2.6	19	0.4	
80-90	7.6	4.2	13.6	2.7	0.48	7.9	2.4	18	0.3	

Site 42

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.5	1.4	5.35	2	0.75	1.6	0.77	14	1.3	<5
20-30	5.5	1.4	5.02	1.1	0.28	2.1	1.2	23	0.5	
40-50	6.9	2	6.93	1.3	0.16	3.7	1.8	26	0.4	
60-70	7	2.6	12.4	2.2	0.3	6.9	3.1	25	0.3	
80-90	7.2	2.3	11.1	2.3	0.22	5.9	2.7	24	0.4	

Site 47

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	5.7	0.4	4.69	1.9	0.63	1.7	0.19	4.1	1.1	<5

Site 48

Depth cm	pH 1:5 water	ECe dS/m	CEC Meq/100g	Ca Meq/100g	K Meq/100g	Mg Meq/100g	Na Meq/100g	ESP %	Ca/Mg	P mg/kg
0-10	6.9	1.1	5.19	1.6	0.26	2.2	1	20	0.7	9

Soil pH is moderately acid (5.5) grading to neutral and mildly alkaline at depth (7.8). Topsoil is non-saline but subsoil can be moderately saline (4.7dS/m). CEC low to very low, indicating the capacity of the soil to hold and exchange cations important in plant nutrition. ESP shows topsoil is non-sodic to extremely sodic (20%) and subsoil is extremely sodic (26%), meaning soil is prone to dispersion when wet and excessive erosion. Low calcium and a prevalence of magnesium on the exchange surfaces will exacerbate dispersion and erosion risk. Phosphorus is deficient in this soil.

The rehabilitation is land suitability class 4 for sustainable beef cattle grazing (Table 3-7). Rehabilitation has severe limitations making it marginally suited for cattle grazing and will require major inputs to ensure sustainability and prevent land degradation. The key limitations to sustainable cattle grazing in this rehabilitation are: topsoil and subsoil erosion risk (Ea4 and Eb4), poor soil water holding capacity (M4); and nutrient deficiency (Nd4).

Table 3-7 Land suitability class

Limitation	Surface soil erosion	Subsoil erosion	Water supply	Surface condition	Rockiness	Micro-relief	Wetness	Real acid drainage	Pot. Acid drainage	Nutrient deficiency	Elemental imbalance	Soil depth	Salinity	Vegetation	Landscape complexity
Code	Ea	Eb	M	Ps	R	Tm	W	Ar	Ap	Nd	Tx	Sd	Sa	V	Lc
Class	4	4	4	3	3	2	3	2	1	4	3	3	2	2	1

4 Assessment against conditions of the EA

Relevant conditions of the EA have been identified and the extent to which rehabilitation complies with conditions has been determined (Table 4-1).

Table 4-1 – Assessment against conditions of the EA

No	EA condition	Compliance	Comment
A1	Financial assurance The activity must not be carried out until the environmental authority holder has given financial assurance to the administering authority as security for compliance with this environmental authority and any costs or expenses, or likely costs or expenses, mentioned in section 298 of the Act.	Yes	An amount of financial assurance is in place.
A2	The amount of financial assurance must be reviewed by the holder of this environmental authority when a plan of operations is amended or replaced or the authority is amended.	Yes	Financial assurance is reviewed and paid with each replacement plan of operations.
A5	Monitoring and records Record, compile and keep for a minimum of five (5) years all monitoring results required by this environmental authority and make available for inspection all or any of these records upon request by the administering authority.	Yes	All rehabilitation monitoring data is kept in perpetuity.
G4	Rehabilitation success criteria All surface areas significantly disturbed by mining activities must be rehabilitated to a safe, stable and non-polluting landform, with a self-sustaining vegetation cover in accordance with Appendix 4: Rehabilitation success criteria . Underground workings must be rehabilitated to be safe, stable and non-polluting.	Yes	As outlined herein.
G5	Appendix 4: Rehabilitation success criteria The environmental authority holder must apply to amend the environmental authority to update Appendix 4: Rehabilitation success criteria for all domains excluding voids by 28 April 2017 .	Yes	Completed by due date.
G7	Rehabilitation activities Rehabilitation must commence progressively in accordance with the Rehabilitation Management Plan required by Condition G11 .	Yes	Rehabilitation is conducted progressively.

G11 G12 G13 G14	To do with the Rehabilitation Management Plan.	Yes	Plan was developed and implemented in accordance with requirements of the EA.
G25	Rehabilitation monitoring Rehabilitation monitoring in accordance with Condition G11 must be conducted by a suitably qualified person on a yearly basis and provided to the administering authority upon request.	Yes	Rehabilitation monitoring is conducted throughout each year by competent persons.
G26	An annual report that describes rehabilitation status against the requirements of Condition G4 must be developed by a suitably qualified person and provided to the administering authority upon request	Yes	Report completed annually.

4.1 Summary status of the rehabilitation

Monitoring and assessment of the rehabilitation demonstrates it has been satisfactorily rehabilitated. The rehabilitation:

1. Meets or exceeds objectives for rehabilitation and agreed indicators and criteria (Section 3). Although some water quality threshold limits are exceeded, rainfall runoff leaving the rehabilitation is non-polluting to receiving waters in Boggy Creek.
2. Is compliant with relevant sections of the EA (refer to Table 4-1).

5 Stakeholder consultation

Extensive stakeholder consultation about rehabilitation was conducted for preparation of the mine Environmental Impact Statements (EIS'). Amongst other important aspects, the EIS' clearly state the target post-mining land use for most rehabilitation is cattle grazing, consistent with surrounding land uses. Ensham has met commitments made in the EIS with respect to land rehabilitation on the subject land.

More recently Ensham has conducted the following stakeholder consultation with respect to rehabilitation on ML70049.

5.1 Background landholder

Ensham personnel meet regularly with the background landholders (identified in Table 2). As this landholder has grazed the rehabilitation subject to this application for several years, rehabilitation and land use are standard items of discussion. The landholder has expressed no valid concerns about the standard of rehabilitation delivered by Ensham and would like access to more rehabilitation to augment his grazing of the broader Yongala property. The landholder independently manages grazing of the rehabilitation, including cattle types and numbers, and graze / spell durations, while Ensham continues to monitor the rehabilitation annually.

Ensham and the background landholder are currently negotiating the retention of final voids and other mining infrastructure, e.g. access roads, electrical transmission lines, tanks and bores, by the landholder at mine closure. Although none of these matters are directly relevant to this application, the landholder has expressed an unwillingness to participate in this progressive rehabilitation certification process until these other matters are resolved to his satisfaction. He has expressed an opinion that if the reshaping rehabilitation being undertaken at Pit E is indicative of what would be carried out at Yongala, he could live with it.

5.2 Central Queensland Mine Rehabilitation Group (CQMRG)

In 2009, Ensham hosted a meeting of the CQMRG. This group includes representatives from a broad range of stakeholders and is focussed on land rehabilitation and extension of relevant research, knowledge and experience. The group inspected several areas of rehabilitation at the mine and Ensham received positive feedback about its pasture / grazing focus.

5.3 Government

Ensham has welcomed government officers to inspect rehabilitation at various times to date and will continue to do so. For example, recent compliance audits by the former Department of Environment and Heritage Protection occurred on 8/12/16, 15&16/3/17 and 29/11/17 and included inspections of mine rehabilitation.

A recent tour by high level officials of DES, DNRME and Treasury inspected this area at Yongala as well as other rehabilitation areas and were impressed by the results.

6 Contaminated land

The subject land is listed on the *Environmental Management Register* due to the EA listing the following Environmentally Relevant Activities as being located on the mining leases.

ERA 8(3) Chemical Storage – storing more than 500m³ of chemicals of class C1 or C2 combustible liquids under AS1940 or dangerous goods class 3 under subsection (1)(c).

ERA 16(2)(a) Extractive and Screening Activities – extracting, other than by dredging, in a year, the following quantity of material - 5000t to 100,000t.

ERA 56 Regulated Waste Storage – receiving and storing regulated waste.

ERA 60(1)(d) Waste Disposal – operating a facility for disposing of, in a year, the following quantity of waste mentioned in subsection (1)(a) - more than 200000t.

ERA 62 Waste Transfer Station Operation – operating on a commercial basis or in course of carrying on a commercial enterprise, a waste transfer station that receives a total quantity of at least 30t or 30m³ of waste on any day.

ERA 63(1)(b)(i) Sewage Treatment – operating sewage treatment works, other than no-release works, with a total daily peak design capacity of more than 100 but not more than 1500EP if treated effluent is discharged from the works to an infiltration trench or through an irrigation scheme.

Schedule 2A:

ERA 13 Mining black coal.

A formal contaminated land assessment and report is not required for this application for certification of progressive rehabilitation because:

- a) None of the listed ERAs, apart from ERA 13, have been conducted on the land subject to this application;
- b) Before applying for surrender of the mining lease, a site-wide formal contaminated land assessment will be conducted, and any contaminated land will be remediated then;
- c) Rehabilitation monitoring, including soil sampling and analysis, does not indicate any contamination on the subject land; and,
- d) The subject land can sustain an agreed post-mining land use (see Section 3.5).

7 Assessment of risk

A thorough assessment of risk was conducted using the Ensham STD.04.00.01 Risk Management system standard.

7.1 Environmental risk assessment

A risk assessment workshop was conducted on 3 July 2018 and a detailed report of that process is provided (Appendix C). This risk assessment identifies all credible risks associated with the rehabilitation. It evaluates the likelihood and effects of events that reach a threshold of significance published by the administering authority. Here, *“threshold of significance published by the administering authority”* is taken to mean environmental harm as defined in the EP Act, i.e. any adverse effect on an environmental value.

This risk assessment was conducted in the following context.

- The period for consideration is from certification until relinquishment of mining tenure and surrender of the EA,
- Ensham shall manage the rehabilitation during this period and is responsible for its maintenance to the condition in place at the time of certification,
- Risks generally relate to risks to government of Ensham not being able to monitor and maintain the rehabilitation to the standards to which it was certified.

7.2 Residual risk

There is no significant residual risk associated with the rehabilitation.

Enduring obligations to remedy any rehabilitation failure remain vested in the EA holder until surrender. On this basis, certification of the progressive rehabilitation poses no risk to government. Despite certification, Ensham will continue to monitor and manage the rehabilitation including any corrective measures, though none are reasonably foreseeable at this time. Currently the costs of monitoring approximately 1200ha of rehabilitation is approximately (d) Deferral of annually. It has not been necessary to undertake any weed control over this area to date. The rehabilitation will continue to be grazed by the background landholder.

7.3 Ongoing environmental management requirements

Ongoing environmental management needs will be minimal for the rehabilitation. These will include period inspection and annual land condition monitoring and weed and feral animal control as needed. Normal agricultural management practices will continue to be used by the background landholder. Ongoing management needs are not anticipated to be significantly different to those typically required on surrounding unmined land used for the same purpose.

It is important to note that normal agricultural management practices will include minor disturbances within the certified rehabilitation. These disturbances may be for tracks, firebreaks,

fence lines, pasture improvement, water reticulation and other activities typically associated with grazing land management in central Queensland. In accordance with grazing best practice, Ensham will encourage the background landholder to maintain or improve land condition while grazing the rehabilitation.

Published on DES Disclosure Log
RTI Act 2009

8 References

DNRM/DSITIA (2013) Guidelines for Agricultural Land Evaluation in Queensland, Second edition, Queensland Government, Brisbane.

Douglas Partners (2009a) *Report on geotechnical assessment, Ensham mine flood levee C Pit breach area Emerald*. Project no. 47793, 24 June 2009.

Douglas Partners (2009b) *Report on geotechnical assessment, Ensham mine C Pit and B Pit levee upgrade Emerald*. Project no. 47793, 17 September 2009.

Hollingsworth, Dames and Moore (1992) *Ensham Coal Project, Yongala Mine, Environmental Management Overview Strategy*, November 1992

Shields P and Williams P (1991) Soils and land suitability for the Kilcummin area, central Queensland, Department of Primary Industries, Brisbane.

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Appendix A – Field Monitoring Results

Site Name/ Number: En Ramp 10N		Recorder: Terry / Johnelle			Date: 11/10/07	Comments
Ground Cover Categories		TOTAL 1-33	TOTAL 34-67	TOTAL 68-100	SITE TOTAL	Groundcover includes mulch hay
>5%		33	34	33	100	
5-15%						
15-30%						
30-50%						
50-90%						
>90%						
Species frequency by category						General Site Description
Desirable Perennials	RHODES	10	22	15	47	
	BUFFEL	4	4	6	14	
	UNIDENTIFIED GRASS	3		2	5	
	UROCHLOA					
GRASSES						
Less Desirable Annual						
Other unidentified grasses						
OTHERS						

Average Ground Cover = 2.5
 Desirable Perennial Freq. = 57
 Intermediate Frequency = 0
 Crops frequency = 51
 Less Desirable Annual Freq = 0
 Less Desirable Per Freq = 0
 Less Desirable Per + Ann Freq = 0
 Forbes = 5

Site Name/ Number: En R10N		Recorder: Terry			Date: 10/4/08	Comments
Ground Cover Categories		TOTAL 1-33	TOTAL 34-67	TOTAL 68-100	SITE TOTAL	Some legumes (Seca & Verano stylo) in bare areas by Rhodes. Isolated Buffel also in bare areas (not in GC transects). Some immature Acacoas were noted.
>5%		0	0	0	0	
5-15%		0	0	1	1	
15-30%		0	0	0	0	
30-50%		1	0	2	3	
50-90%		3	6	2	11	Estimated contribution to yield (%)
>90%		29	28	28	85	
Species frequency by category						General Site Description
Desirable Perennials	RHODES CALLIDE	22	24	23	69	
	RHODES KATAMBORA	30	33	29	92	
		0	0	0	0	
		0	0	0	0	
GRASSES	Frequency Total	28	34	32	94	
		0	0	0	0	
Less Desirable Annual						
Other Identified Grasses						
CROP						
OTHERS						

Average Ground Cover = 95.1
 Desirable Perennial Freq. = 94
 Intermediate Frequency = 0
 Less Desirable Annual Freq = 0
 Less Desirable Per Freq = 0
 Less Desirable Per + Ann Freq = 0
 Crop Annual = 0
 Native Legumes = 12
 Forbes = 0

Site Name/ Number: R10N		Recorder: Bernie/Benn			Date: 25/07/2014	Comments		
Ground Cover Categories		TOTAL 1-33	TOTAL 34-67	TOTAL 68-100	SITE TOTAL			
>5%		0	0	0	0	Site standing feed (Kg/Ha)		
5-15%		0	0	0	0			
15-30%		0	0	0	0			
30-50%		0	0	0	0			
50-90%		0	0	0	0			
>90%		33	34	33	100	Estimated contribution to yield (%)		
Species frequency by category								
GRASSES	Desirable Perennials	Chloris gayana - katembora	33	34	33	100	General Site Description	
			0	0	0	0		
			0	0	0	0		
			0	0	0	0		
			0	0	0	0		
			0	0	0	0		
	Frequency Total							
		0	0	0	0			
		0	0	0				
	Frequency Total							
	Less Desirable	Perennials		0	0	0		0
			0	0	0	0		
			0	0	0	0	Desirable Perennial Freq. = 100%	
			0	0	0	0		
			0	0	0	0	Intermediate Frequency = 0	
Annual			0	0	0	0	Less Desirable Annual Freq = 0	
			0	0	0	0	Less Desirable Per Freq = 0	
		Other Identified Grasses		0	0	0	0	
		Frequency Total				0	Less Desirable Per + Ann Freq = 0	
			0	0	0	0		
CROP		Annual		0	0	0	0	Crop Annual= 0
			0	0	0	0	Native Legumes= 0	
			0	0	0	0	Forbes = 0	
	Frequency Total				0			
OTHERS	Forbes		0	0	0	0		
			0	0	0	0		
			0	0	0	0		
			0	0	0	0		
			0	0	0	0		
	Sedges		0	0	0			
	WOODY PLANTS		0	0	0			
	Native Legumes		0	0	0	0		
			0	0	0	0		
			0	0	0	0		
			0	0	0	0		
Frequency Total								



Table 20: EnR10N GRASS Check Data

Site Name/ Number: En R10N		Recorder: Terry				Date: 22/04/09	Comments
Ground Cover Categories		TOTAL 1-33	TOTAL 34-67	TOTAL 68-100	SITE TOTAL	Site standing feed (Kg/Ha) 8000Kg/Ha Estimated contribution to yield (%)	Dry matter yield; Callide 50%, Katambora 50%, Burgundy Bean traces.
>5%		0	0	0	0		
5-15%		0	0	0	0		
15-30%		0	0	0	0		
30-50%		0	0	0	0		
50-90%		0	0	0	0		
>90%		33	34	33	100		
Species frequency by category							
GRASSES	Desirable Perennials		0	0	0		General Site Description Several dying patches, up to 5m across. Cause? "Death Path" GPS Photo 1034.
		RHODES CALLIDE	31	27	30	88	
		RHODES KATAMBORA	23	15	12	50	
			0	0	0	0	
			0	0	0	0	
		Frequency Total	28	34	33	95	
			0	0	0	0	
		Frequency Total	0	0	0	0	
	Less Desirable Perennials		0	0	0	0	
			0	0	0	0	
			0	0	0	0	
		Frequency Total	0	0	0	0	
			0	0	0	0	
	Annual		0	0	0	0	
			0	0	0	0	
		Other Identified Grasses				0	
		Frequency Total	0	0	0	0	
CROP	Annual					0	
		Frequency Total				0	
	Forbes	BURGUNDY BEAN	2	1	2	5	
		NATIVE LEGUME	0	1	0	1	
			0	0	0	0	
			0	0	0	0	
		Frequency Total	2	2	2	6	
OTHERS	Sedges						
	WOODY PLANTS						
	ACACIA SHIRLYI						
	Native Legumes		0	0	0	0	
			0	0	0	0	
			0	0	0	0	
			0	0	0	0	
		Frequency Total	0	0	0	0	

Figure 16 June 2018



Figure 17 June 2018

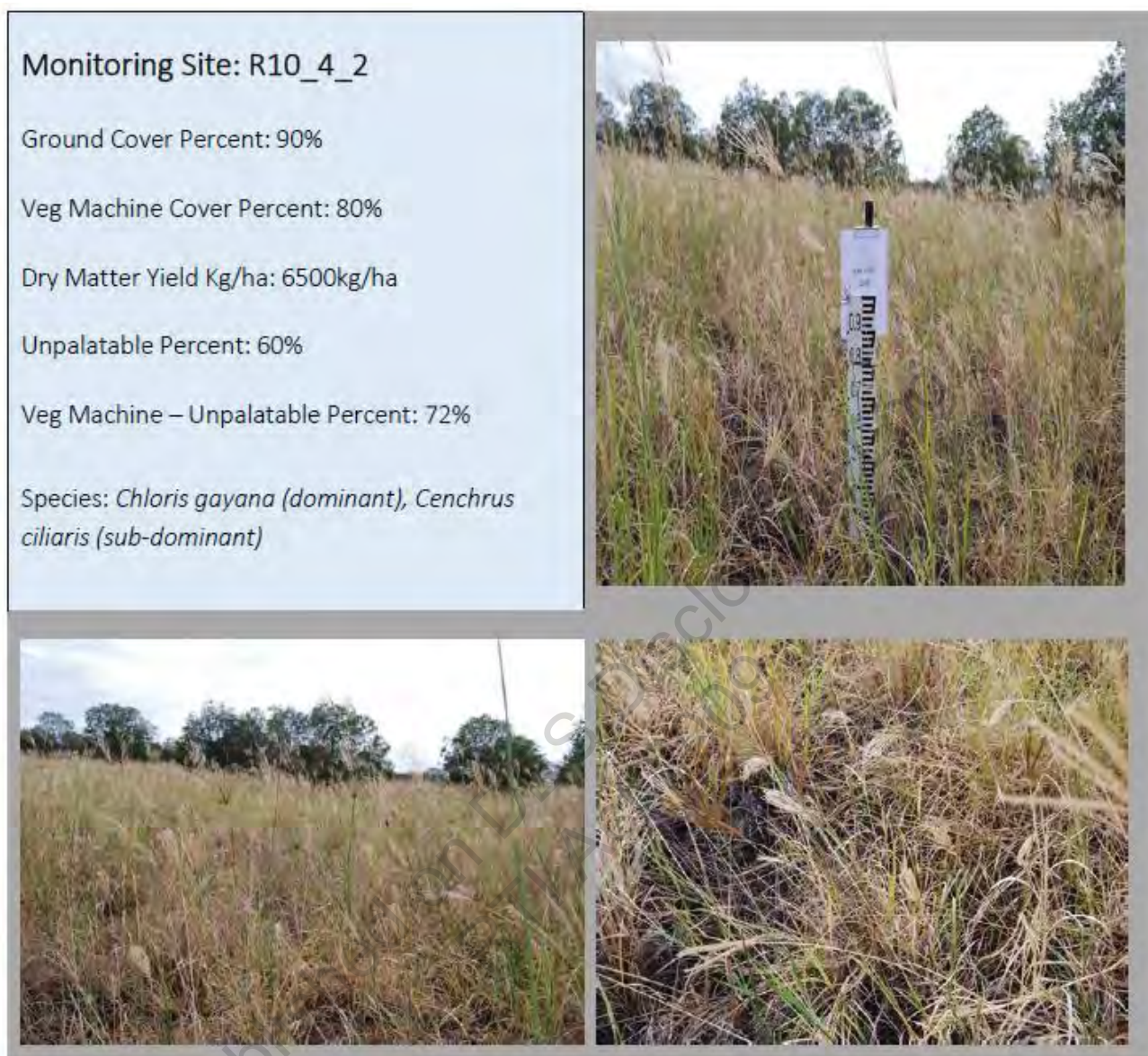


Figure 18 June 2018

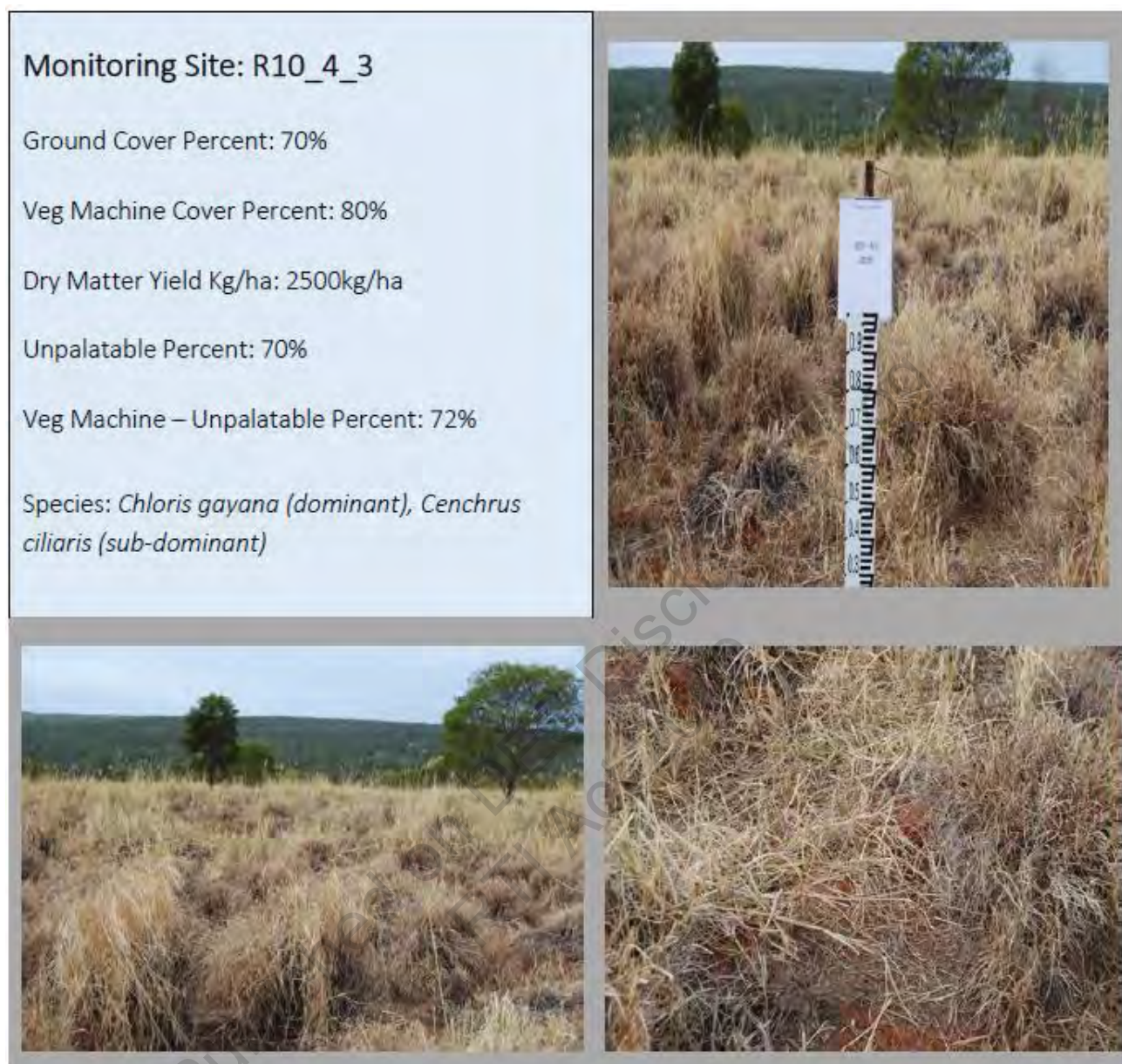


Figure 19 R10_4_3

	
Photo Plate 5: Site 3 Pre assessment	Photo Plate 6: Site 3 Post assessment
Date: 15 th March 2018	Date: 26 th June 2018
GPS: X: 148.51556 Y: -23.35815	

Appendix B - IAR risk matrix and risk acceptance threshold model

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RTI Act 2009

Appendix C – Report of environmental risk workshop

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RTI Act 2009

Report

Environmental Protection Act 1994

Rehabilitation report

This report is the approved form to be used by an applicant submitting a final rehabilitation report pursuant to section 264 of the Environmental Protection Act 1994 (EP Act). It is also the report to be used by an applicant submitting a progressive rehabilitation report under section 318ZF of the EP Act or removing a prescribed environmentally relevant activity (ERA) from an environmental authority as part of an amendment application under section 226 of the EP Act.

How to use a rehabilitation report

The holder of an environmental authority must submit either a final rehabilitation report as part of the requirements of an application to surrender an environmental authority or a progressive rehabilitation report as part of an application for progressive certification. A rehabilitation report must also be submitted to support an amendment application where a prescribed ERA is being removed from an environmental authority. This report must be supported by enough information to allow the administering authority to decide whether the conditions of the environmental authority have been complied with and whether the land on which ERA has been carried out, has been satisfactory rehabilitated. The administering authority may also conduct a field inspection and may request that further rehabilitation be undertaken where relevant.

GUIDE

If you require assistance in answering any part of this form, or have any questions about your application, please contact Permit and Licence Management. Contact details are at the end of this form.

If more space is required for any responses, please attach additional information as a separate page.

The environmental authority number and details may be found on the existing environmental authority or quoted in other correspondence received from the administering authority.

Information requirements

Tick the applicable rehabilitation report type

- ☐ Final rehabilitation report to support an application to surrender an environmental authority
- ☒ Progressive rehabilitation report to support an application for progressive certification
- ☐ Rehabilitation report to support an application to amend an environmental authority

1. Environmental authority number

ENVIRONMENTAL AUTHORITY NUMBER EPML00732813

NAME OF ENVIRONMENTAL AUTHORITY HOLDER/S

Bligh Coal Limited

Idemitsu Australia Resources Pty Ltd

Bowen Investment (Australia) Pty Ltd

2. Author (or compiler) of the rehabilitation report



CONTACT NAME AND BUSINESS NAME (IF APPLICABLE) 4(6) Personal Inform Highlands Environmental	
RESIDENTIAL ADDRESS OR REGISTERED BUSINESS ADDRESS (NOT A POST OFFICE BOX ADDRESS) 4p4(6) Personal Informa Emerald Qld 4720	
PHONE 4p4(6) Personal Informa	FACSIMILE
EMAIL Personal @highlandsenvironmental.com.au	

3. Future contact for rehabilitation/post surrender

Only complete this section if the future contact is different to the author (or compiler) nominated above.

CONTACT NAME AND BUSINESS NAME (IF APPLICABLE) 6) Personal Info Ensham Resources	
RESIDENTIAL ADDRESS OR REGISTERED BUSINESS ADDRESS (NOT A POST OFFICE BOX ADDRESS) Duckponds Rd Emerald Qld 4720	
PHONE 4p4(6) Personal Informa	FACSIMILE
EMAIL 6) Personal Info @ensham.com.au	

4. Disturbance and rehabilitation

PERIOD OF DISTURBANCE: 1993 - 2018	
TOTAL AREA DISTURBED: 972000 m ²	TOTAL AREA REHABILITATED: 972000 m ²

You must attach all of the relevant information for each check box in this section for the rehabilitation undertaken.

5. Description and status of rehabilitation

5.1 All activities	
☒	Describe the nature and extent of disturbance.
☒	Describe the status of the rehabilitation.
☒	Provide an assessment of the rehabilitation against any conditions of the environmental authority or any standards referenced in a relevant

	plan of operations. This must include analysis of any monitoring data and results relevant to any rehabilitation indicators.
☒	Attach maps and diagrams at an appropriate scale that identifies: the proposed rehabilitated area in relation to the property/tenure boundaries GPS coordinates (in GDA 94) of the corners of the rehabilitated area or metes and bounds of the perimeter of the rehabilitated area. the extent of disturbance the final landform (contoured at an appropriate intervals) and drainage pattern the nature of the rehabilitation (if different types were used) any remaining items of infrastructure (if any) including any heritage listed features any inhabited dwellings and community infrastructure any land that was or is contaminated as a result of the activities undertaken onsite.
☒	Attach relevant photographs of the rehabilitation along with a plan illustrating where the photograph was taken from and its aspect.
☐	Attach any statements or certificates by an appropriately qualified person regarding the construction, stability or likely future performance of structures forming part of the rehabilitation (e.g. dams, escarpments).
5.2 Resource activities only	
☒	Provide information about any consultation undertaken regarding the rehabilitation.
☐	Identify and illustrate any areas that have previously been certified under a progressive certification application. ☒ N/A – previous progressive certification has not been done
☐	For surrender applications, describe any mining activities that have occurred in the area, noting historic disturbance that occurred prior to the grant of the current tenement and any previous tenements that gave continuous entitlement to the resource. ☐ N/A – historic disturbance is not separate to this rehabilitation proposal
☐	Provide indicative figures for any amounts of overburden, waste rock or resources that have been removed from the land or is now deposited on the land. ☒ N/A – materials have not been removed or deposited in relation to rehabilitation.

Historic information is only required if you are trying to establish that areas of historic disturbance have not been reworked under the current or preceding tenements with continuous entitlements and liabilities.

6. Do you have an approved transitional environmental program in place or have you submitted one?

- ☐ Yes → ☐ A draft transitional environmental program is approved and all environmental commitments under the program have been completed;
- ☐ A draft transitional environmental program is approved and there is further land management/rehabilitation, monitoring and

maintenance required.

☐ A draft transitional environmental program has been submitted with the correct fee together with this application and there is further land management/rehabilitation, monitoring and maintenance required.

☒ No

There are various reasons why some items of infrastructure may be left post decommissioning or post surrender of an environmental authority. For example the landowner may request that a road remains to provide access to land or that a dam remain for water storage purposes.

- 7. Has the landowner or any proposed future landowner, agreed to take over any infrastructure or areas of disturbance on site?** ☐ Yes → Attach an agreement signed by the current landowner and any future landowner (if applicable) clearly indicating what existing structures or disturbed areas they will be taking ownership of, and the state of the structure or area upon transfer. Please use the template document attached to this back of this form. ☒ No → Go to question **Error! Reference source not found.**

Under the *Mineral Resources Act 1989*, approval from the Mining Registrar is required for infrastructure to be left on the land. For further information see the *Mineral Resources Act 1989*:

- Mining lease: section 276(1)(c) and 312(4)
- Mining claim section 81(g)(ii)

- 8. For an environmental authority over a mining lease or mining claim tenure, has the approval under the *Mineral Resources Act 1989* been obtained to leave any infrastructure on the land?** ☐ Yes → Attach a copy of the approval. ☐ No

☒ N/A

Throughout the life of the activity, the holder of the environmental authority is required to notify the administering authority if a notifiable activity (as listed in Schedule 3 of the EP Act) is being carried out on the land, or if the land has been contaminated by a hazardous contaminant. The particulars of such land are then recorded on the EMR or CLR.

Refer to Chapter 7, Part 8 of the EP Act for further information on contaminated land requirements.

- 9. Is the land on the environmental management register (EMR) or the contaminated land register (CLR)?** ☐ Yes → Provide information on:
- The contaminated land status
 - Contamination from the activity relevant to the environmental authority and from any historic activities conducted on the site
 - How the land this will meet the rehabilitation commitments including the intended future land use for the site
 - Any suitability statements or draft site management plans for the land.

☒ No

10. Is this rehabilitation report for a resource activity?

- ☒ Yes → Complete questions 11 and 12 below.
- ☐ No → Go to the declaration.

The environmental risk assessment must be completed using a methodology agreed to by the administering authority. For information on how to determine residual risk, visit www.business.qld.gov.au.

Natural processes as well as human activities may have an adverse effect on rehabilitation. It is therefore possible that a site that has been satisfactorily rehabilitated may fail at some time in the future. This is called the 'residual risk'. Examples of residual risk include the future costs of likely repairs, any necessary monitoring and maintenance costs or any ongoing monitoring costs.

11. Environmental risk assessment

11.1 Final rehabilitation report

- ☒ Attach an environmental risk assessment that shows any part of the land that is likely to change or fail in future. Include details of the extent that monitoring, maintenance, reconstruction or other remedial action may be necessary. This will determine the residual risk remaining for the site.

11.2 Progressive rehabilitation report

- ☒ Attach an environmental risk assessment that: Shows any part of the land that is likely to change or fail to the extent that monitoring, maintenance, reconstruction or other remedial action may be necessary. Identifies all credible risks for the proposed certified rehabilitated area. Evaluates the likelihood and effect of events that reach a threshold of significance published by the administering authority.

Where rehabilitation is complete and there is no residual risk payment required, you may apply for a complete discharge of financial assurance held, or an amendment of financial assurance in the case of a partial surrender.

In other cases the amount returned will be decreased by the required residual risk payment.

12. Did the environmental risk assessment above identify any residual risk remaining at present?

- ☐ Yes → Attach a proposal that outlines the residual risks associated with the rehabilitation and a calculation of the ongoing financial cost of managing the residual risk.
- ☒ No

Privacy statement

The Department of Environment and Heritage Protection (the department) is committed to protecting the privacy, accuracy and security of your personal information in accordance with the *Information Privacy Act 2009*. The department is collecting your personal information in accordance with sections 226, 262, 264, 318ZD and 318ZF of the *Environmental Protection Act 1994* in order to process your application to surrender an environmental authority or application for progressive certification. The information will only be accessed by authorised employees within the department. Information may be given to the Department of Natural Resources and Mines for the purposes of processing the application to surrender the environmental authority. Your information will not be given to any other person or agency unless you have given us permission or we are authorised or required by law. All information supplied on this form may be disclosed publicly in accordance with the *Right to Information Act 2009* and *Evidence Act 1977*. For queries about privacy matters email: privacy@ehp.qld.gov.au or telephone: (07) 3330 5436.

The latest version of this publication and other publications referenced in this document can be found at www.qld.gov.au using the relevant publication number (EM872) for this form as a search term or by contacting Permit and Licence Management.

13. Declaration

Note: If you have not told the truth in this application you may be prosecuted. I/We declare that: The information provided is true and correct to the best of my knowledge. I understand that it is an offence under section 480 of the *Environmental Protection Act 1994* to give to the administering authority or an authorised person a document containing information that I know is false, misleading or incomplete in a material particular. I understand that failure to provide sufficient information may result in the application being refused. I understand that all information supplied in this form may be disclosed publicly in accordance with the *Right to Information Act 2009* and the *Evidence Act 1977*.

NAME	(6) Personal Information	
SIGNATURE	sch4p4(6) Personal Information	
POSITION OF SIGNATORY	Superintendent Environment	DATE 20/8/2018

Enquiries:

Permit and Licence Management
Phone: 13 QGOV (13 74 68)
Fax: (07) 3330 5875
Email: palm@ehp.qld.gov.au

Attachment 1—Landowner statement

This attachment is to be used by the environmental authority holder to attach to the final rehabilitation report or the progressive rehabilitation that accompanies an application to surrender an environmental authority or an application for progressive certification respectively. It is to also be attached to the rehabilitation report for an application to amend an environmental authority where a prescribed ERA is being removed from the environmental authority.

This form is to be used:

- To obtain a statement from the land owner of their overall satisfaction with the rehabilitation.
- If there is a proposed transfer of remaining infrastructure (e.g. a road) or remaining disturbed areas (e.g. extraction voids) to the landowner in a particular state.

The information provided on this form will be considered by the administering authority in the assessment of whether the conditions of the environmental authority have been complied with and whether the land has been satisfactorily rehabilitated. The administering authority may also conduct a field inspection and may request that further rehabilitation be undertake where relevant.

If you require assistance in answering any part of this form, or have any questions about your application, please contact Permit and Licence Management. Contact details are at the end of this form.

GUIDE

If more space is required for any responses, please attach additional information as a separate page.

Example of land description
Lot: 1
Plan: 123456
Tenure: Special Lease 12
Current usage: Reserve

Information requirements

1. Land description

LOT(S)
PART OF 3
PLAN(S)
CP911009
TENURE
Freehold
CURRENT USAGE
Mining and grazing

2. Environmental authority number

ENVIRONMENTAL AUTHORITY NUMBER
EPML00732813

Where the landowner is not an individual (e.g. a company or group), provide the name and contact details of a person who is authorised to act on behalf of the landowner.

3. Landowner

NAME OF LANDOWNER MD, ME, EM, JD & SM Shaw	
CONTACT NAME (IF COMPANY/GROUP ETC.)	
POSTAL ADDRESS	
PHONE	FACSIMILE
EMAIL	

Examples of remaining infrastructure includes roads, storage sheds etc. Inheritance of disturbed land and infrastructure brings with it responsibilities for maintenance and management.

4. Are there any infrastructure or disturbed areas which you wish to take ownership of?

- ☐ Yes → Briefly described the infrastructure or areas and the status of which you would accept ownership below, then go to question 5.
- ☒ No → Go to question 7.

INFRASTRUCTURE/DISTURBED AREA (I.E. ROAD ALONG WESTERN BOUNDARY)	STATUS (I.E. IN ITS CURRENT STATE AS AN UNSEALED DIRT ROAD)

5. Have you made an agreement with the holder of the environmental authority regarding the infrastructure or disturbed areas which you wish to take ownership of?

- ☐ Yes → Attach a copy of the signed agreement and fill in the table below.
- ☐ No → There must be an agreement in place, and details of the agreement provided to the administering authority for the application to be decided.

DATE OF AGREEMENT	NUMBER OF PAGES

6. Are there any items of infrastructure or areas of disturbance which you believe an agreement is still required, but has not been made?

- ☐ Yes → Provide information of outstanding agreements required below.
- ☐ No

INFRASTRUCTURE/DISTURBED AREA STILL TO BE AGREED UPON

You may attach photographs or plans to illustrate any matters about which you believe are unsatisfactory. Make sure that any attachments are clearly labelled and referenced.

7. Indicate your level of satisfaction of the rehabilitation so far.

- ☐ Satisfactory (further comments may be provided below, if necessary)
- ☐ Unsatisfactory (provide further information below)

FURTHER COMMENTS

Privacy statement

The Department of Environment and Heritage Protection (the department) is committed to protecting the privacy, accuracy and security of your personal information in accordance with the *Information Privacy Act 2009*. The department is collecting your personal information in

8. Landowner certification

Tick the applicable box

- ☒ I am the landowner for the land described in question 1.
- ☐ I am authorised to sign on behalf of the landowner for the land described in question 1.

accordance with sections 226, 262, 264, 318ZD and 318ZF of the *Environmental Protection Act 1994* in order to process your application to surrender an environmental authority or application for progressive certification. The information will only be accessed by authorised employees within the department. Information may be given to the Department of Natural Resources and Mines for the purposes of processing the application to surrender the environmental authority. Your information will not be given to any other person or agency unless you have given us permission or we are authorised or required by law. All information supplied on this form may be disclosed publicly in accordance with the *Right to Information Act 2009* and *Evidence Act 1977*. For queries about privacy matters email: privacy@ehp.qld.gov.au or telephone: (07) 3330 5436.

The landowner or person authorised to act on behalf of the landowner is required to sign this form.

Further information

The latest version of this publication and other publications referenced in this document can be found at www.qld.gov.au using the relevant publication number (EM872) for this form as a search term or by contacting Permit and Licence Management.

Declaration

I/We declare that:

- The information provided is true and correct to the best of my knowledge. I understand that it is an offence under section 480 of the *Environmental Protection Act 1994* to give to the administering authority or an authorised person a document containing information that I know is false, misleading or incomplete in a material particular.
- I understand that all information supplied in this form may be disclosed publicly in accordance with the *Right to Information Act 2009* and the *Evidence Act 1977*.

NAME	
SIGNATURE	
POSITION OF SIGNATORY	DATE



ENSHAM
RESOURCES
PTY LIMITED

ABN 23 011 048 678

As Operator of the
Ensham Coal Project

Duckponds Road
via Emerald
PO Box 1565
Emerald QLD 4720
Australia

Telephone:
+61 7 4987 3601

Facsimile:
+61 7 4987 3622

Website:
www.ensham.com.au

The Ensham Coal Project
is a joint venture of the
following companies which
are liable severally in the
following proportions:

Bligh Coal Limited
ABN 20 010 186 393
47.5%

Idemitsu Australia
Resources Pty Ltd
ABN 45 010 236 272
37.5%

Bowen Investment
(Australia) Pty Ltd
ABN 12 002 806 831
15.0%

4 January 2019

Juliana McCosker
Department of Environment and Science
Emerald Qld 4720

Via email:

Dear Juliana,

Re: Environmental Authority EPML00732813

Notification is hereby given that in accordance with Condition G8 of the EA, the rehabilitation activities listed below have been completed.

Table G8: Rehabilitation schedule

Time Frame	Location	Area	Activity
31 January 2019	Pit E	50 ha	Reshape
31 January 2019	Pit E	100 ha	Topsoil, rip and seed

Any questions or clarification, please contact me.

Regards

(6) Personal Infor

Superintendent Environment

Rehabilitation Progress Report



In excess of 100 ha has been topsoiled, ripped and seeded at Pit E during 2018.

Figure 1 Area topsoiled, ripped and seeded

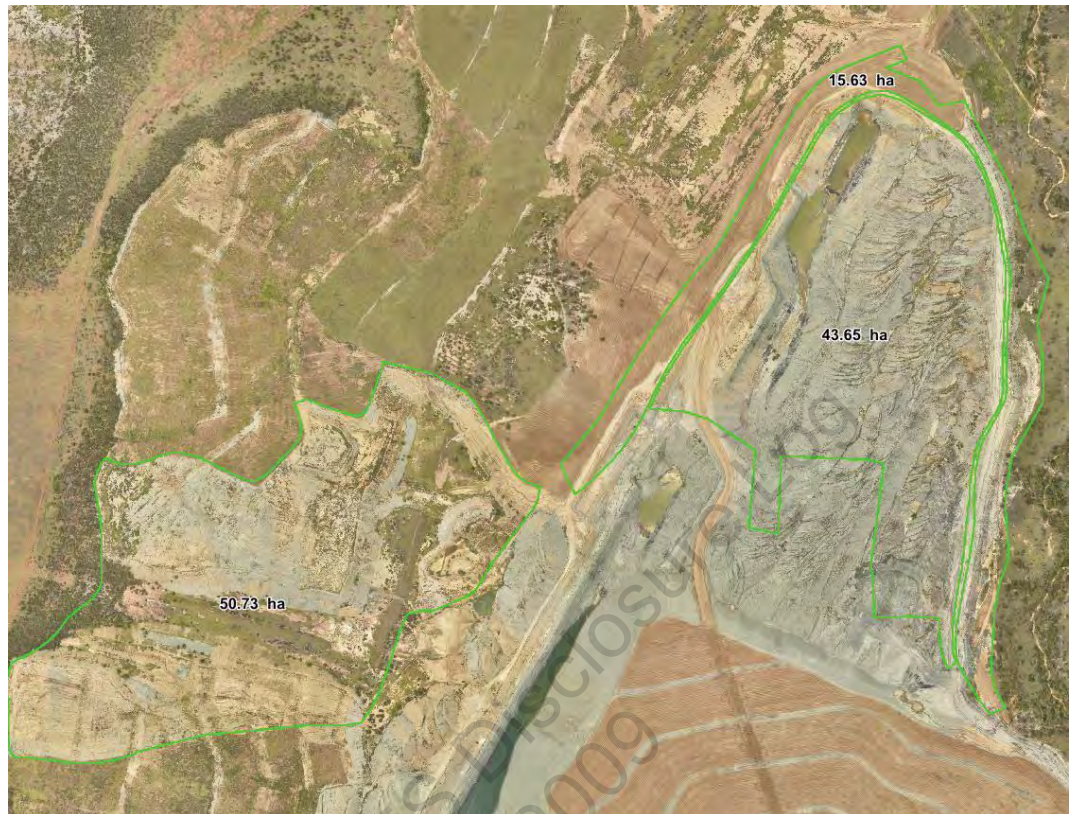


Figure 2 Western Area out of pit





Figure 3 Backfilled pit



Published on DES D
RTI Act 2009